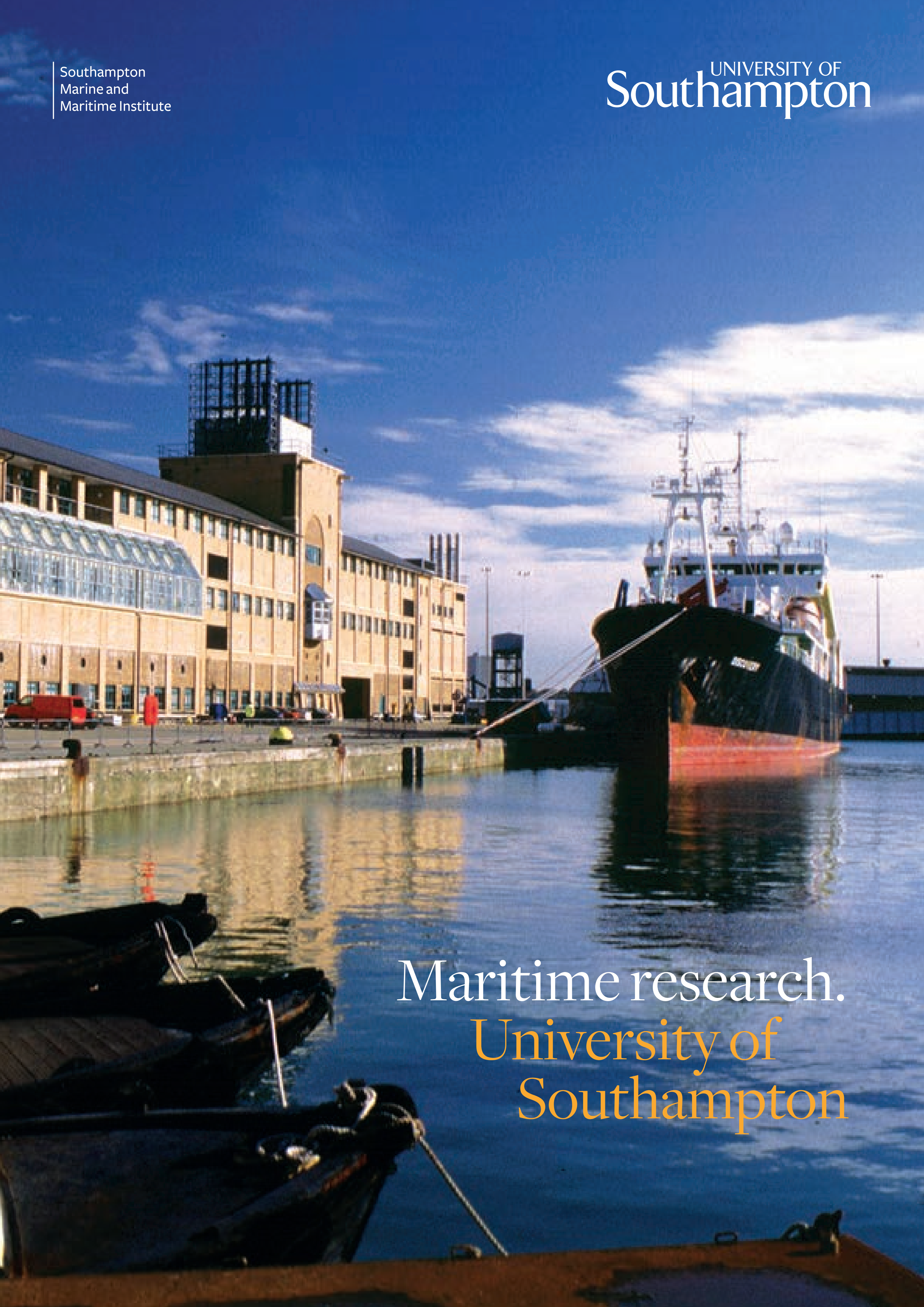


Southampton
Marine and
Maritime Institute

UNIVERSITY OF Southampton

Maritime research.
University of Southampton

The University of Southampton has created a Southampton Marine and Maritime Institute (SMMI). The SMMI will eventually be located alongside Lloyd's Register and will form the initial stage of the development of the Centre of Excellence on the redeveloped Boldrewood Campus of the University, due for completion in 2014. This has resulted in an investment of about £120M in a new campus, the largest such business-focused endeavour in any UK university.

The vision for SMMI is to be the world's leading centre for education, research and innovation in marine and maritime studies. Our mission is to have a transformational impact on society globally through our research, innovative ideas and solutions, as well as supplying highly skilled graduates for the marine and maritime sectors.

Our research addresses important societal issues under four thematic headings:

- Climate and environment
- Energy and resources
- Trade and Transport
- Society and government

This book contains posters covering the research themes that were presented at the VIP Launch of the SMMI in Southampton on 27th March 2012.

Contents

Climate and Environment

Energy and Resources

Society and Government

Trade and Transport

Support for Business

With over 40% of our annual research conducted with industry, and being the top UK University for working with SMEs, industrial partnerships are strategically very important to the University of Southampton. Whether you are a large, world-leading company, an SME, a not-for-profit organisation or a charity, we are keen to develop long-term, mutually beneficial relationships with you.

From solving a problem via a programme of research, to accessing new skills to enable you to embrace a new opportunity or develop new products, the University offers a variety of mechanisms in which you can collaborate with us. Wherever possible, these will also maximise the use of any grant funding that may be available to minimise the cost to your company.

Supporting your research and development

Being a leading research University, there are many ways in which we can help support research and development in your business. From commercial access to world-leading knowledge and facilities, through collaborative research, to sponsoring a PhD, we can help you develop the products and services to keep you at the leading edge in the global market place.

Accessing new knowledge and expertise

Whether it's recruiting our graduates, engaging our academic staff as consultants, or transferring new knowledge into your organisation via a grant funded Knowledge Transfer Partnership, we have all the leading knowledge required to allow you to embrace the opportunities, or resolve the problems affecting your company.

Staff development

The University of Southampton is at the leading edge of new ideas and forward-thinking research. By sharing the latest knowledge, ideas and techniques, we can help you to develop your people's skills, strengths and thinking. If you believe that the quality of your people profoundly affects your business performance, and if you want practical ideas to take your business forward, the University's professional development opportunities can help. We will connect you with specialists in your field who will help you develop your people and prepare your business for the future.

We understand that every organisation has a unique set of needs, so please visit the Business section of our website, or contact us to discuss your specific requirements.

Contact: +44 (0)23 8059 8708 or email us at smmienq@soton.ac.uk

Commercial services

Our consultancy services give businesses unrivalled access to the University's world-class expertise and facilities in many areas, including engineering sciences, oceanography and physical sciences. Consultancy can be delivered through our well-established enterprise units, which have dedicated and professional teams solely deployed to work on projects with external organisations, or via academic consultancy, which could involve short or long-term projects and may be linked to other activities such as the use of our specialist facilities.

Enterprise units

We host a number of highly respected professional enterprise units, providing consultancy services including:

Wolfson Unit for Marine Technology & Industrial Aerodynamics (WUMTIA)

Tank testing, wind tunnel testing, consultancy, design software, onboard systems and innovative research for ship, yacht and small craft design, naval architecture, marine technology and industrial aerodynamics.

Research Institute for Industry (RIfI)

Multi-disciplinary projects in engineering sciences, FEA analysis, cryogenics, materials and surface engineering. RIfI is a cutting-edge applied research organisation, which supports industrial partners in specialist fields of engineering.

ISVR Consulting (Sound and Vibration)

Acoustics, noise, signal processing, modelling, automotive refinement, testing, shock, dynamics. The Institute of Sound and Vibration Research carries out world-class research in the field of sound and vibration.

IT Innovation Centre

The IT Innovation Centre specialises in researching, developing, engineering and integrating innovative IT systems.

GeoData Institute

Environmental services, Geographic Information Systems (GIS), database and web development. The GeoData Institute provides environmental data management, analysis and processing to the marine and coastal sector.

Academic consultancy

Access to marine and maritime expertise and facilities is also available by engaging with our world-leading research centres throughout the University. The following are just a few of the subject areas where we can engage, and please contact us for information about areas not listed here.

Marine corrosion and erosion

The National Centre for Advanced Tribology at Southampton (nCATS) provides research and consultancy on marine corrosion and erosion to help solve a wide range of industry problems, including desalination plants, oil and gas valves, pipe systems loss of contaminant, pump impellers and coatings.

Maritime law

The Institute of Maritime Law (IML) is the UK's leading centre for teaching, research and consultancy in maritime law.

Maritime archaeology

The Centre for Maritime Archaeology (CMA) is committed to the promotion and practice of maritime archaeology, undertaking collaborative projects from a local to international scale.

Maritime history

The Parkes Institute focuses on research by non-Jewish and Jewish scholars and students into the field of relations between Judaism and other religions, with particular expertise in Jewish Maritime History.

Coastal research vessels

Ranging from 5.64 meters to 19.75 meters, our well equipped vessels are available for commercial hire for research, surveying, geophysics, and diving. Supported by highly qualified crews and staff, the vessels are used as a resource to support research and teaching in coastal waters.

Accessing knowledge and skills for your business

Whether you are looking to recruit at graduate level, or require access to grant funded graduate or post graduate skills to transfer new knowledge and understanding into your organisation, the University has a range of ways to assist.

Knowledge Transfer Partnerships

If your company needs access to new knowledge or expertise, a Knowledge Transfer Partnership (KTP) can place a high-calibre graduate into your business, supported by an academic expert and use of our leading facilities. These are for high-impact projects seeking to significantly boost the profitability of your business, and the costs of these are met by up to 67% grant funding. Companies eligible for KTP will typically reap an annual increase in annual profit of over £220,000 (KTP Annual Report 2007/08)

EngDs from the University's Transport and the Environment Doctoral Training Centre

An EngD takes elements of both an MBA and a PhD to deliver of programme of research to tackle issues affecting your business. The first year is spent studying management units, with the following three years seeing the student based in your company. As the majority of the cost of this programme is met by the Engineering and Physical Sciences Research Council, the cost to your company can be as low as £8k per year.

Graduate recruitment

Career Destinations offers a range of services designed to enable employers of all sizes to raise their company profile and promote their recruitment opportunities and engage with our students and graduates. We encourage organisations to register for free on the University's Employer Portal. From here organisations can upload, edit and remove vacancies as required and reach the full student body of over 18,000 undergraduates and 5,000 postgraduates as well as recent graduates. Additionally, you can indicate which services (e.g. Career Fairs, Placements, Knowledge Transfer Partnerships) are of interest, ensuring that you are notified when opportunities in your organisation's areas of interest arise: www.southampton.ac.uk/careers/employerportal

Student projects

Many of our students undertake projects for our wide range of marine and maritime industrial partners. These have included, for example, reviewing the effectiveness of fishery protection operations for the Norwegian Coastguard, planning for the optimal placement of containers within the export yard at Southampton container terminals, or analysis to identify indicators of vessels 'at risk' for Lloyd's Register. Is there a similar issue we could help you with?

Continuing professional development (CPD)

We can provide a number of CPD and executive education courses for the marine industry. These courses will provide you with the advanced technical and managerial skills needed to enhance innovation and business competitiveness. New and emerging technologies are taught in conjunction with business and management applications.

CJR Propulsion case study

With one of the most technically advanced facilities in Europe, CJR Propulsion is a world leader in the design and manufacture of shafts, propellers, rudders and other associated stern gear for a variety of marine vessels, such as larger pleasure boats, ferries and other working boats.

CJR Propulsion worked with the University of Southampton's Faculty of Engineering and the Environment to apply CFD to propeller design to improve boat speed and fuel efficiency, as well as reducing the noise and vibration.

The collaboration has been very successful leading to:

- Increased energy efficiency though optimally matched propeller and associated stern gear
- Significantly reduced the potential for erosion at high speed
- Effected a step-change in the Company's business processes

Land & Water Services case study

Land and Water Services is an award winning group of companies that specialises in marine based civil engineering, dredging and remediation projects. Land and Water Plant operates the largest fleet of specialist long reach excavators and inland floating plant in the UK, available for hire anywhere in the UK or overseas.

Copper was originally used as the main ingredient in antifouling paints for boats to prevent algae and barnacles from attaching themselves to boats and slowing their movement. It was found that tributyltin compounds (TBT) were effective and longer lasting. However after years of use TBT was established to have disastrous effects on marine life and is now considered to be a severe marine pollutant.

Land and Water Services worked with the University of Southampton's Chemistry unit to evaluate and develop viable methods for the remediation of harbour and shipyard sediments that are contaminated with the marine anti-foulant tributyltin.

RNLI case study

The Royal National Lifeboat Institution (RNLI) currently supports 300 lifeboats based at 235 lifeboat stations around the UK and Ireland. The sophisticated vessels are engineered to high standards so the volunteer crews can carry out rescue operations in the worst sea conditions. Equipping and maintaining the fleet can be expensive. A Tamar class lifeboat costs £2.7million to buy and equip, but has a working life of around 50 years.

The RNLI worked with the Southampton's Management School, and its Engineering and the Environment unit, to develop computer models to capture the commercial and logistic issues around the costs of building and maintaining the lifeboat fleet.

The project looked at how the technical design issues involved in deciding how frequently the boats and their equipment need maintenance, in order to better manage these costs. The information needed to fit in with industry standards and relate to the existing software.

Climate and Environment

The ocean covers approximately two thirds of the Earth's surface, which means it is the largest environment for living things on Earth. Apart from the natural resources sustained in and by this environment, the oceans are also a great influence on the earth's climate.

Understanding the behaviour of the ocean surface waves, the sub-sea currents and air circulation currents is vital for climate predictions. Equally important is knowledge about the subsea environment and how it promotes habitats for living organisms. Extracting oil and gas from deeper waters in the oceans also represents ever greater challenges in scientific and technological domains.

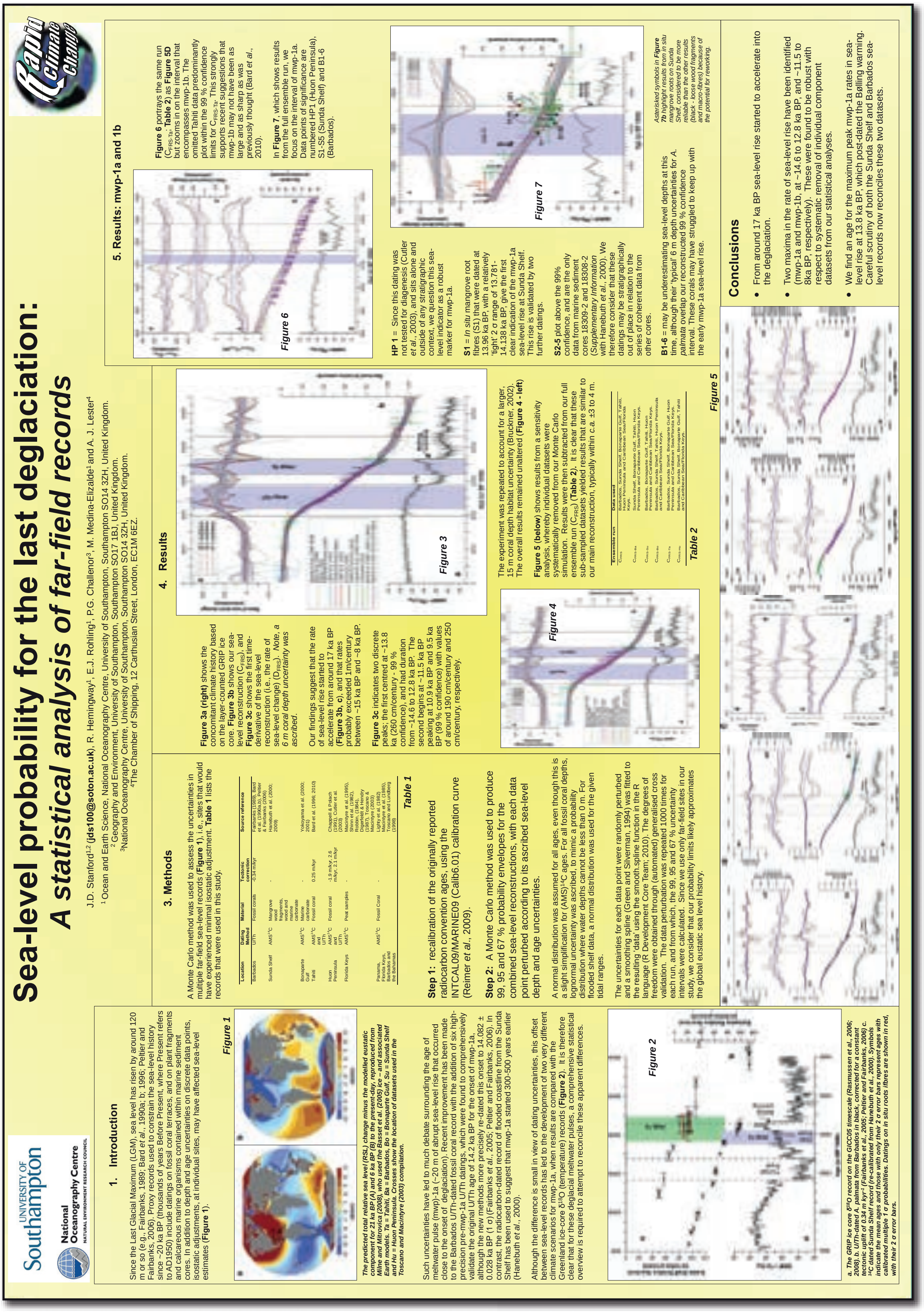
Our interests range from understanding of the basic science of influencing the behaviour of the environment, to searching for the resources within it. We are developing technology for managing and extracting resources, and the legal instruments, which define the use of the maritime and ocean space.

The University of Southampton undertakes research in diverse areas related to climate and the marine environment.

Sea-level probability for the last deglaciation: A statistical analysis of far-field records

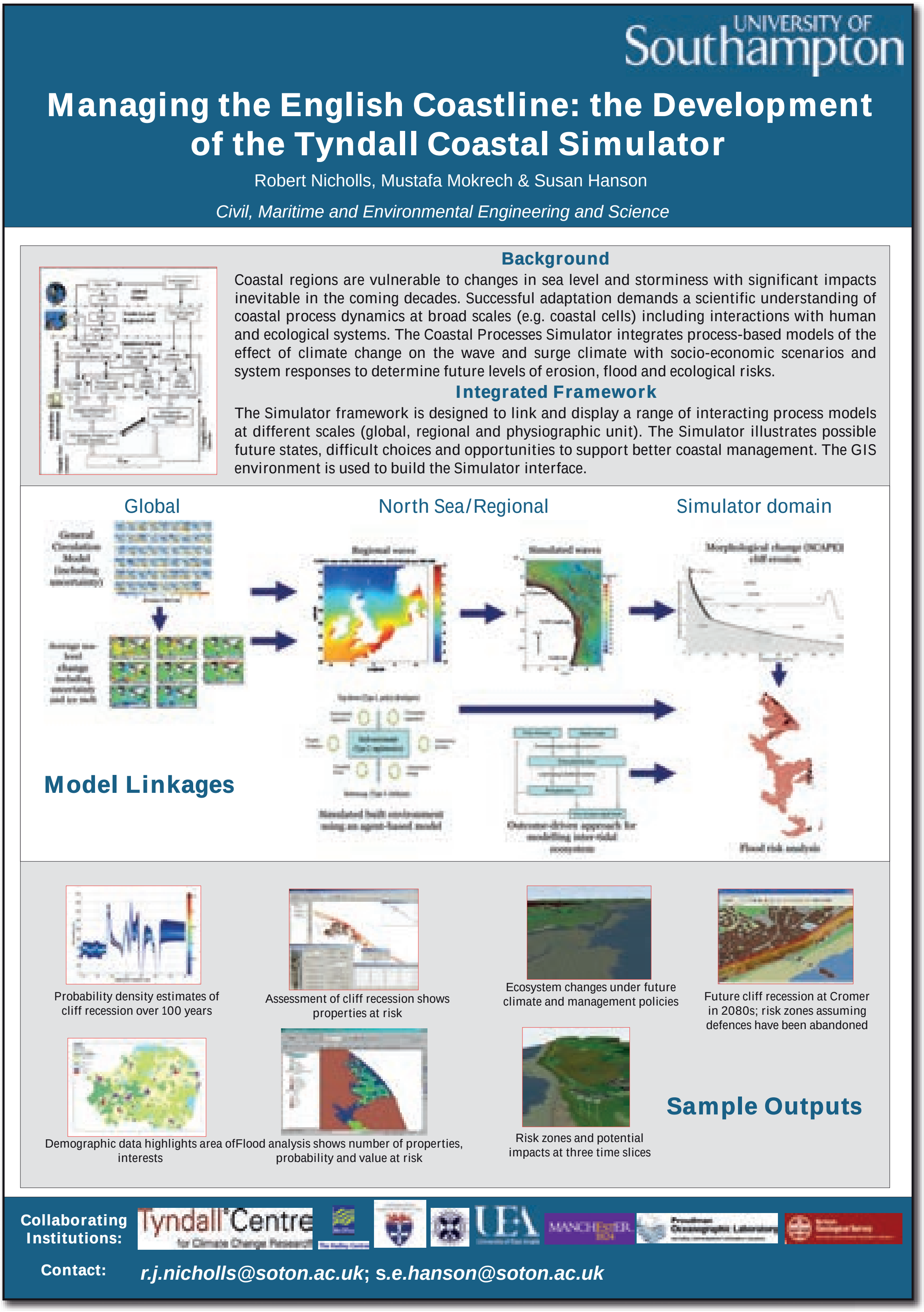
Dr J Stanford

CE1



Managing the English Coastline: the Development of the Tyndall Coastal Simulator

Dr M Mokrech



Professor S Darby

CE3

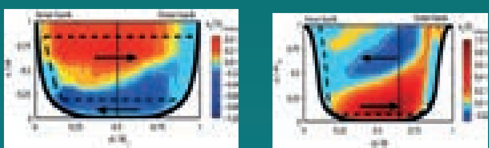
UNIVERSITY OF Southampton
School of Geography

Environment

Simulating the Bed Topography of Submarine Meanders

Description of the research

Submarine meanders scoured by turbidity currents are common features of the deep ocean floor. Hydrographic surveys have revealed aspects of their planform morphology, but their deep water location inhibits access, so knowledge of their fluid mechanics, sediment transport and bed morphology remains limited, **conceptual models having been developed by analogy with the well understood mechanics of fluvial meanders, due to similarities between their planform shapes**.



However, recent experimental investigations [*Corney et al*., 2006; *Keevil et al*., 2006] have revealed that **the secondary flow structure in submarine channels with density-driven gravity currents is the opposite to that of fluvial bends** (**Figure 1**). Unlike sub-aerial channels, in which the downstream velocity maximum occurs near the surface, gravity currents exhibit a near-bed maximum. This distinction results in the occurrence of outwards near-bed secondary flow, whereas near-bed secondary flow is directed inwards in the case of fluvial bends.

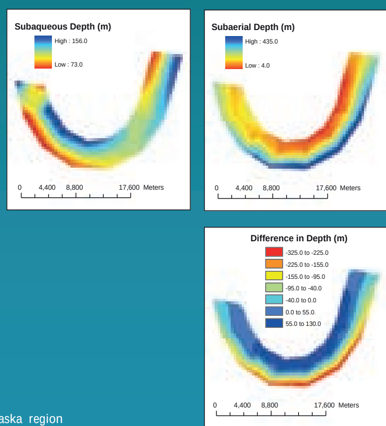
This research explores the implications of this behaviour with respect to the bed morphology of submarine channel bends.

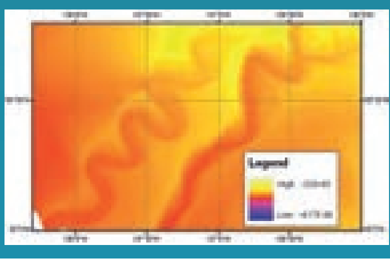
Research results

Our model replicates the relatively flat transverse bed profiles observed in the study bend very well, at least in those parts of the bend at, and downstream of, the apex (i.e., in the region of fully developed flow)

Figures below indicates that submarine meanders exhibit key differences in bed morphology relative to equivalent fluvial bends:

- In submarine bends **the outer-bank pool is shallower and the 'point-bar' is less pronounced, giving a transverse bed profile that is much flatter**
- In submarine bends **the 'point-bar' is located further downstream of the bend apex**





These data reveal a spectacular meandering channel system (location: ~55.5N,137.5W) at a depth of ~3000 m, and with dimensions (wavelength = 39.8 km; sinuosity = 1.9; width = 4.75 km, depth = 115 m) consistent with other submarine channels

Bathymetric survey data for the Gulf of Alaska region showing the meander system and specific bend modelled in this study. *Data from*: http://www.ccom- jhc.unh.edu/

for more information please contact:

School of Geography, University of Southampton, S.E.Darby@soton.ac.uk **Web:** www.geog.soton.ac.uk
School of Earth and Environment, University of Leeds J.Peakall@see.leeds.ac.uk **Web:** www.see.leeds.ac.uk

Geo-Distributed Service Orientated Architecture for Marine Environmental Risks & Decision-Support Systems

Dr Z Sabeur

CE4

Environment

UNIVERSITY OF Southampton

Geo-Distributed Service Oriented Architecture for Marine Environmental Risks & Decision Support Systems

The University of Southampton IT Innovation Centre has developed generic sensor data fusion and modelling services in the EC IST project Sensors Anywhere (SANY).

These services have been used to predict spatial patterns of wind fields near the Gulf of Gdansk, Poland. The services fetch meteorological data remotely using the OGC (Open Geospatial Consortium) Sensor Observation Service specification.

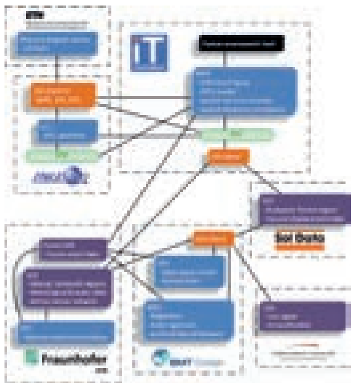
The services are interoperable within a Service Oriented Architecture (SOA). A set of geo-distributed services, developed in collaboration with several European partners, are invoked by multiple users to simulate coastal zone environmental risks, using a Service System Environment portal based in Brussels.

Research impacts include:

- Re-usability of fusion services in other environmental applications (e.g. urban ground displacement risks in industrial tunnelling, air quality risks in urban zones, etc.)
- Interoperability of fusion services with existing meteorological databases and information systems
- Cost-effective spatial management of sensor networks for marine environment monitoring and minimisation of spatial prediction errors

Research Partnership

Service Oriented Architecture

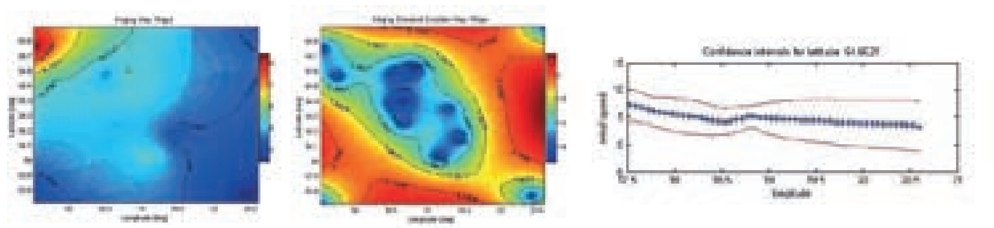


Environmental sensor data fusion and modelling

The environmental sensor data are automatically processed, modelled when necessary, and combined with phenomenological models. This provides a robust approach to forecasting environmental parameters for critical decision support.

The challenges which have been addressed include:

- Predicting parameter values in areas where there are no sensors
- Predicting parameter values when sensors breakdown
- Control of the propagation of spatial errors
- Managing spatial deployment of sensors



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Development of an integrated model to determine the impacts of climate change on coastal recession

N Carpenter

CE5

UNIVERSITY OF Southampton

Development of an Integrated Model to Determine the Impacts of Climate Change on Coastal Recession

1) Problem Statement

Soft rock cliffs create geomorphologically diverse coastlines owing to the complex interactions between geology, combined with the applied forces of marine and terrestrial processes. They are highly susceptible to recession and one key challenge is to understand how climate change aspects (e.g. sea-level rise, increased seasonal rainfall) will alter this process. As such, traditional methods to predict recession (by extrapolation of historic rates) should no longer be considered acceptable when past conditions are not representative of the future. In response one alternative method is process-based numerical modelling, which enables system changes and process interactions to be simulated. However, this method is relatively in its infancy and many models are criticised for the generalised manner in which they treat cliff behaviour. This relates to the key assumption that it is coastal processes that drive recession. This may be problematic for complex cliff sites, potentially leading to inaccurate future predictions of cliff-top position if the effect of climatic factors on slope stability are omitted.

2) Research Description

The aim of this study is to develop a coupled, process-based model which considers the influence of both coastal *and* slope (geotechnical) processes on soft cliff recession. The model will be developed considering the complex study frontage of the south-west coast of the Isle of Wight, UK (Figure 1).

Figure 1: Isle of Wight Study Frontage

This 17km site has a varied soft rock geology, exhibiting a series of headlands and a range of cliff behavioural units. Therefore, it provides strong opportunities to validate the more integrated coastal cliff recession model than those currently available.

3) Preliminary Results

Considering the complexity of the cliff recession process, the first stage has been to develop a generalised conceptual model (Figure 2) to understand all systems, parameters and processes involved in the cliff recession process. This highlights the plethora of interactions and feedback mechanisms within the cliff system and subsequently will form the foundation for the development of the numerical model.

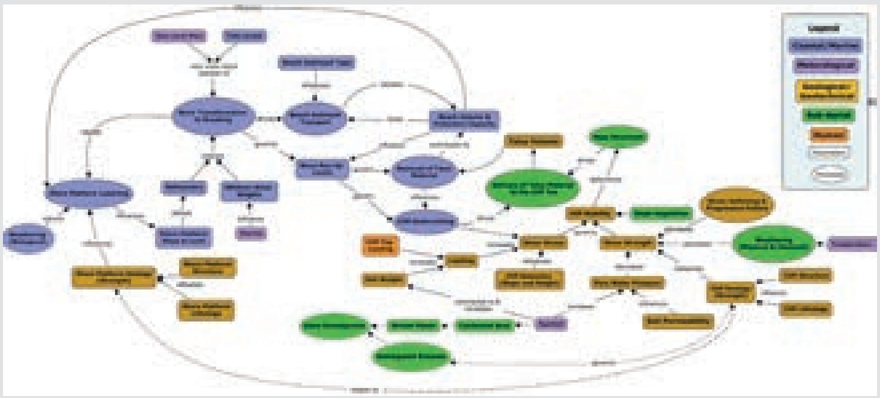

Figure 2: Generalised Conceptual Model of Soft Cliff Coastal Recession

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A Systems Analysis of Coastal Flooding using the SPRC Model

Professor R Nicholls

CE6

Innovative technologies for safer European coasts in a changing climate

UNIVERSITY OF Southampton

A systems analysis of coastal flooding using the SPRC model

Problem Statement

Increasing rates of sea-level rise and concentration of coastal assets are likely to increase damages due to coastal flooding in future. Traditional coastal modelling works from the flood source outwards, estimating damage to receptors within the modelled floodplain. This method fails to pinpoint receptors critical to the health of the system. This has lead to oversights in coastal defence management with catastrophic flooding consequences such as in hurricane Katrina (USA), cyclone Sidr (Bangladesh) and storm Xynthia (France).

Research Description

This PhD is being undertaken within the EU THESEUS project (www.theseusproject.eu) based on eight case study sites across Europe. The PhD tackles flood modelling starting from the receptors rather than the sources, to gain an understanding of the system prior to application of flood models. The coastal flood system is studied using a systems linkage diagram based on the Source-Pathway-Receptor–Consequence (SPRC) model (Fig 1).

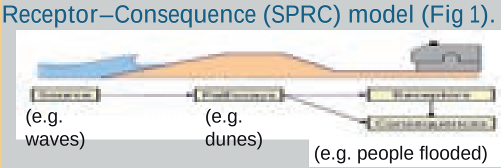

Figure 1: The Source – Pathway – Receptor – Consequence (SPRC) Conceptual Model

Preliminary Work

The simplistic version of the model shown in Fig 1 is developed into a more comprehensive description of the coastal flood system for the Dendermonde region of the Scheldt estuary, Belgium (Figure 2), one of the eight THESEUS case study sites. Based on land-use, it highlights possible connections between different elements. This analysis effectively illustrates the complexity of the system and the vulnerability in terms of connections of certain receptors.

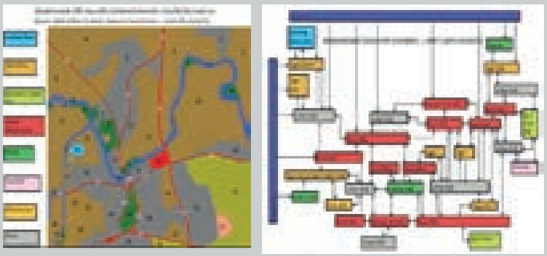

Figure 2: The land-use map (left) and SPR Systems Linkage Diagram (right) for Dendermonde Town, Belgium.

The system diagram makes explicit prior to flood modelling several key points such as the interconnection between receptors, possibility of flooding from two directions and the possibility of flood propagation via the roads and railway. This can be used to selectively inform flood models. Further work will include development of system fault-trees for analysing flood risk and the effects of changes to elements on overall system health.

Research impact

Coastal flood modelling until recently has been unable to pinpoint receptors critical to the health of the flood system and their relation to surrounding elements. This research will create a tool to facilitate an understanding of coastal flood systems in terms of the elements within, their inter-connections with one another and their effect on the health of the system and its constituents. The research is funded by the EU THESEUS project and the preliminary concept has been presented at the EGU 2011 conference .

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Siddharth Narayan (PhD Student supervised by Prof. Robert Nicholls and Dr. Derek Clarke), Faculty of Engineering and the Environment. Funded by the EU FP7 THESEUS project. sn3g08@soton.ac.uk

Ocean Modelling & Forecasting (OMF)

Dr R Marsh

CE7

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment: climate change/science

Ocean Modelling & Forecasting (OMF)

The Ocean Modelling & Forecasting Research Group at NOCS has world-class expertise in high-resolution ocean modelling, with embedded models of marine biogeochemistry and sea-ice. We are also developing innovative climate and Earth system models.

The research carried out by the OMF group focuses on the changing state of the ocean and its role in the global climate system. Topics of particular interest include:

❑the extent to which our models can reproduce the present state of the ocean and its variability

❑the rate at which CO_2 is taken up by the ocean, and the biological and physical mechanisms controlling this process

❑the ways in which the ocean may respond to changing climate, and its role in affecting the climate of Europe

Recent & Planned Collaborations:

- ❑ NERC projects with other UK university partners (QUEST, RAPID, HiGEM, ICOM, GENIE projects)
- ❑ UK Met Office (model development & climate forecasting, JCRP project)
- ❑ European & US colleagues (NEMO & CHIME projects)
- ❑ Insurance industry (under discussion)

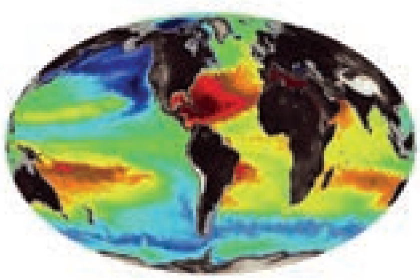
Impacts of our Research:

❑Clearer understanding of changes in the World Ocean since the 1950s, due to both natural variability and climate change

❑An alternative version of the UK Met Office climate model featuring a novel ocean component (CHIME), broadening the suite of 21st century climate predictions

❑Improved representation of physical & biogeochemical processes, and sea ice, using a new ocean model framework (NEMO, also used by the UK Met Office)

❑Working closely with the UK Met Office to improve regional climate predictions, on seasonal to decadal timescales



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Global Port Cities with High Exposure to Coastal Water Level Extremes

S Hanson

CE8

Global Port Cities With High Exposure to Coastal Water Level Extremes

UNIVERSITY OF Southampton

Susan Hanson & Robert Nicholls

Civil, Maritime and Environmental Engineering and Science

Globally, seaborne trade has tripled over the past 30 years and thirteen out of the twenty most populated cities in the world (2005) are ports. A series of scenario-based studies have investigated the exposure of the 136 of the worlds largest port cities (population over 1 million in 2005) to a 1:100 flood event during this century, the benefits of global climate mitigation and the costs of local adaptation.

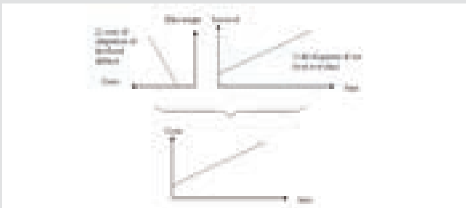
Port exposure was initially assessed in terms of population and assets located within the flood plain. Extreme water levels were estimated by combining information on current and future 1:100 event wave height, relative sea level and anthropogenic subsidence. Future socio-economic scenarios, including urbanisation, were also included in the assessment of future exposure. Future exposure levels are largely driven by population growth and urbanisation, exacerbated by environmental change.

Top 20 cities for asset exposure in 2070 (US$ million). Circle size indicates magnitude of exposure.

Asset exposure avoided by 2070 with an annual reduction of emissions of 5% beginning in 2016. Circle size indicates magnitude of the reduction.

A range of greenhouse gas scenarios were then used to assess the timing and extent of the benefits of climate mitigation. This showed that, due to the delay in the response of sea levels to changes in global temperature, any reduction in exposure will not be appreciable until towards the end of the century. Therefore the earlier mitigation begins and the larger the annual decrease in emissions possible the greater the benefits.

The delay in the benefits of climate mitigation means local adaptation to reduce exposure levels is essential. Many cities with high exposed populations have been shown to have low levels of protection and there can be variation between and within cities. Standard of protection is not exclusively related to wealth, cultural and political factors often being more important. However, the cost of protection schemes can only be expected to increase over time.



Conceptual scheme that shows how the development of adaptation costs over time depends on the development of sea level rise and the relationship between costs and sea level

Project funding/partners:

OECD   Met Office   AVOID – Avoiding dangerous climate change   Risk Management Solutions   CIRED

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Impacts and Costs of Sea-level Rise

Dr S Brown

University of Southampton

Impacts and costs of sea-level rise

Research description

Coastal zones are some of the most densely populated areas in the world, with fishing, agriculture, industry, tourism and port income generating a large proportion of a country's wealth.

Figure 1: The coastal zone has many uses.

As temperatures increase due to climate change, sea levels will also rise threatening vital infrastructure and putting more people at risk of flooding. Within the Faculty of Engineering and the Environment, a coastal model (the Dynamic Interactive Vulnerability Assessment, or DIVA) has been developed which provides global, regional and country estimates of the impacts of sea-level rise throughout the 21st century. As well as impacts, the DIVA model estimates the associated economic costs.

Results: Case study of Europe

An EU funded project 'ClimateCost: The Full Costs of Climate Change', projects a temperature rise of 3.5ºc, and a 37cm rise in global sea levels by the 2080s. Results indicate that if coastal defences are not upgraded to cope with changing conditions:

- 35% of EU wetlands could be lost;
- 55,000 people per year could be flooded;
- 440,000 people would be forced to move as they are flooded more than once a year;
- Damage costs could be in excess of €25 billion per year.

Impacts are not uniform throughout Europe, and those in north-west Europe are typically the worst affected.

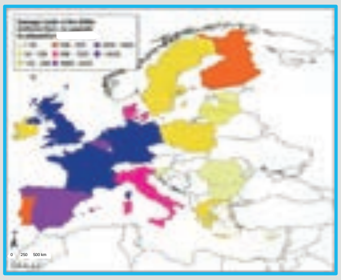

Figure 2: Damage costs in Europe due to a 37cm rise in sea levels caused by a 3.5°C temperature rise by the 2080s.

Strategically planning for climate change (e.g. deciding whether to retreat, accommodate or protect) can reduce impacts and damage costs.

Research impact

These results help organisations strategically plan for climate change, direct resources to those in need, and where appropriate, adapt to changing conditions. Funding organisations include the European Commission, the World Bank, NERC, the Department of Energy and Climate Change (DECC), UNEP and DFID. Results have been presented to EU policy makers in Brussels, and will be presented by the Foreign Office / DECC at the internationally important 2011 UN conference on climate change in Durban.

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Dr Sally Brown & Prof Robert Nicholls, Faculty of Engineering and the Environment and Tyndall Centre for Climate Change Research. sb20@soton.ac.uk, R.J.Nicholls@soton.ac.uk

Hotspot Ecosystem Research and Man's Impact on European Seas

Dr D Billett

CE10

Environment and Resources

UNIVERSITY OF Southampton

Hotspot ecosystem research and Man's impact on European seas

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

The HERMIONE project (Hotspot Ecosystem Research and Man's Impact on European Seas) is a new interdisciplinary project co-ordinated by the National Oceanography Centre, Southampton. Funded by the European Commission's Framework 7 Programme, it follows on the from the highly successful FP6 HERMES project.

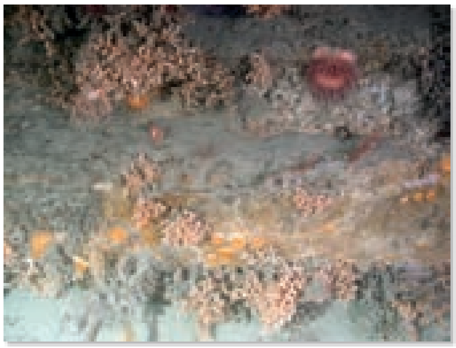
HERMIONE sets out to investigate Europe's deep-sea ecosystems in terms of their distribution, dimensions and interconnections, and how they might be (or are already) affected by global change – including climate change, human impacts and large-scale events.

To achieve this, the HERMIONE Consortium comprises 38 partner institutions around Europe, including leading experts on slopes and basins, cold-water corals, seamount ecosystems, submarine canyons and chemosynthetic ecosystems. In addition, the project benefits from a dedicated team of socio-economists and policy experts, who will work with our scientists to provide knowledge to policymakers in support of deep-sea governance and sustainable management of resources.

HERMIONE will examine deep-sea ecosystems around Europe's margins, including:

- The Arctic, because of its importance in monitoring climate change;
- The Nordic margin with abundant cold-water corals, extensive hydrocarbon exploration and the Håkon Mosby mud volcano natural laboratory;
- The Celtic margin with a mid latitude canyon, cold water corals and the long term Porcupine Abyssal Plain monitoring site;
- The Portuguese margin with its highly diverse canyons;
- Seamounts in the Atlantic and W. Mediterranean as important biodiversity hotspots potentially under threat;
- The mid-Atlantic Ridge to link cold seep to hot seep chemosynthetic studies;
- Mediterranean cold water cascading sites in the Gulf of Lions and outflows of the Adriatic and Aegean Seas.

At each study site, a range of multi- and interdisciplinary observations, measurements and experiments will be implemented to understand the ecosystems, their relationship to the surrounding physical environment, and how they might respond to change. As such, the project is underpinned by an ambitious cruise programme that involves over 1000 days of shiptime aboard Europe's research vessel fleet.



Above: Cold-water corals in the Whittard Canyon, Celtic Margin. Image taken by ROV Isis during cruise JC36, summer 2009. Copyright NOCS.

The multidisciplinary research under HERMIONE is designed to fill the knowledge gap about threatened deep-sea marine ecosystems and their environments. It will reveal the impact of man on these ecosystems, both directly - e.g. via bottom trawling - and indirectly via climate change. The results will feed national, regional (EU) and global policy and decision makers with the information needed to establish policies to ensure sustainable use of the deep ocean.

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Dr V Byfield

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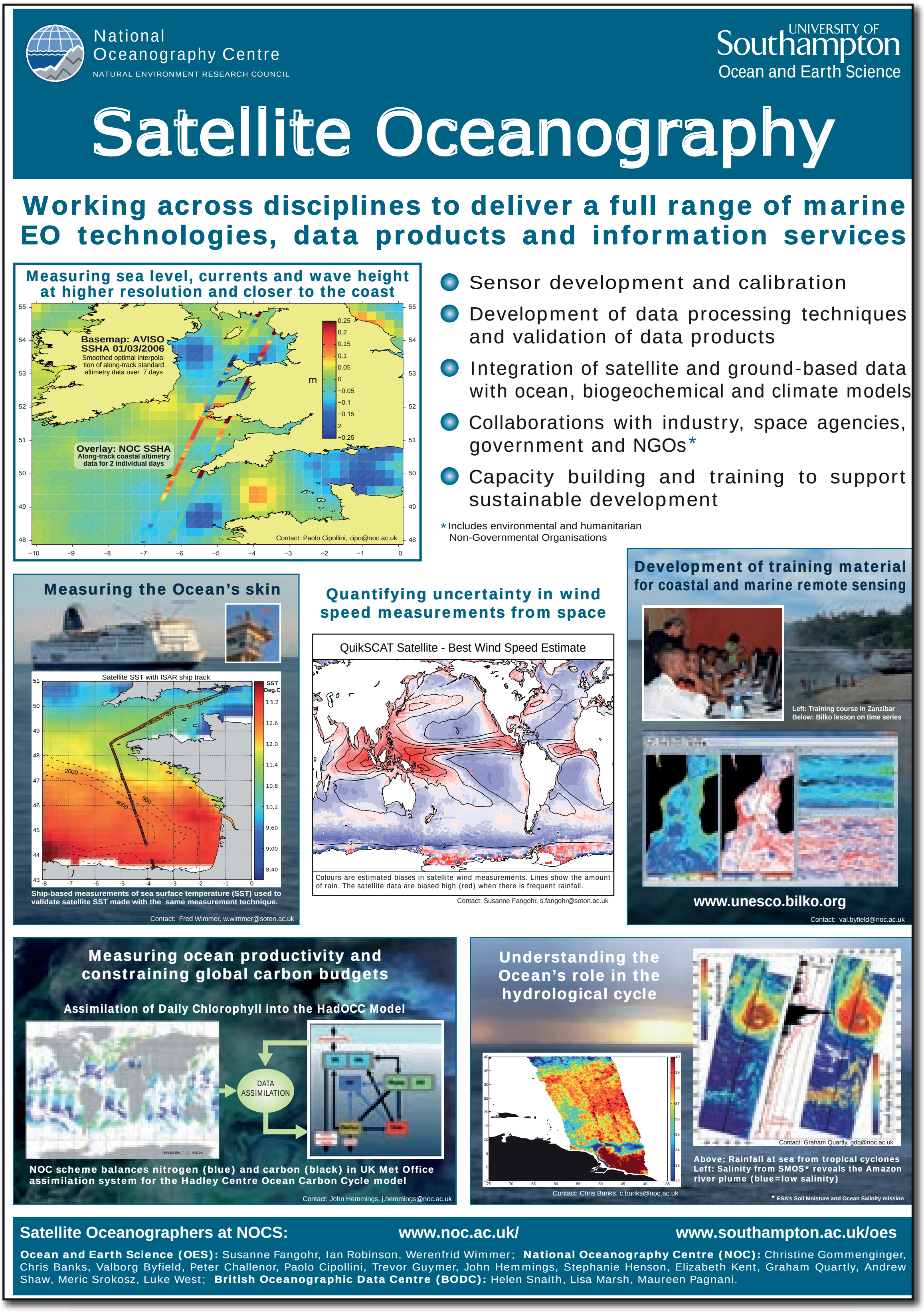

Dr C Thompson

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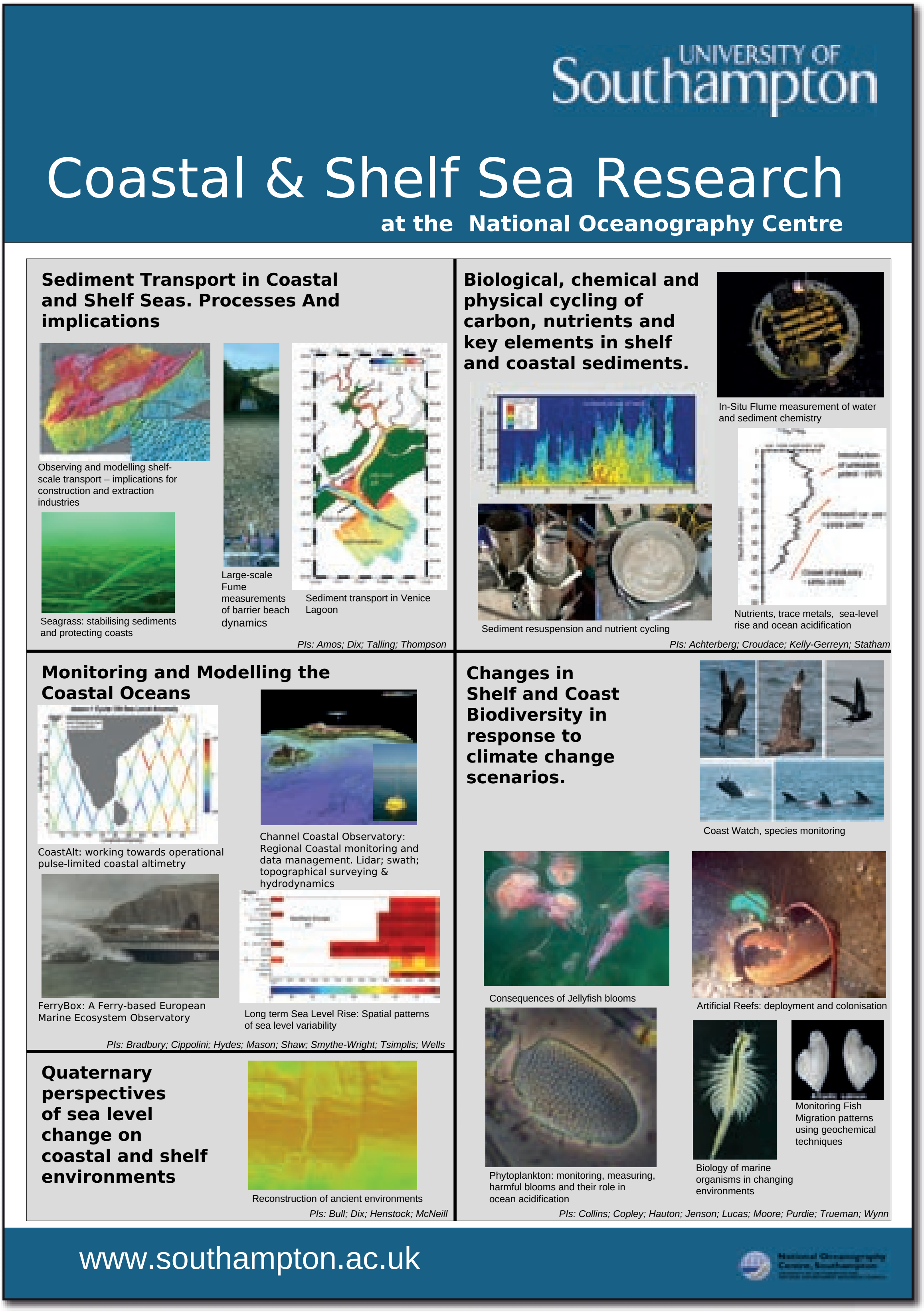


Professor P Carling

UNIVERSITY OF Southampton
School of Geography

Environment

Intertidal mud runnels in the Severn Estuary

Description of Research

- Multiple linear, parallel runnels typically 1 to 2 metres apart, running parallel to tidal currents and cut into mudflats and in the muddy bottom of the continental shelf, have been described widely around the coast of the UK and elsewhere.
- Although common they are little-studied; how these features are formed and maintained was unknown before this investigation.
  - Are they erosional and depositional, or both?
  - What are their hydrodynamic and sedimentological properties?
  - What practical applications are there for understanding of these features?
- These questions were addressed using state-of-the-art field and laboratory equipment .

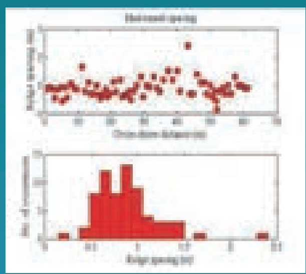
Application of Research

✓ A model of hydrodynamic control by helical flow and sedimentological response has been developed, for the first time.

✓ Quantified conditions of bed roughness, flow speeds and suspended sediment regime can be extracted which aid understanding of mudflat dynamics and substratum stability indicators.

✓ Results can inform the management of the sediment fauna as a food source for conservation of wading birds and aid in understanding of the impact of estuarine barrages on sediment dynamics.

✓ Additional applications to exploration of the continental shelf and the interpretation of possible water-related landforms on Mars



Publications:

Carling et al. 2009, Continental Shelf Research, Impact factor: 2.136

Williams et al. 2008, Estuarine, Coastal and Shelf Science, Impact factor: 2.072

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Dr P Kemp

UNIVERSITY OF Southampton

Environment and migration

Facilitating fish movements between the sea and freshwater in developed coastal zones: engineering solutions to challenges of fish passage

The Research

•The importance of shallow-water coastal and estuarine "transitional" habitats is important for many economically significant fish species (e.g. salmon and trout, eel, mullet, sea bass, and flounder).

•Little is known of how fish utilise and move between these habitats, and how habitat utilisation is linked to productivity and population viability.

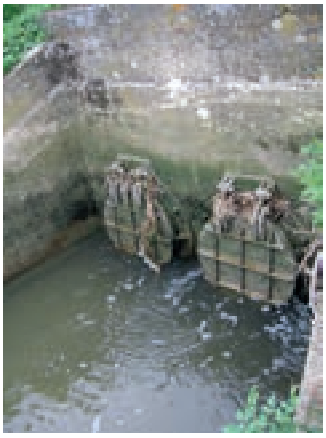
•The impacts on fisheries of coastal development and associated habitat fragmentation and loss, exacerbated by climate change, are thought will likely be significant, but remain poorly defined.

•Recent and future legislation (e.g. Water Framework Directive and Marine and Coastal Access Bill) has enhanced protection of transitional environments, yet there is a need to better understand how these systems function and how they are perturbed to identify mitigation solutions by engineering means.

•Research conducted at the University of Southampton aims to investigate the importance of transitional habitats for multiple life phases of key target species and quantify the impacts of critical engineering structures on ecological integrity, particularly structures that impede the movements of fish between essential habitat. Engineering solutions to aid fish passage will be developed.

Impact

The research will provide engineers and managers with the critical information needed to design multi-species fish passage facilities/strategies to mitigate for the environmental impact of continued development of the coastal zones (e.g., sea defences, tidal barrages and weirs, and tidal gates and sluices).



Tidal flaps can Significantly block Fish movement

In the field of fish passage research, the School of Civil Engineering and the Environment at the University of Southampton collaborates closely with, and is funded by, the Environment Agency, the Centre for Ecology and Hydrology, and the Game and Wildlife Conservation Trust. For more information see www.icer.soton.ac.uk

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In Situ Lab on a Chip Sensors for Measurement of Marine Biogeochemistry

Dr M Mowlem

CE15

In situ lab on a chip sensors for measurement of marine biogeochemistry

UNIVERSITY OF Southampton

Matt Mowlem[1], David Barat[1], Robert Zmijan[2], Xi Huang[2], Maria-Nefeli Tsaloglou[1], Mahadji Bahi[1], Vincent Sieben[2], Alan Taberham[2], Iain Ogilvie[2], Cedric Floquet[1], David Owsianka[1], Hywel Morgan[2]

1)Sensors Development Group, National Oceanography Centre, Southampton

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Introduction

The oceans play a crucial role in the prosperity and future of civilisation. They provide essential natural resources such as fish, minerals, offshore energy and a route for global transport of goods and resources. Natural biogeochemical cycles in the oceans, provide "ecosystem services" valued at US$19 trillion p.a., equivalent to the global GNP. The oceans play a key role in climate regulation arguably the most important environmental issue facing mankind.

Despite their global importance, the vast (1.3 x 10^9 km3) oceans remain largely under sampled (in both space and time). This research develops in situ chemical and biological sensor technology to enable dense networks of autonomous sensors. The aim for this network is delivery of ubiquitous and synoptic data on biogeochemical processes, which is essential for understanding, modelling, predicting, and managing our environment.

Miniaturisation of biogeochemical sensors has a number of advantages, but crucially it allows the low cost volume production of devices and hence should enable a paradigm shift in the quantity of data collected. Typically we see envisage that these sensors would be deployed on existing the Argo float array which currently has ~3600 free drifting floats in the worlds oceans . These floats currently only measure temperature conductivity and depth. They have variable buoyancy and sink and refloat periodically allow measurements to a depth of ~2000m. This research is developing an array of sensor types based on MicroSystem Technology (MST) and four are described here.

Chemical Sensing

Marine chemistry (nutrients and pollutants in particular) is sensed with a lab-on-a-chip (LOC) chemical analyser. Fabricated from polymers a microfluidic chip is used to mix seawater with reagents that induce a colour change. This is measured precisely using an on chip dual beam spectrophotometer which compares the absorption of the reacted products to the absorption of the seawater sample. A number of colourimetric and fluorescence based protocols are widely used for analytical and environmental applications and hence this technology is in many senses generic. To date we have successfully tested determination of concentrations of Fe, Mn, NO_3, NO_2, and PO_4 using this device. Detection limits of the order of 200nM are routine.

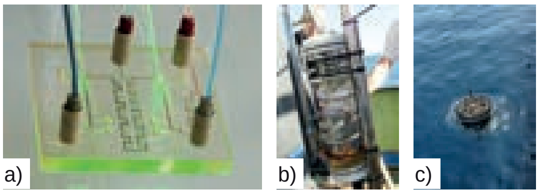


Figure 1: Lab-on-a-chip chemical sensor: a) Polymer microfluidic chip with dual beam spectrophotometer connected optically by fibres and fluids by tubing, b) assembled sensor system (Mk1) incorporating electronics and off chip pumps and valves, c) deployment of the system using a tethered oceanographic instrument package . The system operated continuously and without damage to the maximum depth tested (1600m)

Current research is enhancing the capability and ease of manufacture of the LOC and the complete system. This includes development of on-chip valves, new polymer microfabrication and bonding techniques, new optical systems, improved limit of detection and improved off chip pumping.

Cytometery

A LOC cytometer counts and identifies phytoplankton present in seawater by measurement of their physical and optical properties. These microbes are central to many aspects of the ocean's economy. They fuel the marine food web, that ultimately leads to fish and marine biomass. They photosynthesise assimilating CO_2 and so drawdown CO2 from the atmosphere and help to ameliorate the "greenhouse effect". Under conditions of high nutrients, they can grow excessively making eutrophic conditions and harmful algal blooms possible.

Counting and characterisation of phytoplankton is achieved in a microchannel. Phytoplankton are arranged into a train of single cells flowing through the detection region by injecting fluid either side of the sample stream. Known as sheath flow this focuses particles present in the sample into the middle of the channel. The detection region includes electrodes to measure the electrical properties of the cell, and optical fibres to illuminate and collect light from each phytoplankton.

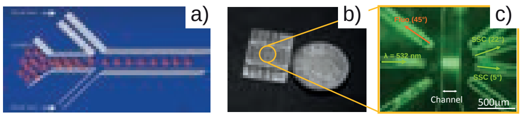


Figure 2: LOC Cytometer: a) schematic of particle focusing using sheath flow b) Cytometer chip (Mk1) with electrodes and contacts showing strong reflections, c) detail from the centre (detection region) of the chip showing arrangement of optical fibres for excitation light (532nm laser), fluorescence detection, and side scattered light (SSC) at 5° and 22°.

A prototype chip (Mk1) has been demonstrated in the laboratory and has successful counted and distinguished between three different phytoplankton species in a mixed culture. The results are equivalent to that obtained using a commercial bench-top system. Current research is developing a submersible sensor system incorporating a new generation of LOC technology. This includes design and modelling of improved optics, designs using new polymer microfabrication and bonding techniques, design and construction of an integrated optical, electronic and fluidic system, and characterisation of pumping technology.

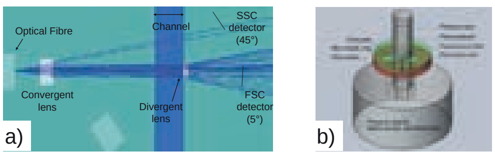


Figure 3: LOC Cytometer: a) Optical model of optical design (Zemax) b) Overview of submersible cytometer system. The LOC element is at oceanic pressure whilst pressure cases are used for sensitive elements. Closely coupled photon multipliers are used to collect fluorescence light. Laser excitation and scattered light are guided using optical fibres.

Nucleic Acid Analysis

A LOC analyser enables speciation and study of the physiological state of marine microorganisms by analysis of their RNA using the Nucleic Acid Sequence Based Amplification (NASBA) protocol and fluorescence detection. Prior to NASBA amplification and detection a number of sample processing steps are required i.e. collection of seawater, filtration to collect and concentrate target phytoplankton in a size range of interest, disruption of cells to yield RNA (lysis), extraction and purification of RNA. NASBA is then used to amplify and measure the concentration of specific target sequences. To date we have demonstrated lysis, NASBA and fluorescence detection on chip. Detection of amplified RNA is achieved by using a fluorescently labelled beacon (probe) formed from RNA. This fluoresces when it hybridizes with the target RNA sequence. To make the protocol quantitative an internal control (IC) sequence of RNA is added at a known concentration but detected with a different fluorescent beacon with a different emission wavelength. This enables variability in amplification efficiency (which is subject to a number of environmental factors) to be accounted for in interpretation of the results.

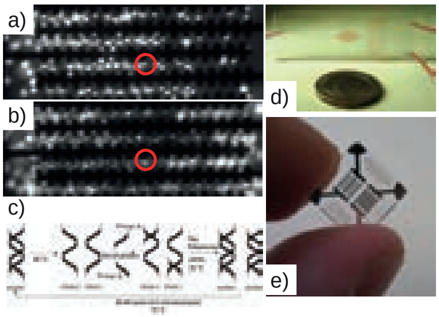


Figure 3: RNA analyser a) Fluorescently labelled (propidium iodide) cells prior to lysis on chip showing defined nuclear perimeter b) on chip lysis demonstrated by ruptured nuclei c) overview of the NASBA amplification pathway, d) prototype chip for mixing of extracted RNA with reagents and fluorescence detection (diamond shaped chamber), e) lysis chip (pyrex substrate with aluminium / titanium electrodes)

Current research is optimising lysis and fluorescence detection on chip and is designing new on and off chip systems for sample processing and RNA extraction.

Physical Sensing

A microfabricated conductivity and temperature (CT) sensor enables measurement of these key physical parameters. Unlike the sensors above, small commercial CT sensors exist. However truly miniaturised CT sensors have insufficient performance for many applications including climate studies. High performance CT sensors are large (~>2l) and expensive (~£10k). This project aims to develop low cost miniaturised high performance CT sensors as shown in the table below. The existence of such a sensor would enable sensing from an animal tag (e.g. a fish tag) and would enable construction of complete sensor systems incorporating chemical biological and physical sensors.

	Argo CTD (large)	StarOddi (fish tag)	CEFAS (G5 fish tag)	DTU (fish tag)	Goal this project (fish tag size)
Conductivity (accuracy)	0.005psu 0.004mS/cm	0.75psu ±0.8mS/cm	None	0.5psu 0.45mS/cm	<0.01psu <0.009mS/cm
T (accuracy)	0.002°C	0.1°C	0.1°C	0.13°C	0.002°C

Table 1: Performance characteristics of commercial and research (DTU and this project) CT sensors

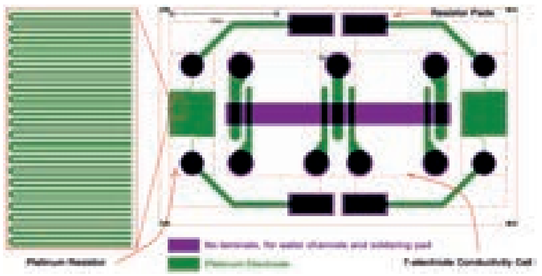


Figure 4: Microfabricated Conductivity (7 electrode design) and temperature sensor. (resistive serpentine) Formed from Ti/Pt on pyrex with epoxy laminate insulation.

Current research is testing the first prototype. The next goal is to evaluate and enhance long term stability and incorporate a bare Platinum disc microelectrode oxygen sensor and development of an Application Specific Integrated Circuit (ASIC) to perform signal conditioning with ultra miniaturised electronics.

Conclusions

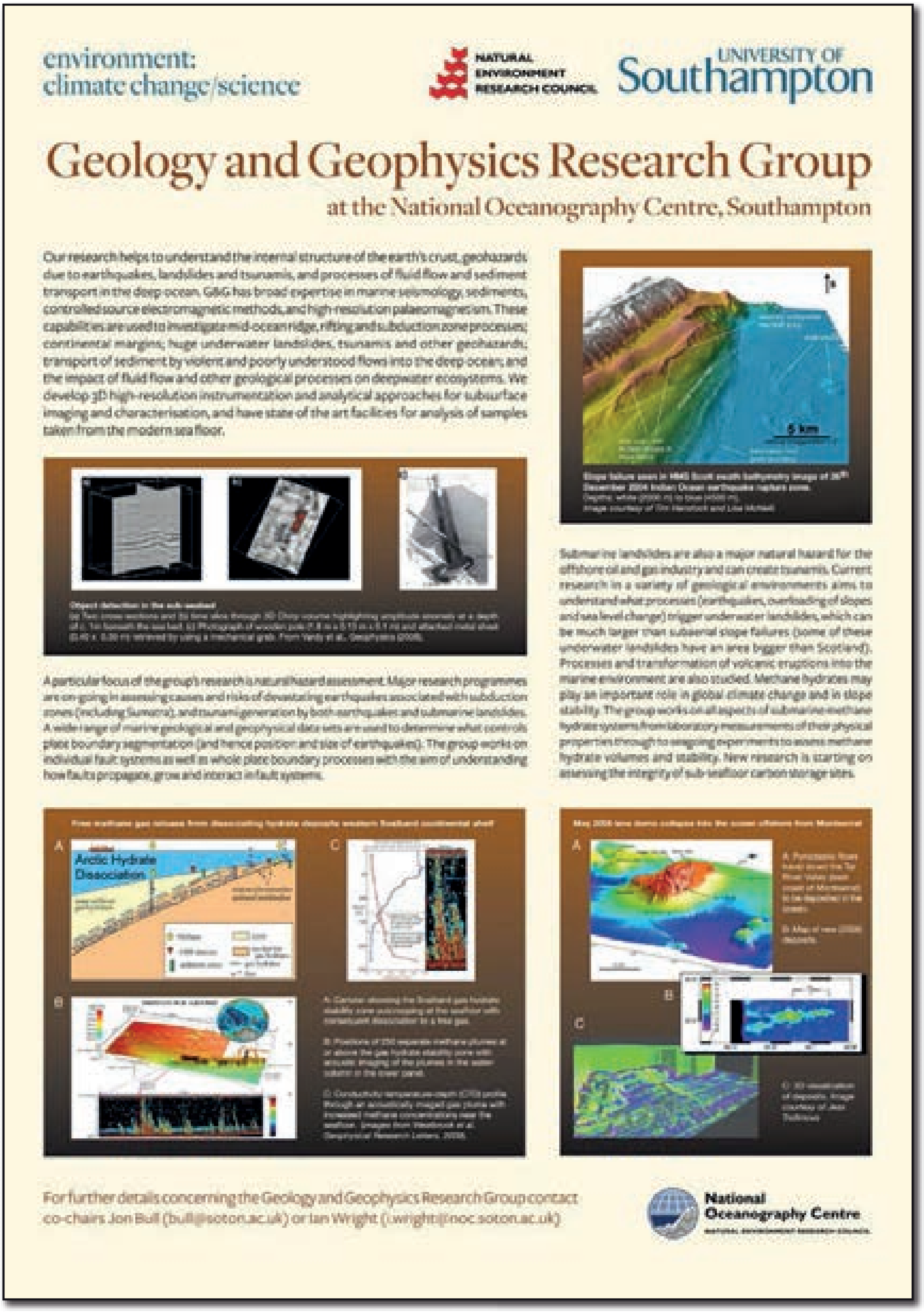
MST and miniaturisation techniques have been successfully applied to four key environmental metrology challenges. Initial results on the bench, and in deployments to 1600m demonstrate the effectiveness of this solution. Current research is optimising and enhancing this technology to produce robust and fully functional sensing systems using MST and promises to deliver a paradigm shift in the data available to environmental science

Acknowledgements

This work is funded through the NERC Oceans 2025 programme (theme 8.1), the collaborative EPSRC /NERC grant EP/E016774/1, and an FP7 Integrated project (labonfoil) . Commercialisation is funded by NERC

EPSRC · NATURAL ENVIRONMENT RESEARCH COUNCIL · UNIVERSITY OF Southampton School of Electronics and Computer Science · National Oceanography Centre, Southampton · Oceans · LABONFOIL

Professor J Bull **CE16**



University of Southampton

Underwater Anthropogenic Noise

Background

There is a growing awareness of underwater anthropogenic (man made) noise and its potential impact on marine life. The EC has recognized this by including two indicators of underwater noise in its criteria for the good environmental status of marine waters, as part of the Marine Strategy Framework Directive (MSFD).

In addition to long term monitoring there is a need to measure and monitor the noise generated by noise sources including ships, marine construction and off-shore renewables.

The University of Southampton has been involved in a project to measure the noise generated by dredging vessels during marine aggregate extraction operations. Each year these provide 20 million tonnes of sand and gravel from the seabed in UK coastal waters for use in construction industries. For aggregate extraction, a trailing suction hopper dredger is used, which lowers a drag head and suction pipe to the sea floor to extract the sand or gravel.

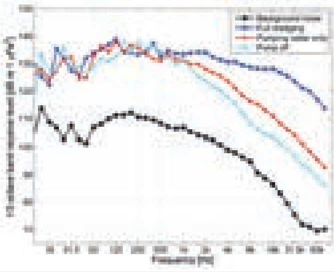
The Sand Falcon undertaking dredging in Area 473 in the English Channel.

Research

The research consortium performed measurements on 6 vessels in 3 different areas around the UK's coast, with one vessel being measured in two different areas. The radiated underwater noise was measured using hydrophones deployed from a survey vessel, autonomous recording buoys and a vertical array with electronic position sensing.

In addition to measuring the radiated noise at given distances, the use of propagation loss models allowed the source levels of each vessel to be calculated. These source levels are an essential input to numerical models for calculating noise maps and exposures.

The cooperation of the vessel masters enabled the noise generation mechanisms to be identified by operating the vessels in various modes (e.g. pumping water but not aggregate). In addition, the use of the vertical array enabled sources to be identified in elevation, in particular the noise from the mid-water pump on the suction pipe.

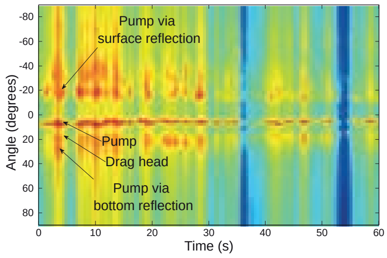


Received levels from the Sand Falcon at 100 m comparing levels for full dredging (draghead down, pump on), pumping with draghead raised from the seabed, and with the pump switched off. Also shown is the ambient noise level.

Impact

This work has:

- Provided a definitive set of data on the radiated noise from a representative cross-section of vessels within the U.K. marine aggregate extraction fleet.
- Provided data that will be used as the basis for making environmental impact assessments when applying for licences for new dredging areas.
- Aided the development of techniques for measuring the radiated noise level and source level that will be used in further work and that will help guide the development of measurement standards in this area. Key investigators are on the new ISO Committee on Underwater Acoustics (ISO/TC43 SC3).



Identification of noise sources using the vertical array showing strong radiation from the mid-water pump. The beamformer output has been summed over all frequencies and is plotted as a function of time.

Collaboration

This research was performed by a consortium led by the National Physical Laboratory, with Loughborough University, the University of Southampton and Gardline Environmental Ltd. This work was funded by MALSF under project MEPF 09/P108. The support of the vessel operators is greatly appreciated.

Victor Humphrey, ISVR Fluid Dynamics and Acoustics Group (vh@isvr.soton.ac.uk)

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Anthropogenic Noise from Offshore Wind Farm Construction

Professor V Humphrey

CE18

UNIVERSITY OF Southampton

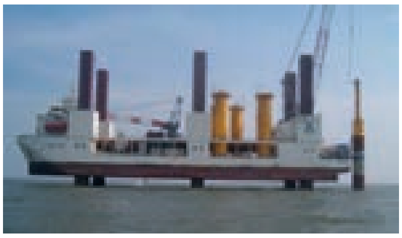
Anthropogenic Noise from Offshore Wind Farm Construction

Background

A key element of the UK plan for the delivery of renewable energy is the development of offshore wind farms. It is envisaged that up to 10,000 additional turbines will be installed by 2020.

The favoured construction method is to drive a monopile (steel tube) into the seabed using a percussive (impact) hydraulic ram. These monopiles can be up to 6 m in diameter and are driven up to 25 m into the seabed. This piling process radiates high levels of impulsive noise into shallow coastal waters.

With a growing awareness of the potential impact of anthropogenic (man made) noise on marine life it is important to gain an improved understanding of the physics of the noise generation process and how the sound propagation into the shallow water environment is affected by the pile, hydraulic piling, seabed and water column characteristics.

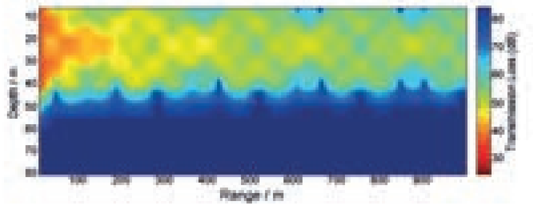


Pile-driving a monopile (on right of picture) into seabed from a platform.

Research

This research aims to provide an improved understanding of the noise generation process via a combination of numerical modelling and experimental measurement. It will eventually include:

- Finite Element modelling of the impact process in order to determine the acoustic field distribution near to the source;
- Numerical modelling of the sound propagation through the seabed and water column;
- Scaled laboratory experiments to obtain confirmation of the generated sound under controlled conditions, with easily varied system parameters;
- Comparison with data collected at sea to verify the performance of the models developed;
- Calculation of acoustic metrics used in assessing the impact on marine life; these include the peak pulse pressure, and pulse energy - important for calculation of sound exposure level (SEL).

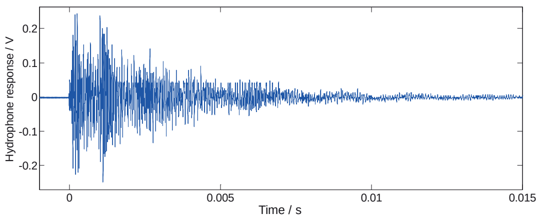


Numerically modelled signal loss as a function of range from a uniform 200 Hz extended source in 40 m of water and 20 m of sediment.

Impact

An improved understanding of the generation of underwater pile-driving noise will have an impact on construction planning, mitigation measures, environmental impact and commercial development.

- An improved knowledge will facilitate impact assessments at the planning stage, and help to develop strategies for minimising environmental impact.
- The development of effective mitigation measures – such as acoustic baffles – will be aided by an understanding of the noise generation process.
- An improved understanding and mitigation measures will enable the environmental effects to be minimised and help to prevent environmental concerns delaying construction.
- An improved understanding will aid the construction industry as the world market in this area grows.



Experimentally measured acoustic output from an impact generated in a scale model system in the laboratory.

Collaboration

This research is part of an ongoing collaboration with the National Physical Laboratory (NPL) and the Department of Electronic and Electrical Engineering at the University of Loughborough. They have already made measurements of piling noise in situ. Avenues for funding research in the area of anthropogenic noise are being jointly pursued.

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Exploring Beneath an Antarctic Ice Shelf with the Autosub3 AUV

S McPhail

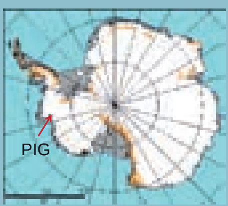
CE19

Exploring Beneath an Antarctic Ice Shelf with the Autosub3 AUV

Stephen McPhail, Maaten Furlong, Miles Pebody, James Perrett, Peter Stevenson, Andy Webb, Dave White
(All with the National Marine Facilities Division, NOC, Southampton, UK.)

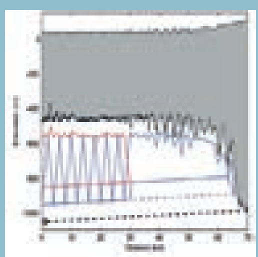
The most recent report of the Intergovernmental Panel on Climate Change (IPCC) noted that because so little is understood about ice-sheet behavior it is difficult to predict how ice sheets will contribute to sea level rise in a warming world.

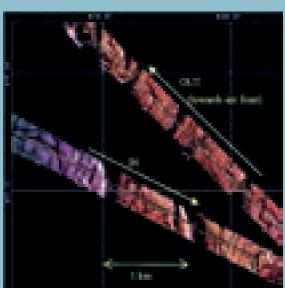
The Pine Island Glacier (PIG) ice shelf in the Western Antarctic has been thinning and accelerating over the past decades. It is vitally important to understand why this is happening, so in January 2009 a team of scientists and engineers set sail from Punta Arenas, Chile, on the US icebreaking ship, the *Nathaniel B. Palmer*. The collaborative effort involved the National Science Foundation, who provided the ship time, (cruise chief scientist and co PI Dr Stanley Jacobs of Lamont Doherty Earth Observatory), the British Antarctic Survey (PI Dr Adrian Jenkins) provided the scientific rationale, and the National Oceanography Centre, Southampton, provided the technology for the investigation with the Autosub3 Autonomous Underwater Vehicle.



Objectives were the mapping of the ice shelf, the seabed beneath and the study of the flow of water in the cavity. Sensors on board the AUV included high precision conductivity, temperature, and turbidity sensors, plus a high resolution (2 m pixel) multibeam mapping sonar, configured to either point upwards at the ice, or downwards at the seabed below.

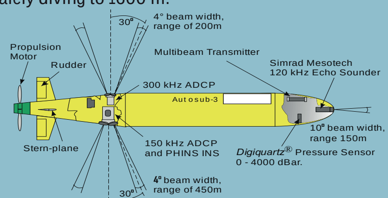
The ice (grey in the figure) is 500 m thick at the ice front, and 1000 m thick at 70 km in, where it contacts the seabed (the grounding line). In the example mission plan, the AUV runs into the ice cavity at constant depth (blue trace). When it cannot safely continue it turns and flies a constant distance from the ice above for a distance of 20 km, whereupon it continues towards the ice front in profiling mode.



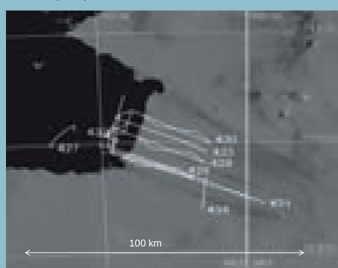


The upward looking multibeam sonar system provided never before seen detail of the underside of an ice shelf. The image shown shows two 300 m wide swaths of multibeam data, one collected as the AUV headed in towards the grounding line, the other as the AUV headed out towards the ice front. The AUV was set to fly at 100 m below the ice – not a easy task, given the fissured nature of the under ice surface.

The Autosub3 Autonomous Underwater Vehicle was developed at the Underwater Systems Laboratory (USL) within the National Marine Facilities Division at NOC, Southampton. Here it is ready for launch at the start of its first of 6 missions under the Pine Island Glacier (the ice front can be seen on the horizon). Autosub3 is 7 m long, weighs 2.5 tonnes in air, and is powered by over 5000 primary D cell batteries, giving a maximum endurance of 400 km at a speed of 1.5 ms^{-1}. It is capable of safely diving to 1600 m.



Under the ice shelf, the AUV self navigates relative to either the sea floor or the ice above, using a combination of upwards and downwards looking Doppler sonars, and inertial navigation system. Typically it achieved accuracies of 1 m error in every 1000m travelled, ensuring the AUV returned close to its rendezvous position with the ship. To avoid collision with either the ice above or the seabed, several pencil beam sonars are used together with the bespoke (USL developed) control and collision avoidance software.



In total, over a period of two weeks, 6 missions were run under the ice shelf (shown over a satellite image of the PIG – the sea is black), the longest lasting 30 hours and covering 170 km.

Sustained Observations in the Atlantic and Southern Oceans

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CE20

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Sustained Observations in the Atlantic and Southern Oceans

The marine environment requires sustained observations to obtain meaningful information on environmental changes and their causes. To this end, the National Oceanography Centre, Southampton, supports a number of marine time-series and monitoring studies in the Atlantic and Southern Oceans. The primary aims are to provide data and knowledge on a wide range of oceanic processes, from ocean circulation to biodiversity. They have been developed not only to provide long-term data sets but also to capture extreme or episodic events and to play a key role in the initialisation and validation of models.

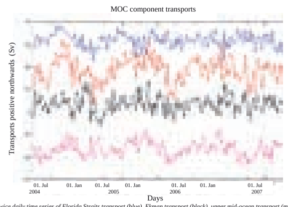
The Atlantic Meridional Overturning Circulation (AMOC) East-West mooring array

The aim of the project is to observe on a daily basis the strength and structure of the AMOC and deliver a decade-long time series of calibrated and quality controlled measurements .

The AMOC at 26.5°N, carries a northward heat flux of 1.3 PW and as it moves north much of this heat is transferred to the atmosphere and subsequently is responsible for maintaining the UK climate about 5°C warmer than the zonal average at this latitude. However, due to sparse data, it is unclear whether the AMOC is slowing in response to global warming as suggested by recent model results.

The data from the arrays and elsewhere will be used to determine and interpret recent changes in the Atlantic MOC, assess the risk of rapid climate change, and investigate the potential for predictions of the MOC and its impacts on climate.

So far results* demonstrate that the AMOC, has dramatic and unexpected variability with a mean strength in the first year of 18.7±5.6 Sv.



Twice daily time series of Florida Straits transport (blue), Ekman transport (black), upper mid-ocean transport (magenta) and reconstructed MOC transport (red).

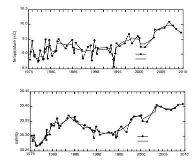
*Cunningham, S. A., et al. (2007), Temporal variability of the Atlantic Meridional Overturning Circulation at 26.5°N, Science, 317, 935-938.

The extended Ellett Line

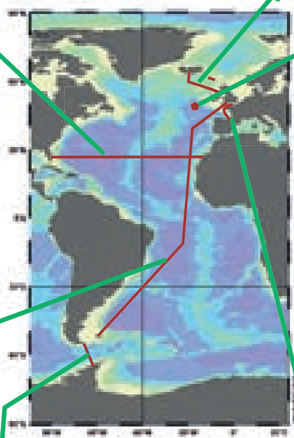
This annually occupied, full depth hydrographic section between Scotland, Rockall, 60°N 20°W and Iceland is designed to capture the warm saline inflow into the subpolar gyre and the Nordic Seas, and the path of the deep returning flow in the lower branch of the meridional overturning circulation. The aim is to create a time series that can be used as measure of climate change in the Northeast Atlantic and against which numerical models can be assessed. In addition there is an ADCP mooring monitoring the Wyville-Thomson Ridge overflow.

The line from Scotland to Rockall has been occupied since 1975 and the extension to Iceland since 1996. Results show a steady increase in both temperature and salinity in the upper ocean over the last 30 years with variability of up to 1.5°C and 0.1 in salinity. Both temperature and salinity have remained at an all series high over the last 5 years.

More details are available at http://www.noc.soton.ac.uk/obe/PROJECTS/EEL.index.php



Temperature and salinity trends 1975-2009 along the extended Ellett Line



The Porcupine Abyssal Plain (PAP) fixed-point observatory

The observatory sited at 49°N, 16.5°W in the Northeast Atlantic is the longest running deep ocean time-series observatory in Europe. The aim is to collect high resolution in-situ multidisciplinary time-series data of climatically and environmentally relevant parameters from the euphotic zone to the benthic boundary layer. These include sub-surface measurements of temperature, salinity, chlorophyll-a fluorescence, nitrate, pCO2 and deep ocean particle flux. Data are sent in near real-time from the upper 1000m through Iridium telemetry to shore stations.

Trends from 2003 to 2005 indicate a higher temperature and salinity signal in surface waters from 2003 to 2005 with increased stratification, decreased nitrate concentration and consequent decline in productivity and delay in the spring bloom. In addition, there is evidence that the levels of pCO2 being absorbed in this persistently undersaturated region are reducing which has future implications for the global carbon cycle and importance of the oceans as a

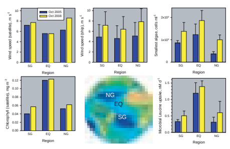
Variation in temperature at the PAP observatory site from 2003 to 2005. Triangles = in situ subsurface mooring based measurements (from 20m to 225m; black line = Sea Surface Temperature (SST) data from the National Center for Environmental

*Hartman, S. E., et al., Seasonal and inter-annual biogeochemical variations at PAP (49°N, 16.5°W) 2003-2005 associated with winter mixing and surface circulation. Deep Sea Research, accepted.

Atlantic Meridional Transect

The Atlantic Meridonal Transect Programme, which began in 1995, is an open ocean in-situ observing system that utilises the passage of the RRS James Clarke Ross between the UK and the Falkland Islands southwards in September and northwards in April each year. The aim of the programme is to understand ocean plankton communities and improve our ability to predict the role of the open ocean in the global carbon cycle.

Recent results show that the abundance of the smallest algae, which are responsible for a major part of CO_2 fixation, were about twice as high across the Atlantic Ocean from 30ºN to 30ºS in autumn 2008 compared to autumn 2005. The observed differences are more likely related to large-scale changes of wind forcing rather than to seasonality, taking into account a corresponding ~50% increase in the mean wind speed in autumn 2008 compared to autumn 2005. This suggests that climate-change induced increase in wind stirring could elevate phytoplankton growth & sequestration of CO_2 in the open ocean.



Inter-annual differences in wind speed, chlorophyll, algal numbers & microbial activity in the three major regions of the Atlantic Ocean

Drake Passage

The UK maintains an annual full-depth repeat hydrographic section in the eastern Drake Passage. The first occupation was in 1993, and only two years have been missed since then. The measurements are mainly physical: CTD and shipboard ADCP, with Lowered ADCP added in 1996, at a maximum station spacing of 35 km.

This coast-to-coast transect across the Antarctic Circumpolar Current enables the baroclinic transport of the current to be measured, and this is found to have an average of 137 x 106 m3/s, with an interannual variability of about 6%. The variability means that 20 years of measurements would be needed to be sure of detecting a change of 10%, and an even longer time series would be needed to detect smaller changes.

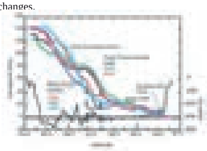


Illustration of the variation in transport across Drake Passage for six years of data. The main current jet, the Polar Front tends to be found in one of two locations. The volume transport is accumulated from south to north each year.

Climate quality surface marine observations and products

The aim of this programme is to take historical and operational data collected by international meteorological programmes and satellite agencies and develop data sets and data products that can be used in ocean circulation and climate research.

In situ marine meteorological data sets contain well-known variations in sampling density with good data coverage in the main shipping lanes and in Northern mid-latitudes, but are sparse in other areas of the world; there are also issues of quality control. Using state of the art flux parmeterisations , improved bias corrections, data homogenization and uncertainty estimates, a 36-year (1973-2008) global monthly mean surface meteorological and flux dataset has been produced *. The dataset includes global marine monthly fields of air temperature, SST, humidity, wind speed, pressure, sensible and latent heat fluxes and shortwave and longwave radiation. The next steps for the flux dataset are to extend the record back to the late 1950s and to include selected satellite parameters.

Improved satellite datasets are also being constructed: a global wave height and period dataset from satellite altimeters is under development and research is working toward new methods to derive wind and wave parameters from GPS satellite "signals of opportunity" **

The NOCS v2.0 Net Surface Flux, Climatological Average 1973 -2002

*Berry D. I. and E. C. Kent, 2009: A New Air-Sea Interaction Gridded Dataset from ICOADS with Uncertainty Estimates. Bull. Amer. Meteor. Soc.: 90, 645-656.
**Clarizia, M. P., C. P. Gommenginger, S. T. Gleason, M. A. Srokosz, C. Galdi and M. Di Bisceglie, 2009: Analysis of GNSS-R Delay-Doppler Maps from the UK-DMC satellite over the ocean. Geophysical Research Letters, 36, L02608. doi:10.1029/2008GL036292

The Portsmouth-Bilbao transect

This route is traversed twice weekly throughout the year by the commercially operated P&O ferry MV Pride of Bilbao. The ship is fitted with a dedicated seawater intake for scientific work and has been instrumented by NOCS with a standard 'Ferrybox' system which logs temperature, salinity, oxygen, fluorescence and occasionally carbon dioxide. There is also a radiometer above the bridge for sea surface temperature measurements. Data is received at NOCS via satellite link (EU Ferrybox project) and the novelty of the project is the long time series of integrated simultaneous measurements that began in 2001. Since the ferry crosses a number of oceanic and biological provenances, it provides data over a variety of temporal and spatial conditions.

Ecosystem trophic state as revealed by the oxygen anomaly along the MV Pride of Bilbao route: Mean 2005-2007

Argo

The UK has been a strong supporter of Argo since the program began, and is fully committed to the Argo goal of maintaining a global array. It has deployed nearly 300 floats since the start of the program in 2000, in the North and South Atlantic, Indian and Southern Oceans, and has been pleased to collaborate with other countries including Ireland and Mauritius on deployments and data handling.

Within the UK, the main customers for float data are the data assimilation activities at the Met Office, either for short-term ocean forecasting or seasonal combined ocean-atmosphere forecasts, and nearly 50 individual projects or researchers in Universities and Government Laboratories.

Deploying an Argo float in the South Atlantic. RRS James Cook Cruise 032 in March 2009

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NATURAL ENVIRONMENT RESEARCH COUNCIL

Mapping and Understanding the External Engagement of the University of Southampton in the MARITIME Sector

Dr R Comunian

CE21

UNIVERSITY OF Southampton
School of Geography

Mapping and understanding the external engagement of the University of Southampton in the MARITIME sector

Background

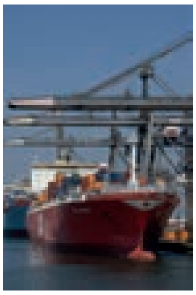
- This research project will take place between October and December 2009 and will involve academics of the Maritime Studies strategic research group. It is part of a Business Fellowship within the Employer Engagement Initiative, which is funded by HEFCE and led by the Learning and Teaching Enhancement Unit.

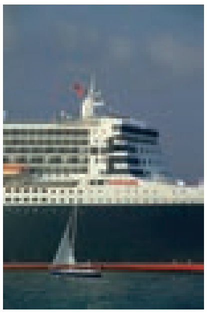
Aim

- The project aims to map and understand external engagement of academic staff, within the Maritime USRG, in order to assess the type of relations and exchanges taking place with companies, public sector bodies and other organisations.

Methods

- **Social network analysis**: to create a map of external engagement dynamics: such as type/nature of relations, type of external partners involved, strength of exchange etc.
- **Qualitative interviews:** to investigate the nature of these collaborations, how they get established and what facilitates or inhibits their development.



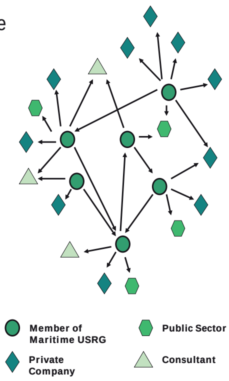


Research Questions

- How do academics establish relationships with outside organisations and businesses in the maritime sector?
- What is the knowledge and awareness of the University of the collaboration taking place between academics and external partners?
- What are the advantages and difficulties of collaborating with private companies and public sector bodies in this sector?
- What initiatives and activities support and facilitate collaborations across the sector?
- What features of the University are considered more relevant by external partners?
- How can the University become a core partner for the strategic development of the maritime sector locally and nationally?

Mapping knowledge collaboration to:

- Identify the nature of people and organisations involved;
- Understanding of key connections and direction of interaction;
- Consider the role of collaborations across disciplines;
- Identify the role of the local context and its people in relation to the national landscape.
- Visualise how knowledge flows in order to identify strengths and weaknesses;



Understanding knowledge exchanges to:

- Capture the knowledge engagement taking place at the University in the maritime sector;
- Explore the nature of the collaborations established and the important of the local context and social dynamics;
- Consider what kind of infrastructure or support facilitates the growth and development of these collaborations;
- Identify the key motivations for knowledge to be exchanged;
- Explore case studies and best practice to help develop these collaborations further.

for more information on the research project or to get involved please contact:
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(c) Ian Britton - FreeFoto.com

Serpent Project - Science and Industry in Partnership

Dr B Bett

CE22

National Marine Facilities Sea Systems – An Overview

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Integrated provision of hardware and services to UK marine science

Sea Systems operates under the following principles:

- We operate specialised science platforms; with an embarked science capability.
- We deliver a service which is shared by the marine and technical components and which is underpinned by an integrated strategic resource plan.

To deliver our mission, we provide three key services:

- The multi-disciplinary Royal Research Ships *Discovery* and *James Cook*
- The National Marine Equipment Pool (NMEP), comprising about £20M worth of equipment ranging from day grabs to complex state-of-the art underwater vehicles.
- A team of approximately fifty marine technicians, providing specialist support to research cruises on a wide range of international and British Antarctic Survey (BAS) vessels as required, as well as Sea Systems' own research ships.

Sea Systems supports around thirty research cruises each year, with about twenty on our own vessels, and the remainder being onboard BAS or international barter ships. The main activities of the organisation are managed under four branches: *Programme Management, Scientific Engineering, Research Ships* and *Support Services*. Overall planning and service coordination is through the Programme Manager who acts as the primary contact for all proposed cruises that are yet to be published in the programme and is also responsible for identifying any new equipment which may be required to support future cruises. Once a cruise is published in the programme, cruise planning is handed over to Cruise Managers. A Cruise Manager is assigned to each cruise and will act as the first point of contact for all operational enquiries as well as ensuring that all logistical arrangements for the ship, equipment and staff are fully harmonized.

Scientific Engineering provides foundation engineering services and provision of technical staff to support scientific equipment onboard.
The group is organised in four sections ensuring a full technical service is provided

Sensors and Moorings – Extensive experience working with a broad range of equipment, including vertical profiling systems, towed and undulating vehicles, moored instruments and mooring technologies

Deep Platforms – Comprising Sea Systems specialist deep-water vehicles, the AUV Autosub3, the ROV *Isis*, an deep towed platforms TOBI, BRIDGET and SHRIMP

Portable Systems – Responsible for facilities such as coring, trawling and seismic systems as well as general laboratory equipment such
as fume hoods and gas generators. specialised container laboratories for clean chemistry and radio nuclide work

Ship Systems – manages all engineering activities connected with equipment permanently fitted to the Sea Systems managed vessels including computer networks and a sophisticated acoustic suite

The *Research Ships* team are responsible for the safe and effective operation of the Royal Research Ships *Discovery* and *James Cook* including operational and logistical arrangements for people joining vessels, diplomatic clearances, accommodation, liaising with ships agents and ensuring compliance with the International Ship Management code. The group is also responsible for ships engineering looking after propulsion and power generation, ship fitted winches and handling systems as well as managing refits and recertifications.

The Sea Systems group is also responsible for maintaining the *National Marine Equipment Pool* (NMEP) on behalf of NERC. The NMEP consists of a wide range of equipment which is primarily used to support the NERC Marine Facilities Programme.

The operation is underpinned by *Support Services,* providing bespoke data systems for marine planning and equipment tracking as well as logistics services who ensure the supply and transportation of equipment worldwide.

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Environment and Resources

UNIVERSITY OF Southampton

Deep-water science and survey

Greenland Halibut, prized by deep-sea trawlermen.

Upside-down octopus at 1,200m water depth.

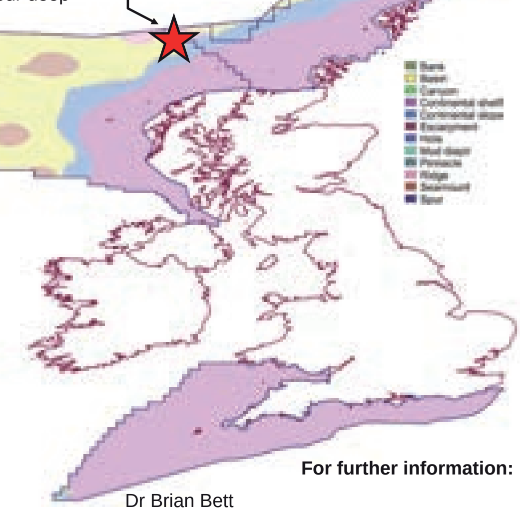
The predominant environment on our planet is the deep-ocean floor. About 70% of the Earth is beneath waters deeper than 200m. Our oceans have an average depth of 3,200m compared to the average land height of just 800m.

The National Oceanography Centre, Southampton is a world-leading institution in the science and survey of deep waters. The UK's deep-water territory covers an area greater than that of its land surface. NOCS science teams have surveyed much of this area, on behalf of the Oil Industry and the Government. It is an area particularly rich in habitats and high in biodiversity. Our biologists and geologists are working to map this diversity, to promote the appropriate management of our deep-water realm.

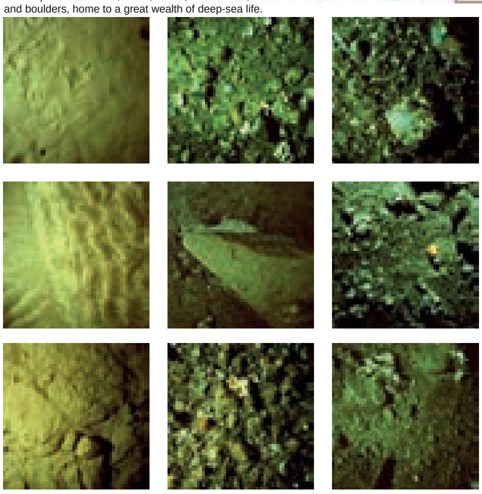
National Oceanography Centre, Southampton

Darwin Mounds – *UK's first deep-water marine protected area. In 1998 NOCS scientists discovered these unique sand volcanos covered in growths of deep-sea corals. Returning to study them in 2000, our team found they had been damaged by deep-water trawling.*

Following a change in European law, they were given protected status in 2004.



UK deep-water habitats, muds, sands, sand dunes, cobbles and boulders, home to a great wealth of deep-sea life.



To find out more about UK deep-sea habitats and wildlife visit the deepseascape website

To find out more about exploring UK and other deep waters with robots visit the serpentproject website

www.deepseascape.org.uk

www.serpentproject.com

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National Oceanography Centre, Southampton

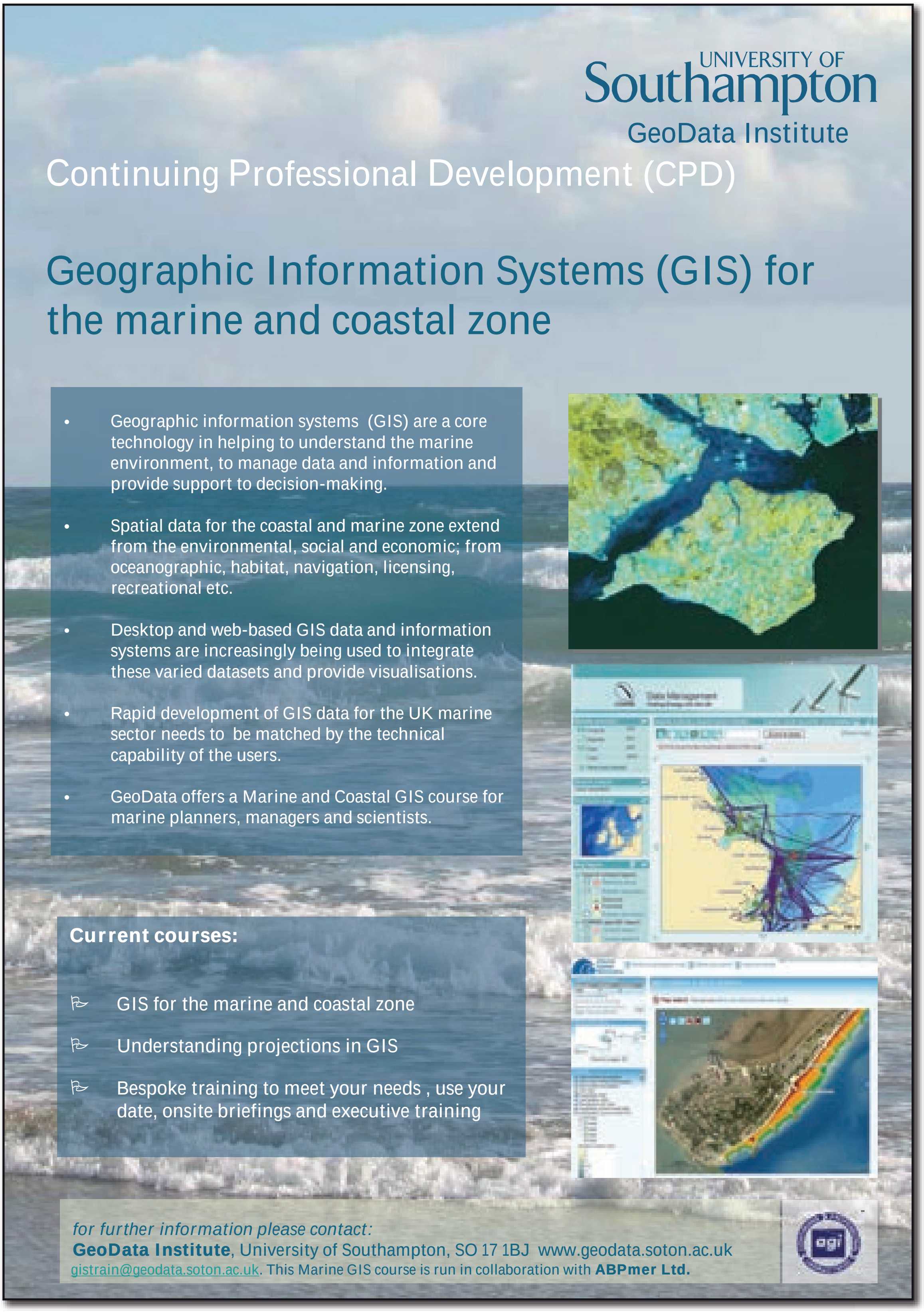
NATURAL ENVIRONMENT RESEARCH COUNCIL

www.southampton.ac.uk

Geographic Information Systems (GIS) for the Marine and Coastal Zone

C Hill

CE25



C Hill

CE26

UNIVERSITY OF Southampton
GeoData Institute

Environment

Marine Environmental Data Management

Marine and coastal data management

Managing the marine environment is a complex issue, with mineral extraction, fishing, energy, navigation, conservation and recreation often competing within increasingly busy sea areas.

The Government has recognised, through the Marine Bill, the need for an effective planning process - the Marine Plan - and is currently developing the approaches to deliver spatial planning for the marine and coastal zone.

GeoData Institute, the University's environmental assessment, data and information consultancy, is been helping to manage the marine information from a number of domains.

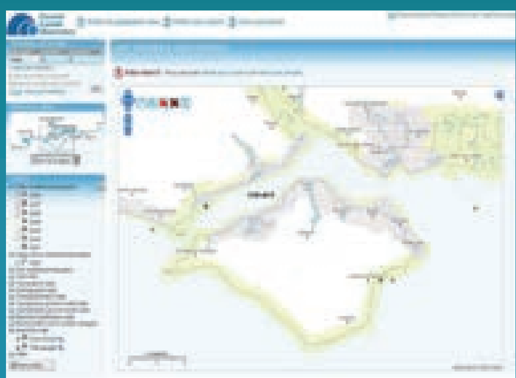
Using Open Source software and integrating spatial data and metadata the Institute is providing public access to a wide range and large volumes of environmental information.

Key applications include:

- Marine Aggregate Levy Sustainability Fund (mALSF) GIS www.marinealsf.org
- COWRIE Collaborative Offshore Wind Research into the Environment www.data.offshorewind.co.uk
- Channel Coast Observatory – real-time metocean and survey data for the South Coast. www.channelcoast.org.uk
- Software development for the marine sector

Key Impacts

- Supports operational management of the coastal zone, for flood and erosion risk management.
- Real-time data access, for hazard warning and mitigation.
- Support research using high quality, accessible environmental data.
- Advancing information management and knowledge exchange for the marine community.
- Support to marine spatial planning, and integrated coastal zone management.
- Leading edge research into data management and semantic query design.



Channel Coastal Observatory – real-time and baseline data for the South Coast
Channelcoast.org.uk

for more information please contact:
GeoData Institute
Tel: +44 (0)23 8059 2719 Email: geodata@soton.ac.uk, Web: www.geodata.soton.ac.uk

Minimising the Propulsive Power Consumption of a Fleet of AUVs

Professor P Wilson

CE27

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Minimising the Propulsive Power Consumption of a Fleet of AUVs

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Motivation

In nature, birds form a 'v' formation for long distance migration (Figure 1). Many fish species swim in shoals or schools to increase hydrodynamic efficiency and for defence against predators (Figure 2). Bottlenose Dolphin calves swim close to the aft quarter of the mother in order to reduce its energy consumption. These simple observations suggest potential AUV fleet configurations to reduce power consumption. BUT an AUV is a machine propelled by a propeller, not a swimming marine animal So can the fleet configuration be optimised to reduce the energy consumption of all the AUVs in the fleet?

Figure 1: 'V' formation of Birds [1]

Figure 2: A school of 50 Atlantic bluefin tuna [2]

Research Aims and Objectives

The research aims of this work is

To minimise the energy consumption of a fleet of AUVs by optimising their swimming formation.

To accomplish this task requires the completion of the following objectives:-

1.To investigate a fleet of cooperative AUVs by considering a generic AUV shape of revolution (e.g. prolate spheroid) using a 3-Dimensional commercial RANS simulation software (e.g. ANSYS CFX)
2.To investigate and model the mathematical body of revolution and determine the hydrodynamic constraint of the optimal shape.
3.To develop the drag model by using the boundary layer solution, potential flow, transition prediction and drag calculation.
4.Optimisation of a leading AUV by using simple search strategy (e.g. Powell method) and advance search strategy (e.g. Genetic Algorithm)
5.To define the optimum shape and optimum distance between the cooperative AUVs.

Investigation of Twin hulls AUVs

- In 1997, Molland and Utama [3] performed an experimental investigation into the drag characteristics of a pair of prolate spheroids in close proximity. The experiments where performed in the 7'x5' low speed wind tunnel at the University of Southampton. Up to 40 m/s wind speeds were used, to give a Reynolds numbers (based on model length) of up to 3.2×10^6. The experimental results show that there is significant interaction between both models placed side by side. The closest spacing increased the drag coefficient compared to the reference hull by approximately 8%, Figure 3.
- In 2002, RANS simulations of the experiments were performed by Molland and Utama [4], these results are also shown in Figure 3. The simulation domain is 5lx2lx2l (LxWxH). Their grid had 0.8M elements with y+ = 11.50. The RANS simulation is about 10%-20% higher than the experimental results.
- **In the present study**, the validation compare to the experiment had been done
  - the model of domain was set at 14lxlx1.8l the size of the wind tunnel. The commercial software ANSYS CFX 12.1 has been used, using the Shear Stress Transport (SST) turbulence model.
  - Grid convergence of the model is shown in Figure 4. For further studies the mesh parameters of the 8M grid at y+ = 30 have been used.
  - The results of the drag of an AUV hull when there is another hull placed side by side also shows in Figure 3 which is about 10%-20% lower than the experimental results. However the simulation result show the same trend as the experimental results for the S/L = 0.27 and 0.37. In case S/L = 0.47 and 0.57, it was possible that there was an effect of the wind tunnel wall into the model.

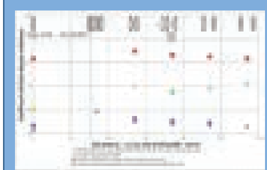


Figure 3: Comparison of the drag coefficient of the referent hull when there is the similar hull placed side by side

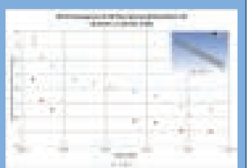


Figure 4: Grid convergence of the twin hulls simulation of this present study

Simulation of Multiple AUVs

The presence of the second hull near the reference hull affected the drag coefficient of both of hulls, hence the authors investigated further for alternative arrangements, shown in Figure 5, Figure 7 and Figure 8. Figure 6 is the reference of the drag coefficient of the reference hull.

Figure 5: The multiple hulls model where:
S/l is Spacing between both hulls in the vertical direction
D/l is Drafting between both hulls in the horizontal direction
and l is Length of the hull body

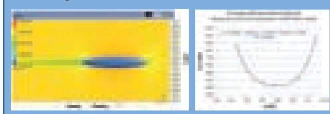


Figure 6: Single hull simulation and the drag coefficient at the various y position in the wind tunnel

Figure 7: Simulation of two hulls in different spatial configurations

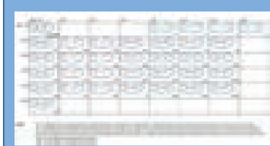


Figure 8: The numerical results of the drag coefficient of twin hulls' interaction at the various position

Future Works:

- Analysis the simulation data of multiple hulls
- Simulate the propeller effect into the wake behind the reference hull
- Optimise the energy of the overall fleet of AUVs by minimise the drag of the overall fleet

Reference:
[1] Picture credit: http://en.wikipedia.org/wiki/File:V-formation.jpg
[2] Picture credit: Hanrahan, B. and Juanes, F. Estimating the number of fish in Atlantic bluefin tuna schools using models derived from captive school observations. Fishery Bulletin 99(3). 2001
[3] Molland, A. F. and Utama, I. K. A. P. Wind tunnel investigation of a pair a ellipsoids in close proximity. Ship Science Report 98, University of Southampton, 1997
[4] Molland, A. F. and Utama, I. K. A. P. Experimental and numerical investigations of a pair a ellipsoids in close proximity. In *Proceedings of the Institution of Mechanical engineers, Part M: Journal of Engineering for the Maritime Environment.*

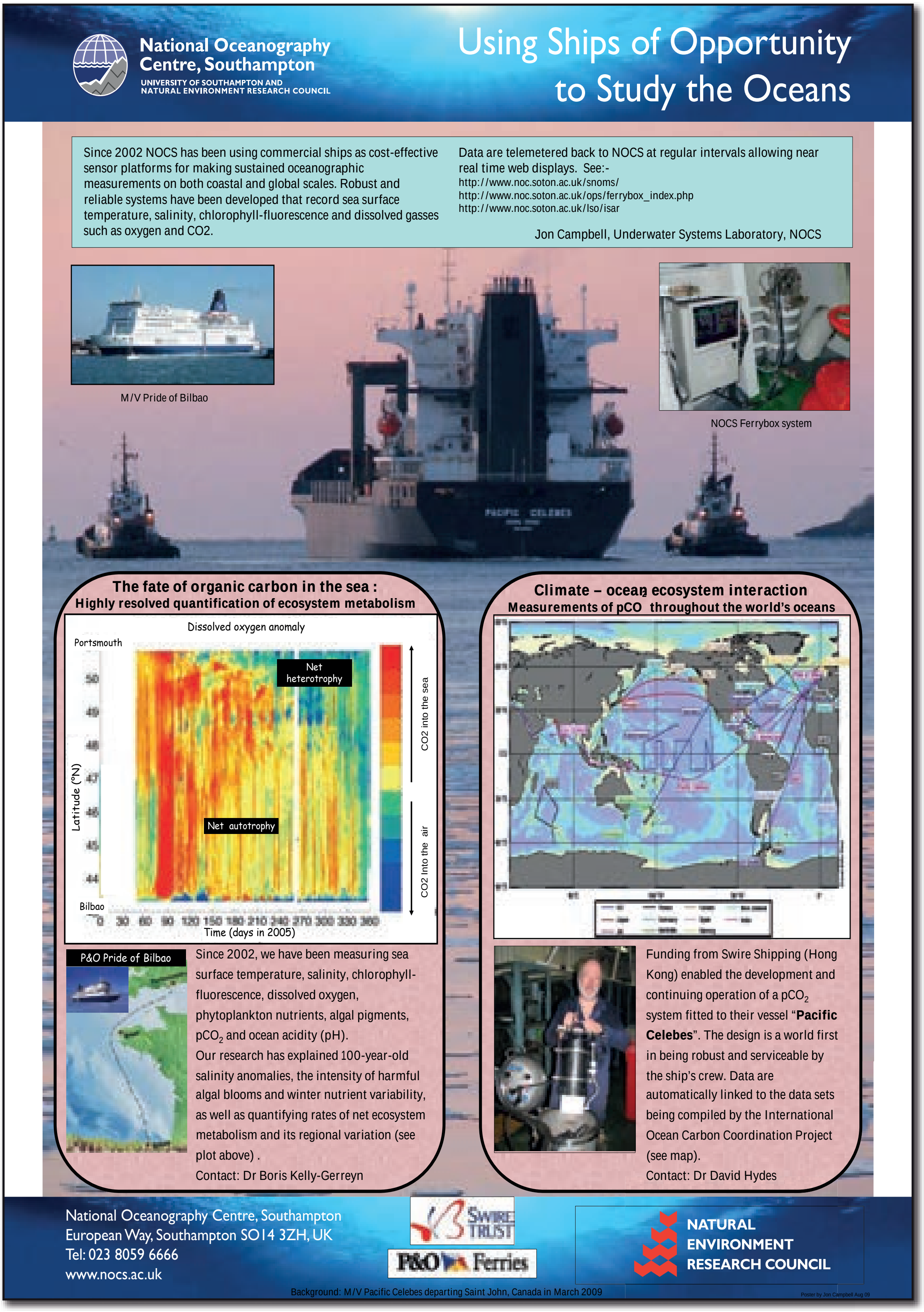
FSI Away Day 2012

Acknowledgement: This project is supported by funds from the **Royal Thai Government**

Using Ships of Opportunity to Study the Oceans

Dr D Hydes

CE28



Bubble Acoustics

Professor T Leighton **CE29**

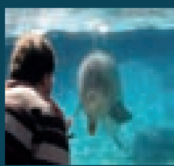
Research theme: Environment/Science

UNIVERSITY OF Southampton
Institute of Sound and Vibration Research

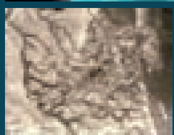
Bubble acoustics

Sound is the best radiation for exploring underwater, & bubbles are the most potent acoustical entities underwater

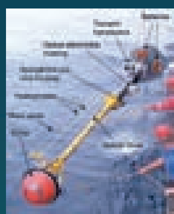
Some projects in oceanic bubble acoustics:



Do dolphins think nonlinearly?
Ideas of why dolphin sonar performs so much better than man-made sonar led to the development of a pioneering sonar device.



What is the sound of a waterfall in space?
Prediction of possible splashdown and waterfall sounds for Cassini-Huygens mission to Titan



Determining atmosphere/ocean gas transfer rates
More than 1000 million tonnes of atmospheric carbon alone transfer between atmosphere and ocean, and a huge unknown amount is transferred by bubbles under breaking waves. Our acoustic and fibre-topic sensors were mounted on an NOC buoy in the Atlantic and combined with our models of wavebreaking to quantify the bubble-mediated contribution.

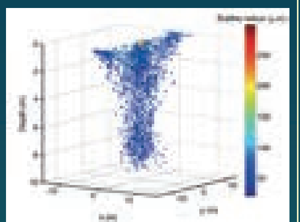
The bubble nets of humpback whales
Proposal that humpback whales use their bubble nets to generate a wall of sound to trap prey.

Measurement of gas bubbles in marine sediments
Equipment designed and deployed to provide measurements of gas bubbles in marine sediments (with assistance of NOC).

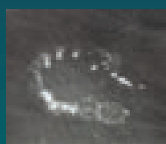
Impact:

Directly led to the development of the only sonar in the world capable of working in bubbly water (since deployed by NATO; pat. pending). A number of papers since published on finding and using the dolphin pulses which we predicted would be there.

These predictions have led to further consideration of sound on other worlds, including national radio (BBC and USA) and discussions on introducing features to planetaria (commercial ventured discussed).

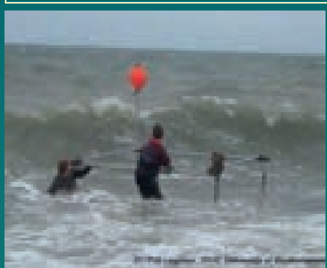


World-first measurement of climatically-important Parameters. Sensors now used by US Dept. of Energy For monitoring Neutron sources.



Theory adopted and broadcast in TV nature documentaries in UK and USA.

Methane bubbles in underwater sediments represent a major 'greenhouse issue; bubble presence affects sediment stability for marine civil engineering; petrochemical exploration.



For further details contact:

T. G. Leighton (tgl@soton.ac.uk)

ISVR, Southampton University

Energy and Resources

The ocean is an important source of food and other resources. Since well before recorded history, humans have used the sea as a source of food. While only 5% of the protein consumed by world populations comes from the sea, it is still an important contribution to the diet of millions of the world's inhabitants. The oceans and seas are repositories of vast natural resources other kinds. We derive: energy, fossil based (oil and gas) as well as from renewable sources (wind, waves, tides, thermal gradients and the sun). The oceans and sea also have many different mineral resources available for extraction, including silver, gold, copper, manganese, cobalt, and zinc. These raw materials are found in various forms on the sea floor, usually in higher concentrations than terrestrial mines.

Our interests range from understanding of the basic sciences influencing the search for such resources, the technology for managing and extracting them and the legal instruments for exploiting such resources.

Dr D Hudson

ER1

Environment

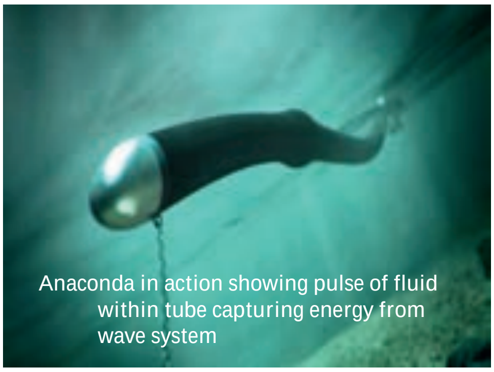
Maritime Energy – sustainable and secure

Research

Cost-effective access to maritime energy resources is essential. The rapid development of offshore renewable energy systems in particular wind and to a lesser extent tidal current and wave energy are seen as one method of the UK meeting its climate change obligations. Likewise, the on-going exploration and extraction of subsea oil and gas reserves will provide a vital component of energy security for many years.

The maritime environment presents many challenges notably due to extreme conditions arising from the very resources from which energy can be captured.

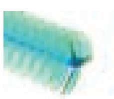
Winner of The Engineer energy sector innovation award the Southampton integrated generator is under development (TSI technology Ltd) to provide 10kW units for reliable river and tidal energy.



Anaconda in action showing pulse of fluid within tube capturing energy from wave system

Example Projects

- The novel Anaconda pulsed internal wave energy device is utilising a combination of fundamental fluid dynamics, structural response and experimental testing.
- Bend twist coupled carbon composite tidal turbine blade provide a smart structure that maximises reliability, blade life and energy capture
- Estimates of UK generation go as high of 10% from tidal currents. To achieve such levels arrays of devices are required that are optimised to ensure the maximum available energy can be utilised without significant environmental impact.
- Economic viability of tidal energy or indeed wave or offshore wind is controlled by the robustness of the system when immersed in the ocean with its salty, corrosive environment.



Impact

Providing a sustainable, secure energy supply is essential. The maritime environment will be a vital component of the UK's energy future. Our work at Southampton seeks to resolve the technological barriers to cost effective energy generation

Collaborations

A mix of large Energy providers and many SME provide funding for fundamental and applied research alongside EPSRC andTSB

www.southampton.ac.uk

Dr D Billett

ER2

Environment and Resources

UNIVERSITY OF Southampton

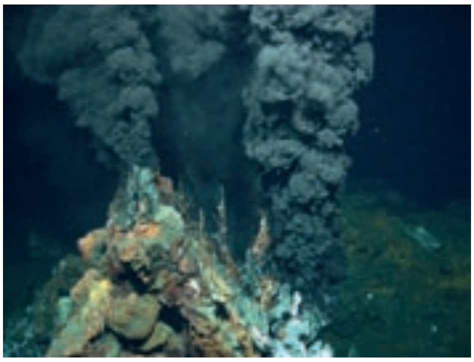
Deep-sea mineral resources and environmental management

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

The United Nations International Seabed Authority (ISA) is responsible for managing mineral resources on the deep ocean seabed in areas beyond national jurisdiction. Minerals may occur in massive polymetallic sulphides on ocean ridges, cobalt rich ferromanganese crusts on seamounts and polymetallic nodules lying on abyssal sediments. Dr David Billett, Co-Chair of the Ocean Biogeochemistry and Ecosystems Group, NOCS, is a member of the UN ISA Legal and Technical Commission, charged with ensuring that deep-sea mineral resources are exploited within a robust environmental management plan.

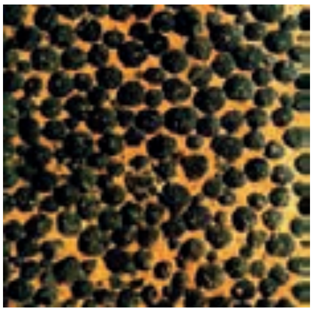
Mining in the deep-sea will have significant local impacts. Large areas of seafloor will be disturbed leading to the complete removal of fauna. It is therefore essential to know how quickly areas will be recolonised and over what scales biodiversity needs to maintained to allow seabed communities to recover. This requires knowledge of how species are distributed in different habitats in the deep ocean, their life processes, such as reproduction and dispersal, and the major drivers of species change in the deep sea. The drivers include sea surface primary productivity which fuels the vast majority of species in the oceans, even in the deepest parts.

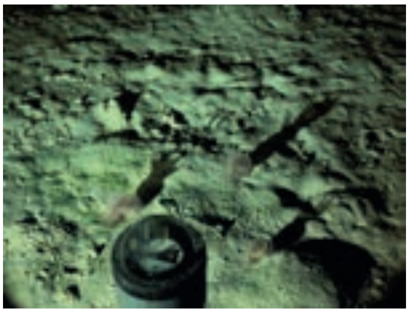
Research at NOCS is using molecular and experimental techniques to understand how widely, or not, species are distributed in the world ocean, how interconnected localised communities are, for instance on different seamounts, and how productivity leads to species change in space and time.



International treaties are charged with deciding on how spatial planning of the ocean might allow the exploitation of resources and the conservation of biodiversity, including the creation of large Marine Protected Areas (MPAs). NOCS research is being used to decide how large the MPAs should be, what number, what shape and their configuration.

The work is contributing to decisions being taken at the UN International Seabed Authority, the UN Convention on Biological Diversity, the Oslo-Paris Convention for the Protection of the Marine Environment in the NE Atlantic (OSPAR) and the European Commission.





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NATURAL ENVIRONMENT RESEARCH COUNCIL

www.southampton.ac.uk

Sustainable Catalysis for Renewable Marine Energy

Dr R Raja

ER3

Chemistry

Sustainable Catalysis for Marine Renewable Energy

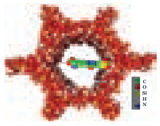
Christopher Hinde, David Xuereb, Matthew Potter, Robert Raja*

R.Raja@soton.ac.uk; http://www.soton.ac.uk/chemistry/about/staff/rr3.page

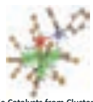
Engineering Sustainable Catalysis

Porous Molecular Frameworks: Design Strategy

- Designing novel framework structures (zeolites, AlPOs, MOFs, ZIFs) with tuneable pore architectures
- Isomorphous substitution of framework anions and cations with catalytically active transition-metal entities
- Take advantage of pore aperture for shape-, regio- and enantio-selectivity



Anchored Organocatalyst on Mesoporous Silica



Nanoparticle Catalysts from Cluster Precursors

Microporous Architectures for Shape-Selective Catalysis

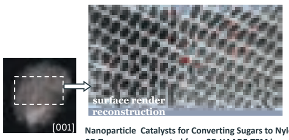
Properties

- Hybrid/hierarchical architectures
- Wide-ranging chemical properties
- Redox Catalysis (selective oxidations, epoxidation)
  - Acid Catalysis (Alkylations, isomerisations, dehydration)
  - Bifunctional and cascade reactions
  - Oxyfunctionalisation of alkanes and aromatics (C-H activation)
- High thermal stability/recyclability

Catal. Sci. Technol., **2011**, *1*, 517-534.

Capitalising on Catalytic Synergy

- Nature of framework and orientation of pore architecture (channels vs. cages) for controlling molecular transport
- Precise location, electronic configuration and coordination geometry of active centres
- Proximity of active sites for enabling transition-states and mechanistic pathways
- Discrete single-sites for enhanced catalytic turnovers
- Single-sites with specific function (e.g. redox vs. acid properties) for targeted catalysis
- Designing active sites with an intrinsic role: e.g. substrate vs. oxidant binding for enhancing rates, facilitating diffusion, stabilizing transition-states and maximising atom efficiency (reduce waste).



Nanoparticle Catalysts for Converting Sugars to Nylon
3D Tomogram generated from 2D HAADF-TEM images

Industrial Collaborations

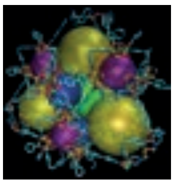
- Greener Nylon
- Terephthalate-based fibres
- Adipic Acid
- ε-Caprolactam
- Bio-ethanol dehydration
- Cascade Reactions and Flow Chemistry
- Clean and Sustainable Chemistry
- Marine Renewable Energy
- Fine-Chemicals
- Pharmaceutical Intermediates

Chem. Eur. J., **2010**, *16*, 8202-8209

Marine Energy and Maritime Engineering

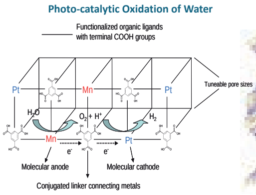
Hydrogen Energy through Photocatalysis of Sea-Water

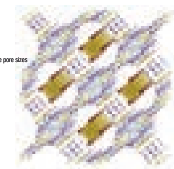
- Functionalised porous framework materials for high-efficiency catalysis (MOFs, Zeolites)
- Photocatalytic splitting of water for H_2 and O_2 generation
- Harvesting marine-energy for potential impact on H_2 economy
- Synergistic behaviour in metal-doped frameworks for enhancing catalytic efficiency (by orders of magnitude) compared to conventional systems



MOF-500 - [(Fe$_3$O)$_4$ (SO$_4$)$_{12}$(BPDC)$_6$ (BPE)$_6$]

Photo-catalytic Oxidation of Water



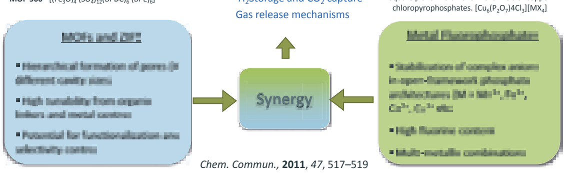


Square planar Au anions in channels of copper chloropyrophosphates. [Cu$_6$(P$_2$O$_7$)4Cl$_3$][MX$_4$]

H_2Storage and CO_2 capture
Gas release mechanisms

Gas Storage and Carbon Capture

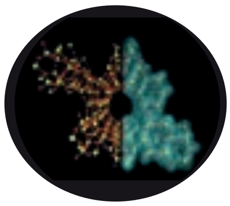
- High surface-area porous materials for increased adsorbtion potentials
- Hybrid inorganic-MOF frameworks for combined properties
- Spillover potential and alkali earth metal doping to maximise gas-storage properties
- Multifunctional frameworks can facilitate carbon capture and its subsequent utilisation in consecutive chemical processes



Chem. Commun., **2011**, *47*, 517–519

Selective Catalytic Reduction (SCR) of Exhaust Waste

- Developing marine exhaust-gas cleaning technologies
- SCR for removal of NO_x, SO_x, VOCs and particulates from diesel engines in ships
- Exploitation of synergy for enhancing rates and maximising selectivity
- Selectivity induced by pore size and hierarchical frameworks

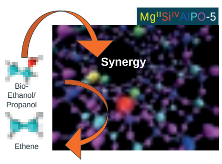


Novel Framework Architectures for Enhanced SCR applications in Marine Engineering

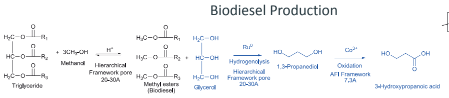
Renewable Feedstocks for Biodiesel & H2 Generation

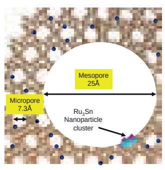
Academic & Industrial Partnership Programs

- Renewable Transport Fuels
- Bio-Ethanol and Biomass Conversions
- Hybrid Biofuels (2nd and 3rd Generation)
- Biodiesel & Bioenergy
- Hydrogen Economy
- Alternatives to PGM Catalysts
- Industrial Hydrogenations
- Low-Temperature Acid-Catalysis
- Renewable Polymers



Multifunctional Hierarchical Architectures for Biodiesel Production





A hybrid approach for biodiesel production and parallel glycerol conversion (tandem reaction)

Acid Sites:

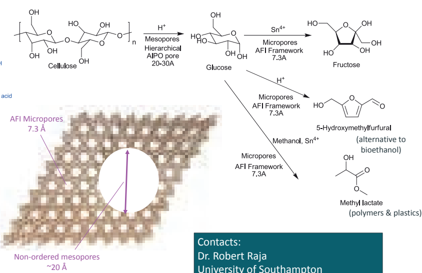
- Solid-acid active centres for the conversion of vegetable oils to FAMES

Nanoparticle Catalyst:

- Simultaneous glycerol transformation to 1,3-propandiol

Dalton Trans., **2012**, *41*, 982-989

Hybrid Catalysts for Biomass Conversions to Selective Chemical Intermediates



Chem. Commun., **2010**, *46*, 2805-2807

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Vibrational Power Flow Analysis of Nonlinear Dynamic Systems and Applications

Dr Y Xiong

ER4

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Vibrational power flow analysis of nonlinear dynamic systems and applications

Jian Yang. Supervisors: Dr. Ye Ping Xiong and Prof. Jing Tang Xing
Faculty of Engineering and the Environment, University of Southampton, UK.
jian.yang@soton.ac.uk

Background

- Predicting the dynamic responses of complex systems, such as aircrafts, ships and cars, to high frequency vibrations is a difficult task. Addressing such problems using Finite Element Analysis (FEA) leads to a significant numerical difficulty.
- Power flow analysis (PFA) approach provides a powerful technique to characterise the dynamic behaviour of various structures and coupled systems, based on the universal principle of energy balance and conservation.
- PFA is extensively studied for linear systems, but much less for nonlinear systems, while many systems in engineering are inherently nonlinear or designed deliberately to be nonlinear for a better dynamic performance.

Aims

- Reveal energy generation, transmission and dissipation mechanisms in nonlinear dynamic systems.
- Develop effective PFA techniques for nonlinear vibrating systems .
- Apply PFA to vibration analysis and control of marine appliances, such as comfortable seat and energy harvesting device design.

Fig. 1 Nonlinear seat suspension system

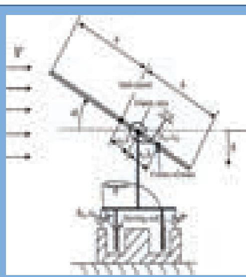

Fig. 2 Nonlinear energy harvesting using a flapping foil[1]

Fundamental PFA Theory

Dynamic equation for a single degree-of-freedom system

$$m\ddot{x} + c(x,\dot{x})\dot{x} + k(x)x = f\cos\omega t. \qquad (1)$$

Equation of energy flow balance can be obtained by multiply both sides of Eq.(1) with velocity

$$m\ddot{x}\dot{x} + c(x,\dot{x})\dot{x}^2 + k(x)x\dot{x} = f\dot{x}\cos\omega t. \qquad (2)$$

$$\dot{T} + p_d + \dot{U} = p_{in}$$

Kinetic energy change rate; Dissipated Power; Potential energy change rate; Instantaneous input power

Typical nonlinear dynamic systems

Van der Pol's (VDP) oscillator -Nonlinear damping

$$\ddot{x} + \alpha(x^2-1)\dot{x} + x = f\cos\omega t. \qquad (3)$$

Duffing's oscillator -Nonlinear stiffness

$$\ddot{x} + 2\xi\dot{x} + \alpha x + \beta x^3 = f\cos\omega t\,. \qquad (4)$$

These nonlinear systems behave differently compared with their linear counterparts as the former may exhibit inherently nonlinear phenomenon such as limit cycle oscillation, sub- or super- harmonic resonances , quasi-periodic or even chaotic motion. Their responses may also be sensitive to initial conditions when multiple solutions exist. Although their nonlinear dynamics have been extensively investigated. The corresponding nonlinear power flow behaviours remains largely unexplored.

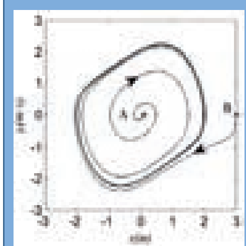

Fig. 3 Limit cycle oscillation of VDP oscillator($\alpha = 0.5, f = 0$)

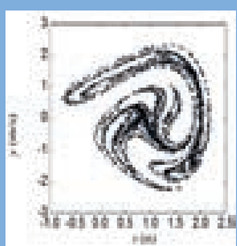

Fig. 4 Chaotic motion of Duffing's oscillator. $\xi = 0.02, \alpha = -1, \beta = 1, f = 1, \omega = 0.6$.

Instantaneous power flow

Fig.5 shows the instantaneous input power flow of Duffing's oscillator when it exhibits chaotic motion. The irregularity in input power pattern shown in Fig.5(a) results from the incorporated infinite frequency components which is demonstrated by Fig.5(b).

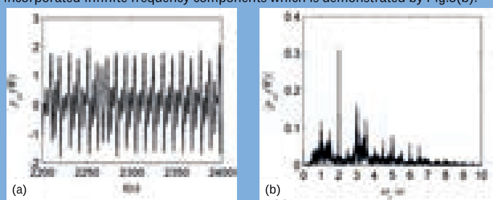

Fig.5 (a) Instantaneous input power and (b) frequency components in the input power of Duffing's oscillator($\xi = 0.02, \alpha = -1, \beta = 1, f = 1, \omega = 0.6$).

Time-averaged power flow

Time averaged input power of the system can be employed to incorporate the effects of multiple frequency components in the response, which can expressed as

$$\overline{P_{in}} = \frac{1}{T}\int_0^T p_{in}\,\mathrm{d}t\,.$$

Fig.6(a) shows the forced response of VDP oscillator may be either periodic or non-periodic for different excitation frequencies. In this situation, the time averaged input power provides a good performance indicator of input power level by using a long time span for averaging. It can be seen that the averaged input power value of VDP oscillator can be negative, which is different from that of linear systems.

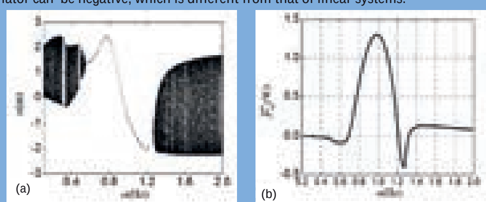

Fig.6 (a) Bifurcation diagram and (b) time averaged input power of VDP oscillator ($\alpha = 0.5, f = 1.0$).

Future work

1. To study power flow behaviours of systems exhibiting inherent nonlinear phenomenon;
2. To develop effective power flow techniques for nonlinear systems;
3. Apply nonlinear power flow theory to vibration control as well as energy harvester design.

Reference

[1] J.Yang, Y.P.Xiong and J.T.Xing, Investigations on a nonlinear energy harvesting system consists of a flapping foil and electro-magnetic generator using power flow analysis, 23rd Biennial Conference on Mechanical Sound and Vibration, ASME, Aug 28-31, Washington, US, 2011.

FSI Away Day 2012

The Influence of Surface Waves on the Added Resistance of Merchant Ships

Dr D Hudson

ER5

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

The influence of surface waves on the added resistance of merchant ships

Björn Windén - b.winden@soton.ac.uk-, Supervised by D.A. Hudson and S.R. Turnock

Causes of added resistance in waves

•Unfavourable shifts in buoyancy forces causing heaving and pitching. This absorbs energy both from the waves themselves but also from the ships momentum causing speed loss.

•Reflection of incident waves at the bow

•Disturbances of the flow around the hull causing boundary layer distortion and poor propeller performance

Background

•Predicting the power needed to achieve the designed service speed in the actual conditions experienced on the intended route has always been an issue for ship designers.

•The subject is complex and there has been no conclusive study able to give a solution to the above issue

•Designers therefore tend to use prescriptive percentage additions to the calculated still water resistance based on experience, e.g. +25% for North Atlantic trades, +15% for coastal operations.

•Older studies by Maruo [1], Gerritsma & Beukelmann [2] and Faltinsen[3] have successfully described the global phenomena giving rise to added resistance and is able to predict it well for certain sea states. No method however is able to predict it over a wide range of sea states.

•Because the limit of what can be done analytically to model the whole phenomenon of added resistance seem to have been reached, later studies have focused more on more detailed apects.

•However, there is a strong indication that coupling between different phenomena plays a major role in understanding why some methods work and others don't in certain conditions.

•With developments in computing power and open source RANS-based CFD software it is possible to use large scale CFD simulations to study the behaviour of ships in waves with a high level of detail.

Aims

•To validate the open source CFD-package OpenFOAM© for predictions of added resistance in waves.

•To conduct new towing tank experiments focusing on areas not previously addressed to support this validation.

•To use results from OpenFOAM© and the experiments to highlight important phenomena giving rise to added resistance.

•To use this information to test how new bow designs could reduce added resistance in waves.

References

1.Maruo H, The excess resistance of a ship in rough seas, International shipbuilding progress, vol 4, No 35, 1957

2.Gerritsma J & Beukelman W, Analysis of the resistance increase in waves of a fast cargo ship, International shipbuilding progress, vol 19, No 217, 1972

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Experimental study

•Has shown that there might be an effect of viscous phenomena on added resistance something that has not yet been confirmed in the literature. Figure 1 (a) shows the added resistance at three different periods of encounter and at different forward speeds.

•In Figure 1 (a) When T_e=0.7 the resistance grows with speed due to resonance. The decrease in added resistance for higher speeds at other T_e could be explained by increased viscous damping. This is supported by a measured increase of the decay rate in heave with speed for the same hull (b).

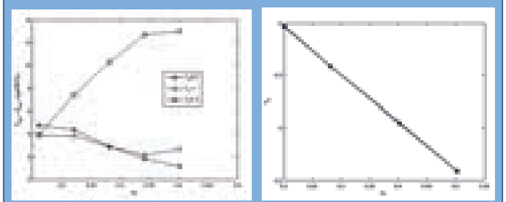


Figure 1 a b

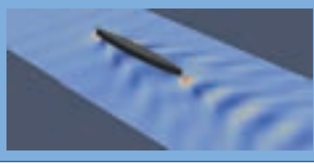
•A large amount of data in regular and irregular waves has been gathered for CFD validation.

CFD study

•Has started with a validation study against a fixed Wigley hull in waves to evaluate how the phase and amplitude of the added forces are predicted. This has proven to be problematic in previous studies.

•Has investigated how best to design the mesh to capture wave propagation and ship-wave interaction without using excessive numbers of cells.

•Has created modified multiphase solvers to deal with wave damping at domain outlet.



Future focus

•To continue to add complexity to the CFD model and monitor the errors arising from each step to get a better understanding of how best to model ships in waves.

•Improve the experiments with more uncertainty analysis and repeated tests to be able to give a confident new contribution to the knowledgebase regarding added resistance.

•Use acquired knowledge and models to test how the bow shape influences the highlighted aspects of added resistance.

Lloyd's Register Educational Trust

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FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Wave making drag prediction for improved design of marine crafts

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Supervisors –**Dr. Mingyi Tan** and **Dr. Zhimin Chen**

Background

•With globalization and associated rising demand on transportation, the volume and size of the merchant fleet will also increase since the majority of goods are transported by sea.

•In shipping, a significant cost both to the ship owners and the environment is the fossil fuels used for propulsion. With the rising price of oil and the growing environmental concern, the motivation to reduce oil consumption has never been higher.

Motivation

•About 50% of the resistance of a fast container ship is due to wave resistance. This means that even a small reduction in the wave resistance can bring considerable reductions both in operating costs and emissions.

•When designing a ship it is important to be able to make fast and accurate prediction of its resistance so that more efficient hull forms can be selected early in the design process. A RANS solver based CFD software is still too time-consuming to be adopted in the initial design process

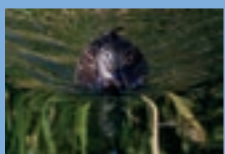

Figure 1: Wave patterns behind a mallard[1]

Aim

- To develop an efficient numerical method for wavedrag based on a dissipative potential theory

Objectives

- To derive a 3-D dissipative Green's function for free surface flow with forward speed.
- To formulate a numerical scheme of study within the frame work of a panel approach.
- To validate and tune the method for wave drag predictions with available data.

Method

- Rayleigh damping, μ_d is introduced in the Navier–Stokes equation, this gives the non-dimensional Bernoulli equation
- [illegible]
- The source influences are given by a Green's function, the main benefit of a Green function approach is that the source distribution satisfies the free surface condition so that the sources can be located on the body only. The dissipative Green function is
- [illegible]

Evaluation

•The double integral in the Greens function can evaluated straight away since it has no singularities thanks to the Rayleigh viscosity.

•According to thin ship theory the sources can be placed along the centre line of the vessel at half the depth. The wave pattern from a Wigley hull are seen in Figure 2 and 4 . The wave pattern behind a wedge shaped hull with constant draft is shown in Figure 3

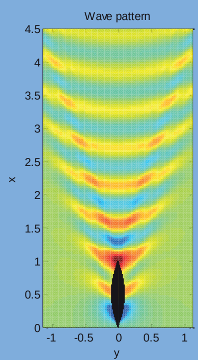

Figure 2: Wigley hull

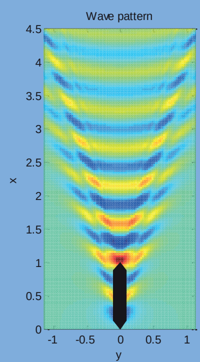

Figure 3: Wedge shaped hull

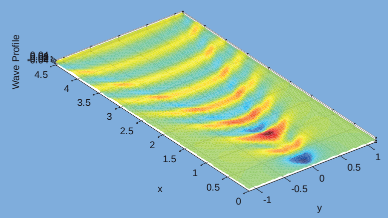

Figure 4: Wave patterns behind a Wigley hull

Next step

•Develop a panel method for 3D hulls.

•Improve the speed of the algorithms.

Outcome

•A fast and reasonably accurate method for ship wave drag prediction.

•A tool for early hull design or optimisation, capable of taking some finer features into consideration.

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Acknowledgement
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Professor S Turnock

ER7

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

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Low Carbon and Hazardous Emissions Shipping

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Supervisors – **Prof. Stephen R. Turnock** and **Dr Dominic A. Hudson**

Motivation and Aim

"The whole is more than the sum of the parts" – Aristotle.

This study is based on the systemic approach of propulsion system (Systems engineering) instead of the traditional optimisation of single components.

Ultimate objective: Provide an alternative reliable, economically feasible, marine propulsion system to reduce CO_2, SO_x, NO_x and particle emissions from ships.

The project investigates the potential of large scale application of Nuclear propulsion using small portable reactors and the installation of energy storage devices for modular operation and controlled energy flow.

Currently, a lot of work has been done in large 2 Stroke engines to reduce SO_x, NO_x using external means, like Selective Catalytic Reaction, Scrubbing but also by optimizing the combustion and the operation of the engines such as valve timing, variable turbine blade area etc.

However, domestic shipping and fishing activity bring emission totals to 1050 million tonnes of CO_2, or 3.3% of global anthropogenic CO_2 emissions. Despite the undoubted CO_2 efficiency of shipping in terms of grammes of CO_2 emitted per tonne-km it is recognised within the maritime sector that reductions in these totals must be made.

Shipping is responsible for a large percentage share of NO_x (~37%) and SO_x (~28%) emissions

Due to the increasing growth of marine the transportation, immediate action is required to stop the climate change

The current state of play is ready for the adoption of new technologies including the nuclear propulsion, combined energy cycles and advanced heat recovery systems.

The combination of such technologies has not been assessed and optimised yet.

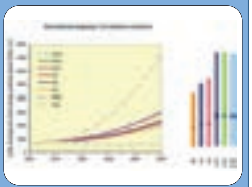

Figure 1: Predicted emissions of the shipping sector according to I.M.O. 2nd Greenhouse emission study.

Ship Simulation (Modular Block Implementation)

A scalable and modular approach in MATLAB/Simulink environment was developed.

Figure 2: Simulator Major Block Description (top) and Engine-Hull simulation schematic (down).

Each block represents machinery comp, weather, engine, ship model

- Hull Resistance (Holtrop – Mennen method, Lap – Keller methods)
- Added Resistance (Aertssen, Kwon methods)
- Wind Resistance (Isherwood, Blendermann methods)
- Wageningen Series open water performance method
- Open thermodynamic system properties (Control Volume Theory)
- Battery models, using Kinetic Energy approach (Manwell, McGowan)
- Heat Transfer (for usage in High Temperature battery applications)

Nuclear Vessel Concepts

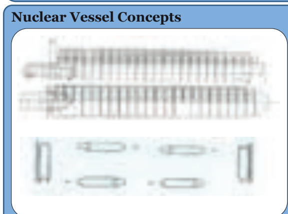

Figure 3: Nuclear Pusher- barge system (top) and schematic of potential commercial chain using pushers and barges (down).

A pusher/ barge concept offers:

- Reactor away from ports (>40nm)
- Well guarded propulsor
- Easy dry-docking for barge/pusher
- Can be leased by ship-owners
- No need for state/ Country regulations
- Hybrid Electric propulsion offers to the Barge self-propulsion capability using energy storage when in national waters and while in open sea, the electricity is supplied by the pusher's Nuclear reactor

Conclusions to date

Fuel savings depending on storage system, vessel condition and vessel type, can reach up to:

- 111,538 tonnes in NO_x
- 74,460 tonnes in SO_x
- 4,162,7 tonnes in CO_2

The above represent a maximum 22.5% reduction in the dry bulk sector and 2.8% of the world's fleet emissions.

The economic feasibility is dependent on the capacity and power of storage medium.

- Sodium Nickel Chloride Battery is more economical feasible option
- Vanadium redox Flow batteries have high potential and it is promising technology
- Depending on vessel type fuel savings can exceed 1m $ per year
- Cost of construction drops
- Initial investment cost remains high
- Internal Rate of Return varies from 4.3% - 44.7%

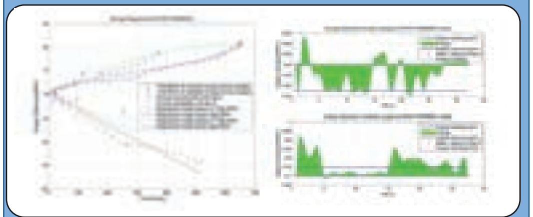

Figure 4: Energy Storage Requirements (left) and Energy fluctuations during Laden and Ballast voyages (right).

- Energy Requirements in Bulk carriers have no flat profile (as it was believed)
- Simulator model accuracy is based on the selected time-step or the amount of given data
- 2-stoke Mechanical Diesel part load optimised and Hybrid propulsion gives notable gains
- Electric propulsion is not suitable for bulks as conversion losses are higher than the fluctuations in Main Engine's fuel efficiency
- Hybrid Propulsion is technically feasible without affecting the basic ship dimensions
- Nuclear Pusher/ Barge system can be achieved using the same principles with the shore power connection ("Cold Ironing")
- Hybrid Propulsion is not necessary when sailing in open sea as Nuclear reactor has rapid load change (5%/ sec. for change up to 15%) without affecting the efficiency

Figure 5: Schematic of two out of total four proposed hybrid propulsion solutions showing conversion efficiencies.

Future planned work

- Code implementation for creation of random weather conditions in order to assess the machinery layout feasibility and verify potential savings in fuel consumption
- Systems engineering by:
  - Concepts of different propulsion systems such as steam, electrical, conventional Diesel
  - Risk and safety assessment for each module of the propulsion system
- Contribute to the Gold based Rules for merchant marine nuclear propulsion

Acknowledgments

The authors wish to thank Lloyd's Register and Foundation Propondis for the financial support of the PhD, the two Greek Maritime companies which prefer to stay anonymous and Carnival Cruises and Plc UK for giving access to the operational data and technical specifications of their fleet.

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Investigation of Numerical Methods for Achieving Energy Efficient Ships

Professor S Turnock

ER8

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Investigation of Numerical Methods for Achieving Energy Efficient Ships

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Motivation

- The increasing cost of fuel is having a significant impact on the maritime industry. Mid and long term fuel prices are expected to increase including surcharges for carbon-dioxide emissions. This increases the need for a paradigm shift in design and powering so as to construct vessels which are more fuel efficient
- The use of flow control mechanisms in restoring the wake flow distribution of the propeller have been identified to improve performance. This requires detailed numerical and experimental tools in resolving such complex flow field with the adequate accuracy.
- The use of Reynolds Averaged Navier Stokes (RANS) simulations have been considered to be a powerful tool for such maritime flow problem.

Figure 1: Hull line optimisation for a specific boat

Figure 2: costa bulb investigation

Aims and Objectives

The aim of the research is to achieve a 15% reduction in fuel efficiency for a proposed LNG carrier.

The project will work towards the following objectives

1.Developing rigorous CFD approaches to ships stern flow
- -conduct validation test on 2D & 3D aerofoils section
- -propeller-rudder study
- -validation of twin skeg LNG carrier hull shapes

2.Investigation of energy saving strategies
- -methodical tests to establish the effect of varying key dimensions and ratios at the aft body on propeller wake field, propulsive efficiency and propeller vibrations
- -investigation of possible improvements to overall propulsive efficiency.

Initial study: Open FOAM Investigation of flow around an airfoil

- The purpose of this study is to evaluate the Open Source CFD tool [Open Foam] for simulating incompressible flow over a 2D NACA0012 aerofoil operating at Reynolds number =3x10^6 over a range of incidence angles. OpenFOAM (Open Field Operation and Manipulation, www.openfoam.org) allows the user to gain full control over implementation of different features in research activities.
- The physical model is based on the mass [∇ · U = 0] and momentum [(U · ∇) U + (∇P/ρ) = ν ∇2U + g] conservation equations and the spalart allmaras one equation model for the turbulent viscosity.

Boundary conditions

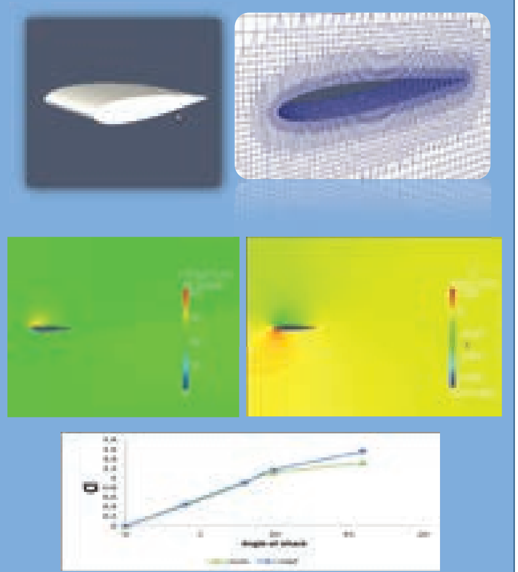
Designation	description	Type of boundary condition
1	Inlet	Freestream
2	Outlet	Freestream
3	Wall	No slip (Fixed wall)
4	Top	Freestream
5	Bottom	Freestream
6	Front	Empty
7	back	Empty

Preliminary Results

- Simulations on an initial coarse mesh (fig 2) generated using snappyHexMesh show good agreement with experimental data up to ten degrees incidence. The coarseness of the initial mesh lead to poorer prediction of stall.

Future work

- Refining of the meshing in order to capture the wake field
- Boundary layer profile



From top :
Fig 1.naca0012 aerofoil geometry,
Fig 2.Zoom of the generated mesh using snappyHexMesh , Fig 3.velocity Fig 4 .Pressure contours, Fig 5.Lift plot vs. incidence

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References
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Investigation of Wall-Bounded Turbulence over Sparsely Distributed Roughness

Dr M Tan ER9

FLUID STRUCTURE INTERACTIONS (FSI) RESEARCH GROUP

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Investigation of wall-bounded turbulence over sparsely distributed roughness

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Background

•Sparse distribution of surface roughness is found in abundance in natural environments and in a variety of engineering applications.

•Barnacle growth on ship's hull (Figures 1 and 2) and Atmospheric Boundary Layer (Figure 3) are classical examples.

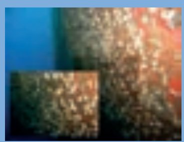

Figure 1: Accumulation of marine growth (barnacles) on the ship's hull. ©2009 Igor Sterzhantov.

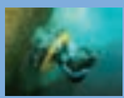

Figure 2: Maintenance of ship hull in situ. ShipHullPerformance.org.

Figure 3: Urban boundary layers and turbulence in the urban canopy. Princeton University.

Roughness Characterization

•**Jimenez (2004)** pointed out that while boundary layers over surfaces with a dense distribution of roughness elements have been the object of numerous studies, the effects of sparse roughness has been poorly investigated (Figure 4).

Figure 4: Equivalent sand roughness for various surfaces versus the frontal solidity. Jimenez (2004).

Figure 5: Frontal and Plan Solidity. Grimmond and Oke (1998).

Regular roughness can be characterized using two parameters:

1.**Frontal Solidity** $\lambda_F = A_F/A_T$ (which is the ratio of the total projected frontal area of the roughness per unit wall parallel area);
2.**Plan Solidity** $\lambda_P = A_P/A_T$ (which is the ratio of the total plan area of the roughness per unit wall parallel area).

Townsend's Similarity Hypothesis

•**Townsend (1976)** stated that the turbulence structure is unaffected by the surface condition, at sufficient distance from the wall. Similarity only holds if the Reynolds Number is sufficiently high and if the mean height of the roughness elements is small, compared to the boundary layer thickness. Our understanding of rough walls heavily relies on this similarity.
•**Krogstad & Antonia 1999**, **Volino et al. 2007** and **Ganapathisubramani & Schultz 2011** have shown evidence of lack of similarity for rough walls characterized by sparse roughness.

Aims and Objectives

•Systematic study of the effect of Frontal and Plan solidity on the structure of the turbulence;

•Evaluate the importance and the effects of additional parameters on the turbulence structure;

•Investigate the validity of Townsend's similarity Hypothesis in the sparse regime.

Experimental Facilities and Method

3x2 Wind tunnel
•0.9 x 1.35 x 4.5 m long test section
•Velocity range = 0.1 – 25 m/s
•Slightly favorable pressure gradient
•PIV "friendly"

Lego® Elements
•cylindrical and rectangular 2x2 bricks
•Staggered arrays

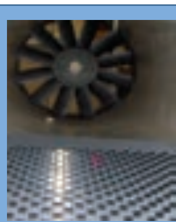

Figure 6: Experimental set up

Experimental Technique

Particle Image Velocimetry (PIV)

•PIV is based on the measurement of the displacement of small tracer particles, that are released into the fluid;

•The tracer particles are illuminated within a thin light sheet generated from a pulsed light source;

•the light scattered by the particles is recorded onto two subsequent image frames by a CCD camera;

•Cross-correlating the particle-image patterns in small interrogation windows, between the first and second image frame, allows the evaluation of the displacement hence, the local fluid velocity.

Figure 7: Schematic of a typical PIV measurements system. Scarano 2010

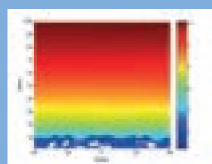

Figure 8: Classical PIV image. Streamwise (x,y) plane. Colorbar shows mean streamwise velocity U.

Future Work

•Analyzing the effect of urban-like roughness on the turbulence structure;

•Considering the problem of step change in roughness;

•Studying the effect of roughness on pollutant dispersion.

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Acknowledgement: This project is supported by **Lloyd Registered Educational Trust**

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Smart Materials and Structures with Hybrid Nonlinear Vibration Control for Marine Applications

Professor RA Shenoi

ER10

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

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Smart Materials and Structures with Hybrid Nonlinear Vibration Control for Marine Applications

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Motivation

- For passenger ships (Figure 1), vibration and noise pollutions affect the comfort of passengers and crew members.
- Vibration and noise generated by marine engines create pollutions, which harm the marine life and become one of the environmental problems.
- New knowledge and technology need to be developed to address these problems by effectively controlling vibration transmission and acoustic noises.

Figure 1 Passenger ship

Background

When ship is travelling, ship structures experience complex and varying dynamic excitations and become the sources of noise radiations.

Magnetoryeological elastomers (MRE) consist of two parts: polymer matrix and active filler. Their mechanical properties can be controlled rapidly, continuously and reversibly by an external magnetic field (Figure 2).

Passive systems are not adaptive to the changing conditions; active ones consume a lot of energy and need a large activation force. It is showed that hybrid control systems are more effective.

Figure 2 MRE without magnetic field and MRE under magnetic field

Aims

Develop the MRE materials to obtain greater MR effects, so as to expand their applications to large scale structures.

Design a vibration control system employing the dynamic properties of MRE material for marine applications.

Develop nonlinear power flow approach to analyse the energy transmission mechanism and evaluate the vibration control effectiveness.

Methodology

- In order to further investigate dynamical properties of different MREs, it is necessary to perform multiple modes dynamic loading tests.
- The nonlinear vibration theory considering the actual strain–stress relationship will be employed to establish mathematical model and predict the dynamic response of the MRE material and structure.
- A hybrid passive/active vibration control system with adaptive MRE materials (Figure 3) will be investigated.
- Nonlinear power flow approach will be developed to analyze the vibration energy transmission mechanism to evaluate the vibration control effectiveness.

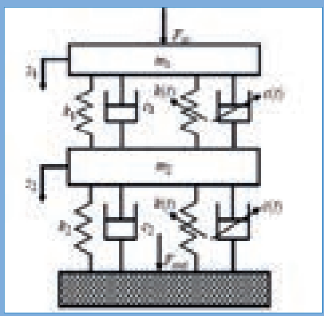

Figure 3 A schematic hybrid control system

Programme

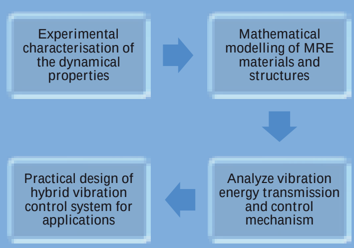

Figure 4 Work programme

Challenges

- Nonlinear mathematical model of MRE materials and structures under multiple loading modes .
- Develop the nonlinear power flow approach to analyse the energy transmission mechanism of the smart nonlinear dynamical systems.
- Develop hybrid active/passive control system to effectively control vibration energy transmissions.

Acknowledgement: Southampton, Lloyd's Register Educational Trust

FSI Away Day 2012

Using Synthetic Turbulence as an Inlet Condition for Large Eddy Simulations

Professor V Humphrey

ER11

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

Using synthetic turbulence as an inlet condition for large eddy simulations

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Background

- Unsteady flows are commonplace in everyday life. In engineering applications, the existence of unsteady flow phenomena can present challenges in the modelling and design of complex systems.
- Two examples of such flows are presented in Figures 1 and 2. In both these cases, the turbulent flow can cause large fluctuating loads which must be accounted for in the design process.
- Specifying appropriate boundary conditions for numerical simulations is extremely important to ensure 'physical' results and reduce computational effort.
- Generally three techniques are available: precursor simulation; mapping; and synthetic generation.

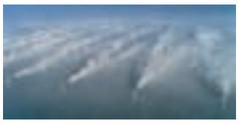

Fig. 1: Wind turbine wakes†

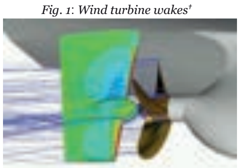

Fig. 2: Hull-propeller-rudder interaction ‡

Motivation and Objectives

The current work in motivated by the need to study hydroacoustic sources, generated by the impingement of turbulence on propeller and turbine blades. The main objectives of the work are to:

1. Assess the ability of a 'synthetic turbulence' generator to produce realistic eddies;
2. Validate the method using canonical test cases;
3. Apply the technique to more complex problems, such as hydrofoil or propeller flows;
4. Compute the acoustic signature due to the inflow turbulence.

Methodology

- The method of Kornev *et al.* [1] is employed, which has been applied to the flow around ship sterns [2]. The method produces inhomogeneous, anisotropic turbulence.
- The method consists of the following steps:
  1. Conduct a precursor RANS simulation to compute the steady flow field;
  2. Extract the velocity field (U), turbulent length scale (L) and Reynolds stress tensor (R) on an appropriate plane;
  3. Map the extracted data to the inlet of an LES where 'vortons' are generated based on these reference fields.
- As initial validation, the channel flow case of Moser *et al.* [3] is used, where the DNS data has been made available. A Cartesian mesh of ~260,000 cells has been used, with $y^+ = 1$ for a friction-velocity based Reynolds number of 395.
- Three cases have been computed:
  1. *LES1* is a channel flow with cyclic boundaries in the streamwise (x) and spanwise (z) directions;
  2. *LES2* uses the inflow generator with U, L and R taken from a RANS simulation;
  3. *LES3* use the inflow generator with L taken from a RANS simulation and U and R taken from *LES1*.

Results

- It can be observed that the inflow generator (*LES2*) does not produce the level of fluctuation of the periodic flow (*LES1*). This led to simulation *LES3*, since it was found that the RANS simulation does not accurately predict the Reynolds stress tensor in the outer boundary layer ($y^+ > 50$) (Fig. 4(b)).
- *LES3* improves the mean velocity profile compared to *LES2*, as well as all the components of the *rms* velocity in the outer boundary layer.

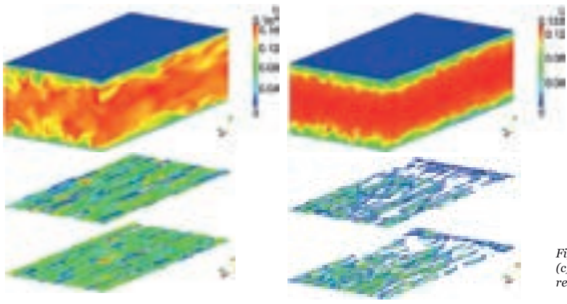

Fig. 3: Visualisation of flow: top – velocity; bottom – vorticity magnitude; left – LES1; right – LES2

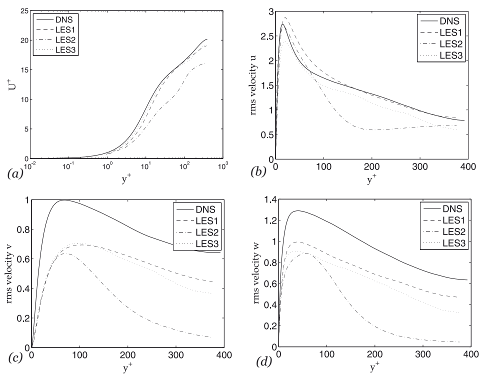

Fig. 4: Mean velocity plots: (a) boundary layer profile; rms velocities: (b) streamwise; (c) wall-normal; (d) spanwise. y^+ and U^+ are the wall-distance and velocity respectively, non-dimensionalised using the friction velocity.

Conclusions

- The inflow generator performs well for the test case considered here, in terms of both mean velocity and *rms* velocities.
- This method is particularly applicable to more complex cases where the use of periodic boundaries to drive the flow to become turbulent is not possible.

Future Development

- Apply the method to more complex cases. These include hull-propeller geometries and other blade – wake interaction scenarios.
- These cases will allow validation in terms of surface pressures and forces, which can be used to derive acoustic sources.

References:
[1] Kornev, N. and Hassel, E., 2007, "Method of random spots for generation of synthetic inhomogeneous turbulent fields with prescribed autocorrelation function", *Comm. Num. Meth. Eng.*, **23**(1). pp.35-43.
[2] Kornev, N., Taranov, E., Shchukin, E., Kleinsorge, L. 2011, "Development of hybrid URANS-LES methods for the flow simulation in the ship stern area" , *Ocean Engineering*, **38**(16), pp. 1831-1838.
[3] Moser, R.D., Kim, J. and Mansour N.N., 1999, "Direct numerical simulation of turbulent channel flow up to Re_τ=590", *Physics of Fluids*, **11**(4). pp.943-945.

†: *www.windbyte.co.uk*; ‡: *www.sva-potsdam.de/cfd-hull-propulsor-interaction.html*

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Acknowledgement: This project is supported by funds from the **Defence Science and Technology Laboratory, QinetiQ** and the **University of Southampton**. The **Institute of Technical Thermodynamics** at the **University of Rostock** is thanked for supplying the inflow generator code.

Passive-Adaptive Composite Structures for Unsteady Fluid Loading

Dr S Boyd **ER12**

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

Passive-adaptive composite structures for unsteady fluid loading.

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Background

• Traditional methodologies for the development of lifting surfaces for all applications (such as wings, wind turbine blades and yacht appendages) have sought to build structures with sufficient stiffness to maintain a single optimised shape which is a compromise over a range of operating conditions.

•A more efficient solution may be the use of tuned deformation in these structures to achieve the dual goals of reducing weight by reducing the stiffness requirement and also increasing the operational efficiency by allowing a tuned deformation response.

•Gust alleviation can significantly reduce the stiffness and strength requirements of the supporting structure. Additionally, the structure stores potential energy when deformed, and by incorporation of the release of this energy in the design blade operation, on passing of the gust may contribute the power output of the turbine.

Aims

•To optimise the efficiency of a composite lifting structure subject to unsteady fluid loading by tailoring the structure to give a tuned deformation response.

Objectives

• Understand current foil construction techniques. Scale the loading regime to the achievable test size.
• Evaluate the quasi-static response of a simple foil under point and fluid loading.
• Design and construct a passive-adaptive composite foil and characterise its performance.
• Investigate the dynamic characteristics of a passive-adaptive composite foil under unsteady loading.

Wind/tidal turbine efficiency

• The power that a wind or tidal turbine can extract from a flow is limited by the performance of the blade design.
• The performance of the blade is modified by varying chord length and twist over the length of the blade, with the goal of optimising the lift to drag ratio for a given flow velocity.
• However, fluctuations in the flow velocity force the blades to operate outside of this optimal lift/drag regime, reducing the efficiency of the turbine.

Figure 1: In-service bending of wind turbine blades.
(Green Energy Ohio: http://www.greenenergyohio.org)

Current structural configurations:

• Load bearing structures of current wind turbine blades vary widely. Some lend themselves to an adaptive design more than others, such as the box spar construction shown here:

Figure 2: Some structural options for wind turbine blade construction.
(Gurit Manual: Wind Turbine Blade Structural Engineering)

Experimental approach

• A phased approach is being taken to build the experimental capability :

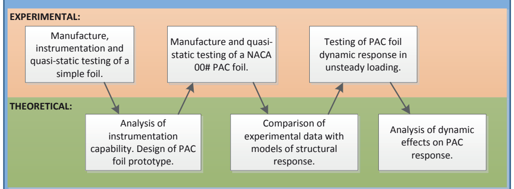

Figure 3: Flowchart of experimental and theoretical stages

Current Work

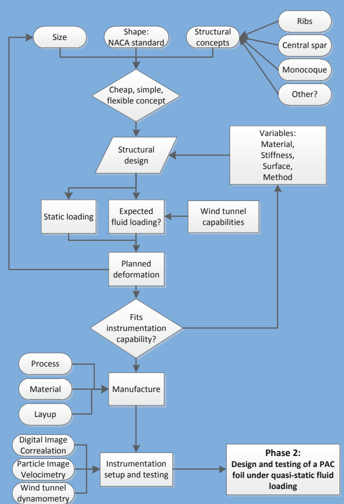

Figure 4: Phase 1 Experimental Plan

• In this initial phase of the project a simple NACA 00# series foil will be designed, constructed and built to verify the instrumentation capabilities for measurement and characterisation of an adaptive composite foil, using Digital Image Correlation and Particle Image Velocimetry in the wind tunnel.
• This will set the design parameters to allow the construction of a passive-adaptive composite foil in Phase 2.

Acknowledgement: This project is supported by the **Engineering and Physical Sciences Research Council**

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Interactions of Fluid and Soft Bodied Structures with Applications to Wave Energy Device

Dr M Tan

ER13

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Interactions of fluid and soft bodied structures with applications to wave energy device

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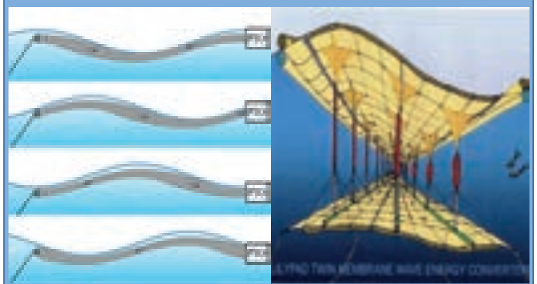
Supervisors – Dr M. Tan and Dr J. Blake

Introduction

•Considered as a source of renewable energy, wave is a resource featuring high variability at all time scales.

•Furthermore wave climate also changes significantly from place to place and those wave energy converter are very often tuned to suit these irregularly wave motion at the project site.

•Structure with large deformation is adopted in investigations in order to suit violent wave motion and improve wave energy absorbed ratio and electrical power generated efficiency.



Anaconda wave energy converter (left)
Lilypad twin membrane wave energy converter (right)

Motivation

•In order for wave energy conversion to be a commercially viable technology, Estimating wave energy converter's power output at a potential installation site and avoiding occurrence of damage caused by dynamic loads on the structures must be taken into consideration.

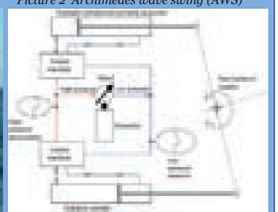
•Accurate numerical simulation of power output and risk assessment can bring considerable cost reduction in both of investment and maintenance

Current typical devices (direct drive and hydraulic system) in operation

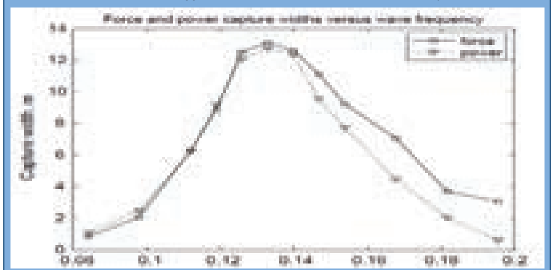
Picture 1 oscillating water column

Picture 2 Archimedes wave swing (AWS)

Picture 3 Pelamis wave energy converter



Picture 3.1 PTO of Pelamis



Picture 4 power capture widths versus wave frequency of Pelamis

Potential improvement

•Flexible structure make it possible to improve power capture ratio and electrical power generated ratio.

•Power capture ratio: power absorbed curve (picture 4) will trend to more gentle which means peak value may decrease but more power will be captured if balance structure stiffness and softness.

•Power generated: e.g. buoyancy force and pressure inside (AWS) will decrease/ increase due to volume changes hence accelerate hood motion.

Aim & Objectives

•The studies carried out in this project aim to improve wave energy device performance by developing a numerical method with the help of open source software

•To assess the different types of wave energy converters and identify their pros and cons.

•To simulate these applications by using OpenFoam as an effective way to understand the numerical methodology.

•To identify, from the study, where design improvements could be made.

•To develop the system commercially.

Further work

•This research area is fresh to the author, the methodology for this project will not be fully planned at the moment while will be developed as the project progresses.

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Design and Development of Effective Nonlinear Energy Harvesters

Dr Y Xiong **ER14**

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Design and Development of Effective Nonlinear Energy Harvesters

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Background

- Ambient energy harvesting is also known as energy scavenging or power harvesting, and it is the process where energy is obtained from the environment.
- The fundamental idea is to convert ambient energy sources or waste energy into usable electricity.

Figure 1. A floating wave energy harvester. [1]

Figure 2. The total energy containing in waves equals to twice of the world's electricity production. (World Energy Council) [1]

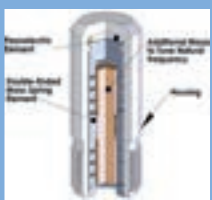

Figure 1. A 1.0×2.25-inch piezoelectric generator for vibration energy harvesting. [2]

Figure 2. A Energy converter for motion energy harvesting [3]

- Currently, almost all the commercial applications so far is the time-invariant nature of the environment in which the harvester operates, i.e., the frequency spectrum of the excitation is stationary with respect to time. This limitation is primarily due to the use of linear mechanical resonators.
- This study is motivated by a growing recent interest in new energy source in terms of vibration energy harvesting.
- Nonlinear oscillator has great potential to enhance power transfer as nonlinear interactions may give rise to a broad-band frequency response or multiple resonance peaks and thus increasing the range of effective functions.

Aim

This project aims to investigate a new nonlinear energy harvesting system to explore novel energy harvesting mechanism and develop an effective nonlinear energy harvester for applications in maritime engineering.

Objectives

- Investigate nonlinear energy flow equation of an oscillator with linear damping to analyze the effect of its smoothness parameter on power transfer of the nonlinear system.
- Investigate the coupling effect of nonlinear damping and nonlinear stiffness on energy harvesting.
- Analyze nonlinear energy transmission mechanisms of the nonlinear oscillator and the effects of super-harmonic resonance or combination resonances.
- Design a model of the oscillator to do corresponding dynamic experiments to evaluate the effect of the nonlinear parameters on the power harvested.

Methodology

Power flow analysis provides an effective technique to describe the dynamic performance, accounting for both force and motion characteristics, of any types of systems. This method is based on the universal principle of energy balance and conservation to investigate dynamic systems. It has been proved that power flow approaches can be successfully developed to model complex structures and applied to vibration control in both linear and nonlinear systems. This approach will be used to evaluate the vibration energy harvesting efficiency.

Nonlinear Oscillator

An nonlinear oscillator system provides adjustable nonlinearity will be investigated first. This system consists of a mass m linked by two inclined elastic springs. Each spring of stiffness k is pinned to a rigid support. The nonlinearity of this oscillator can be smooth or discontinuous depending on the value of the smoothness parameter.

Various of energy generation units, e.g. piezoelectric unit and electromagnetic unit, can be attached on the oscillator to harvest energy from vertical motion.

References:

[1] http://www.oceanpowertechnologies.com/res.htm
[1] R. Murray, J. Rastegar, Energy-harvesting power sources for a wide range of applications, *SPIE Newsroom* , 2007.
[2] http://www.enocean.com/en/enocean_modules/eco-200/

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FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

National University of Sciences and Technology (NUST)

University of Southampton

Design and Development of Duct-Diffuser Augmented Propeller Low Head Hydro Turbines

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Supervisors – **Dr Stephen Turnock , Dr Richard Wills, Dr Syed Waheed (NUST)**

Introduction

- On economic grounds, the criteria for design and development of Low Head Hydro (LHH) turbines are based on minimum cost per unit power instead of maximum delivered power. The drawback of this approach often results in undue design simplification, and hence possibly unfeasible predictions of the likely hydraulic power potential along with below average performance of the design models.
- Governmental and global targets for reduction in carbon emissions, environmental impacts and the capability of serving the ever increasing demand of power requirements in the shortest time are driving forces for small/low head hydro power generation.
- Small-scale hydro power is the key source for further hydro development. Optimization of existing recourses for power harnessing has made application of low head hydro power a choice for water treatment plants, water and waste water networks

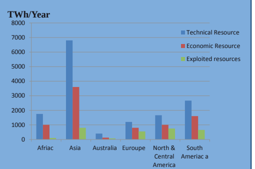

Figure 1 Global Hydro resources review in terms of power production [1]

Design Criteria

- The adopted methodology for maximum deliverable power criteria follow integration of meaningful geometry for generalized design instead of site specific tuning of non-hydro dynamic components. The addition of hydrodynamic flow regulating components for power augmentation and system level modification of component for extended range of application of technology are the main features of proposed criteria.

Design and development status of proposed LHH

- Based on the design to manufacture approach and above mentioned criteria of maximizing energy for extended range of application two LHH configurations namely Diffuser Augmented and Duct-multilevel Diffuser Augmented turbine are proposed.
- Following diagrams highlights schematic and component diagrams

Fig 2 Stator CAD model

Fig 3 3D Runner CAD model

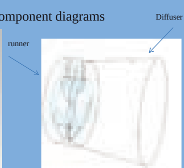

Fig 4 Runner and 7 degree diffuser CAD assembly

Figure 5 Diffuser Augmented complete CAD model assembly

Figure 6 Duct-Diffuser Augmented complete CAD model assembly

CFD modelling and Analysis of proposed LHH turbine models

The modern design, analysis and manufacturing techniques can contribute to investigate hydro potential as low as 1 meter head and a power output of 200 Watts

CAD/CAM based automated design and analysis process for LHH applications is opted for real cost effective LHH designs.

To simulate internal flow within turbine passages for accurate prediction of flow physics, 3 D Navier Stroke equations are solved using commercial software ANSYS CFX. The associated ANSYS ICEMCFD package for grid generation is used along with SolidWorks for CAD modelling.

Application of Computational fluid dynamic techniques particular to LHH turbine operational range of parameters to evaluate

- Complex 3-D flow visualization
- Component behaviour characterisation
- Design optimization

Fig.7 Rotor-Stator Interface modelling

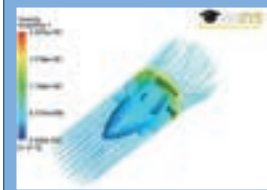

Fig.8 Stream line plot of velocity distribution through the model turbine unit

Fig 9 Velocity distribution in stationary frame for modified geometry

Objectives of the project

This research aims to support more consistent and optimised design with enhanced systems performance for low/ultra- low head hydro-electrical power generations. This project under International Strategic Participation In Research and Education (INSPIRE) initiative of British Council has the following goals

- To exploit the potential of LHH for power output range 0.2Kw to 25kw
- Flexible design for a range of operating conditions at system and component level
- Continuous operation at full capacity for maximum duration with minimum control regulations (on grid/off grid)
- To develop new design concept of low/small scale hydro power generation
- Hydro dynamically efficient turbine runner
- Performance data acquisition of laboratory units for optimum design of site specific units
- Understand fully the design for propeller turbines using CFD modelling, and laboratory experiments

Acknowledgement

This research is jointly sponsored by National University of Sciences and Technology (NUST) and British Council International Strategic Partnership In Research & Education (INSPIRE) Initiative

References

[1] International Journal of Hydropower and Dams: World Atlas. Sutton: Aquamedia Publications, 2000.

Adaptive Composite Blades for Horizontal Axis Tidal Turbines

Professor S Turnock

ER16

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Adaptive Composite Blades for Horizontal Axis Tidal Turbines

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Background

Recently the world has seen a resurgence in the development of the renewables industry, essentially to reduce the environmental impact of energy generation such as that produced from fossil fuels, and create energy security for countries using renewable energy, decreasing reliance on energy imports.

The oceans are an untapped resource, capable of making a major contribution to our future energy needs. They have the potential to equal or exceed wind energy in the make-up of our future electricity demands. In the search for a non polluting renewable energy source, there is a push to find an economical way to harness energy from the ocean. There are several different forms of ocean energy that are being investigated as potential sources for power generation. These include thermal energy, wave energy, offshore wind energy, tidal energy and ocean current energy, but these can only be applied if the technology can be successfully developed to exploit such resources reliably and cost effectively.

Figure 1: Tidal stream energy density around the UK[1]

Aim

This work aims to increase the efficiency of horizontal axis tidal turbines through optimisation of the blade design

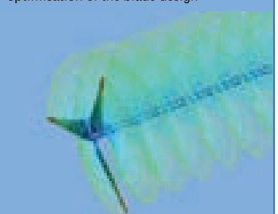


Figure 2: CFD of a horizontal axis tidal turbine

Experimental and Numerical Structural Analysis

- Basis central blade spar - carbon, bend-twist coupled, uniform planform, double box beam
- Laser based experimental setup – Figure 5
- Finite Element Analysis
- Results:
  - Generally good correlation between experiments and FEA, especially at low loads (Figure 6)
  - FEA sensitive to manufacturing accuracy
  - FEA does not model progressive plywise failure or matrix cracking observed in experiments

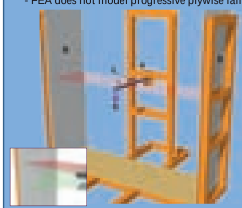


Figure 5: Experimental setup

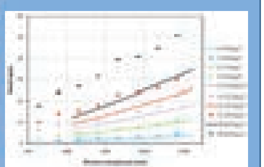
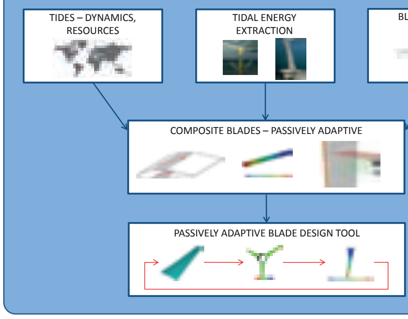


Figure 6: Comparison of FEA and Experimental bend

Conclusions and Further Work

- Tidal energy is an immature industry with great potential, but to further it requires efficient and economic devices to be developed - blade design of HATTs is a key area for optimisation.
- Different blade types have been compared, and it was found that adaptive composite turbine blades could improve device performance with preliminary results suggesting that a 10% reduction in thrust loading and 2.5% increase in annual energy capture is achievable with bend-twist coupled blades.
- A design tool has been created for the development of passively adaptive bend-twist coupled HATT blades and further validation will be carried out

Project Breakdown



Blade Design

- Considerations: Cavitation, Yaw, Structural loading, Efficiency, Cost, Maintenance
- Design tools – BEMT, CFD, FEA, FSI
- Variable pitch blades vs wholly bi-directional blades. Figure 3 illustrates gains in power capture from differing blades

Composite Blades

- An adaptive textile composite = a structure tailored to exhibit desirable elastic deformation behaviour which is not necessarily proportional to the imposed load. E.g. bend-twist coupled beam (mirror layup, Figure 4).
- Preliminary analysis indicated potential improvements of:
  - 2.5% increase in annual energy capture
  - 10% decrease in thrust loading
  - Half as likely to cavitate

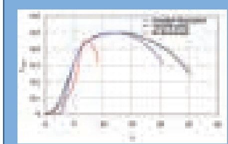


Figure 3: Fixed pitch, variable pitch and bi-directional blade comparison

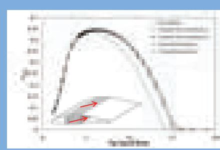


Figure 4: Preliminary analysis of adaptive blades

Adaptive Blade Design Tool

- Blade input geometry developed and manipulated
- CFD run – pressure loading and performance data obtained
- Pressures applied to geometry in FEA – structural deflections noted
- Deformed structure remodelled in CFD
- Iterated until max bend is <10mm
- Results concur with preliminary analysis:
  - >5% increase in C_{pow} – Figure 7
  - >12% decrease in C_T – Figure 8

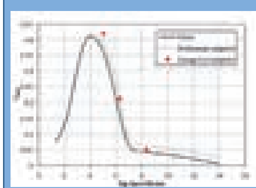


Figure 7: Comparison of fixed pitch, preliminary adaptive and design tool adaptive blades - C_{pow}

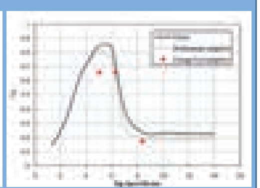


Figure 8: Comparison of fixed pitch, preliminary adaptive and design tool adaptive blades - C_T

References:
[1] BERR, Atlas of UK Marine Renewable Energy Resources: A Strategic Environmental Assessment Report, BERR, Editor. 2008.

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Dr L Myers

ER17

Marine energy resource

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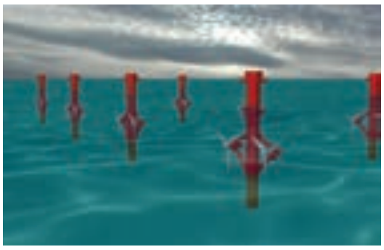
Tidal Turbine flow field effects

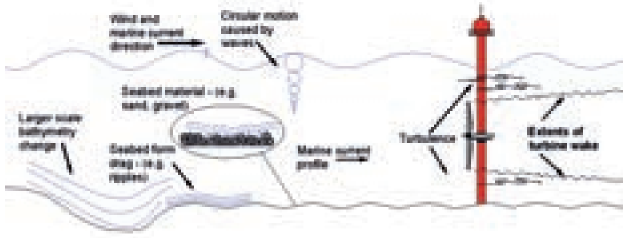
Horizontal axis tidal turbines operate in a very similar manner to wind turbines but are exposed to the strong tidal flows existing around the UK. This highly predictable resource could supply up to 10% of the UK's electricity demand. Arrays of turbines will eventually be installed.



Artist impression of a tidal turbine array

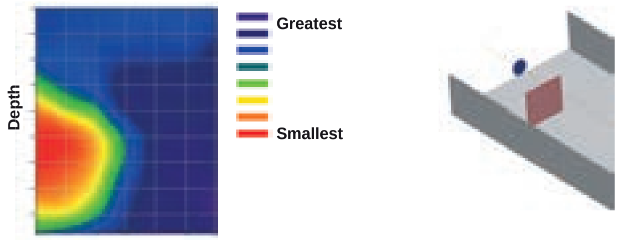
0.8m-diameter tidal turbine installed in a large circulating water channel

Characterising the flow field around tidal turbines will enable array design to be optimised. There are many environmental and device-specific parameters that will affect the flow field.



Variables affecting the flow field around tidal turbines

A comprehensive 3 year project has involved the design, construction and flow mapping around 1/20th scale tidal turbines in large European test facilities. Each flow map consists of several hundred individual points to enable quantification of the flow conditions and optimisation of turbine spacing.



Velocity flow map downstream of 1/20th-scale tidal turbine

Funded by: Technology Strategy Board

Industrial project partners
GARRAD HASSAN
EMD Hydrovision
Lunar Energy

www.southampton.ac.uk | www.energy.soton.ac.uk

Dr L Myers

ER18

Marine energy resource

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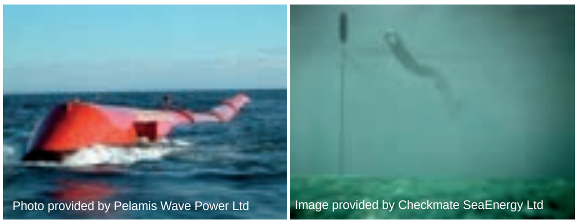
Wave and Tidal energy research

Introduction

Pioneering research on wave and tidal power is being conducted at the University of Southampton. The Sustainable Energy Research Group at the School of Civil Engineering and the Environment has collaborated with several industrial partners and the National Oceanography Centre to focus of a wide range of research areas.

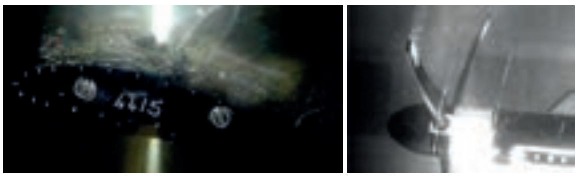
Device performance and testing

Development work on the commercial Pelamis wave energy device was conducted at the University. Scale trials are in progress for the new Anaconda device to design power take off systems and quantify energy yield performance.



Pelamis offshore wave energy converter (left) and Artist's impression of the Anaconda wave energy converter (right) .

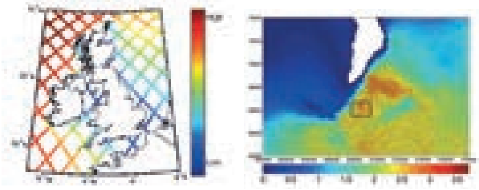
Extensive scale model tests have addressed issues such as tidal turbine blade design, cavitation and the flow field surround marine energy converters.



Cavitation occurring on a 2D tidal turbine blade section (left) and 1/20th scale turbine (right)

Marine energy Resource Assessment

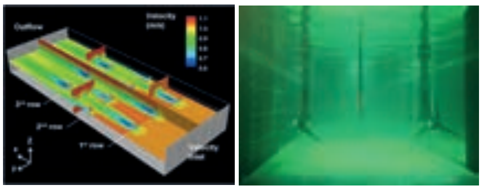
Measured data from the wave and tidal energy resource is gathered and used to validate numerical simulation tools.



Satellite altimetry traces indicating wave power (left) and tidal current magnitude and direction at Portland Bill (right).

Fluid dynamics

Experimental results from flume tests and in-house developed numerical tools are used to quantify the fluid flow around devices



Numerical simulation of a tidal energy farm (left), dual tidal turbine flow mapping experiment (right)

Industrial project partners

IT Power Climate Change Consulting
pelamis wave power
Garrad Hassan
Lunar Energy
Hydrovision

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Dr L Myers

Marine energy resource

University of Southampton
School of Civil Engineering and the Environment

Modelling large arrays of tidal turbines

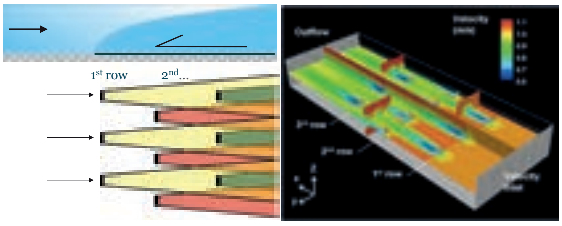
Introduction

Individual tidal stream generator units are limited in capacity and in general cannot completely block a tidal stream. If tidal stream power is to make a significant contribution to the energy mix, multi-row arrays of tidal turbines will need to be built, so tools are required to investigate the possible effects of a large array on the flow.

Modelling tidal stream arrays

Physical models of tidal stream turbine arrays are difficult to produce due to scale. Numerical models tend to be divided into three types of increasing complexity:

1. Added roughness (boundary layer) models
2. Wake superposition models
3. Field models



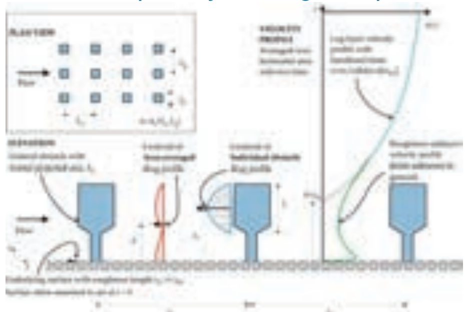
Added roughness/boundary layer type model (top left)
Wake superposition model (bottom left) Field model (right)

Strengths of different models

	Boundary layer model	Wake superposition model	Field model
Details of wake interactions	×	×	✓
Power output of each device	×	✓	✓
Effect of large arrays	✓	×	✓
Optimal spacing of generators	✓?	✓	✓?
Computational cost	£	££	£££

Added roughness model

Based on the theory of rough-wall boundary layer flow over obstacle arrays, these models assume that the momentum balance in a large array reaches a spatially-averaged equilibrium

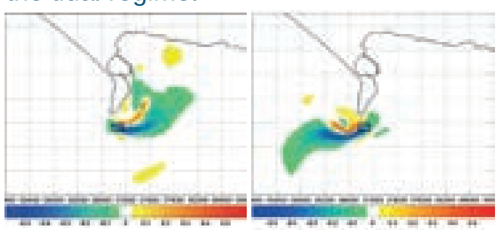


A general obstacle array

In order to make the model useful, assumptions need to be made about the flow profile below the obstacle height (hub height) and the friction with the ground as a proportion of the drag on the obstacles (turbines).

Application of new model

The added roughness model may be used within existing coastal models to simulate large arrays and their effect on the tidal regime.



Simulated flow speed change (m/s) from natural tidal flow state when added roughness is applied in a numerical model of Portland Bill

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Dr L Myers ER20

Marine energy resource

UNIVERSITY OF Southampton
School of Civil Engineering and the Environment

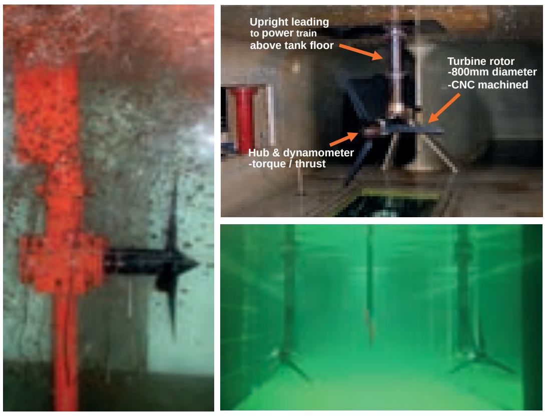
Wave and Tidal energy experimental studies

Introduction

Fundamental research on wave and tidal energy devices has been conducted at the University of Southampton covering a wide range of devices, hydrodynamic and physical parameters.

Horizontal axis tidal turbines

A range of scale turbines have been constructed to investigate power generation performance, cavitation, flow field characterisation and device interaction effects.



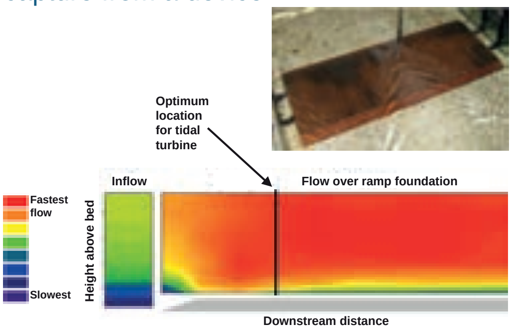
1/40th scale prototype (left), Fully instrumented 1/20th-scale turbine (top right) and dual turbine arrangement (bottom right)

Tidal fences

Investigating the effects of rows of tidal turbines using porous media to simulate energy extraction.

Tidal flow acceleration

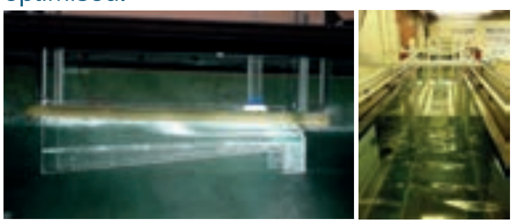
By creating a tapered sea bed foundation for a tidal turbine it is possible to increase the flow speed which will increase energy capture from a device.



Measured flow velocity approaching and flowing over a scale tapered turbine foundation.

OWEL

A 1/40th-scale model of the Offshore Wave Energy Limited device has been developed at the University. Waves enter the open-ended tapered duct and force air through a turbine. Experiments have quantified the power extraction over a range of wave conditions. Based on the results, device geometries have been optimised.



Wave travelling along the duct of the OWEL device (left) and the long wave flume facility used for testing (right).

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Dr L Myers

ER21

Marine energy resource

University of Southampton

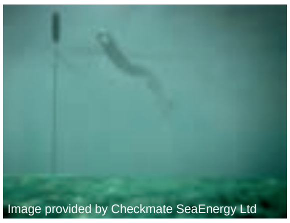
Wave and Tidal energy device development

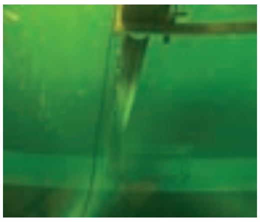
Introduction

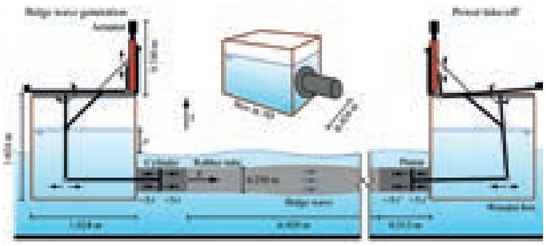
Pioneering research on wave and tidal energy devices has been conducted at the University of Southampton on a wide range of concepts and devices that are now nearing large scale, commercial production.

Anaconda

Waves passing over the anaconda causes pulses of water to move through a giant rubber tube. Energy is extracted from this 'Bulge wave'. Recent tests at a large European wave basin quantified the performance of a 1/30th scale model.







Artists impression (top left), experimental model (top right) and diagram of wave basin set up (bottom).

Industrial project partners

Offshore Wave Energy Limited

Pelamis

Development work on the commercial Pelamis wave energy device was conducted at the University. Mooring response was studied to assess structural loads and survivability in heavy seas was assessed using scale models subjected to extreme waves.

Pelamis wave energy device

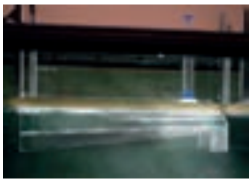
Pulse-tidal

The university has been conducting flume testing in conjunction with IT Power to assess the performance and cost benefit of a foundation structure for the Pulse tidal shallow water oscillating hydrofoil device.

Pulse tidal Humber demonstrator

OWEL

Automated scale model studies of the OWEL wave energy device have been conducted at the University in a wave tank to quantify power production under varying conditions.



Model device in flume (left), Artist impression right)

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High Voltage Subsea Cable Systems at the Tony Davies High Voltage Laboratory

Professor P Lewin

ER22

UNIVERSITY OF Southampton

High Voltage Subsea Cable Systems at the Tony Davies High Voltage Laboratory

Laboratory Overview

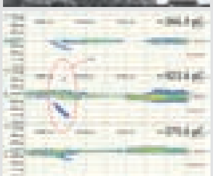
- The Laboratory was constructed on its current site in 1991 with funding from STC Submarine Cable Systems
- We undertake a range of Research, Testing and Consultancy work across a variety of HV Systems
- Seven academic staff, possessing a wide range of high voltage expertise, are based in the laboratory
- Alongside our high voltage facilities we have a fully equipped HV workshop

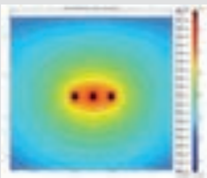
Cable System Testing

- We regularly test high voltage products on behalf of UK/EU based manufacturers
- A wide range of tests can be performed on cable systems (both land and submarine), including withstand tests, impulse voltage tests (lightning and switching) and partial discharge tests
- Tests on cable accessories are also offered, including x-ray analysis to verify the integrity of polymeric cable joints.
- Experience in testing distribution, submarine fibre optic and neutrally buoyant cable systems and accessories such as joints and wet connectors

Research & Development

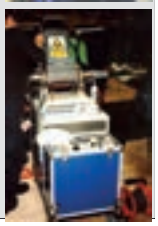
- Substantial breadth of research in cable systems, from blue sky to end application
- Significant work in the development and understanding of novel dielectric materials for both ac and dc application
- Use of novel techniques in cable system condition monitoring to make better use of online data
- Longstanding work in operational modelling and standards development in areas such as current rating
- We have a strong track record of working with industrial partners from manufacturers to transmission utilities





Consultancy & Forensics

- Consultancy has always been a core element of our business, with staff involved in an array of projects both within the UK and overseas
- We regularly draw upon our analytical facilities to assist clients in forensic examinations, either for quality control or failure analysis purposes
- Work carried out in a range of environments from laboratory to cable ships to cable tunnels



www.highvoltage.soton.ac.uk

Contact: Prof Paul Lewin
Faculty of Physical and Applied Science
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Structural Analysis and Loads for a Modular Nuclear Merchant Ship

Professor RA Shenoi

ER23

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Structural Analysis and Loads for a Modular Nuclear Merchant Ship

Mr Jonathan Gravina – J.Gravina@soton.ac.uk – Faculty of Engineering and the Environment
Supervisors: Professor R.A. Shenoi and Dr J.I.R. Blake
Sponsors: Lloyd's Register

1. Background:

About 700 nuclear plants have served at sea over the past 55 years with no serious accidents. Their use has mostly been on naval vessels. Only three merchant ships were constructed in the 1960's which were technically viable however not economically feasible. Nuclear propulsion has been extremely effective on Russian ice breakers.

Currently the shipping industry is being faced with pressure due to its emissions of CO_2 and other pollutants. Consequently there will be a probable introduction of market based control measures such as a carbon tax. The amendments to the MARPOL Annex VI regulations to control NOx and SOx emissions will increase fuel prices considerably by 2020.

The rising price of fuel, depleting fossil fuels and owners' perceptions on their environmental impact is causing interest towards fossil fuel alternatives. Currently nuclear power is the only emissions free energy which can replace fossil fuels entirely (Jenkins, 2011).

Although nuclear power is an attractive and possibly economically viable alternative with a number of advantages, it has its drawbacks.

2. Research Objectives:

Two critical operational drawbacks for a nuclear powered ship are accidents (collision/grounding/fire/explosion) and route restrictions. The overall goal of the research is to address these issues and ensure that a nuclear merchant ship can sustain an accident without catastrophic consequences as well as operate freely at sea without intervention from port states due to the mode of propulsion.

Figure 1: Ship side collision http://www.cargolaw.com/2003nightmare_t-bone.html

The issue with route restrictions will be addressed by designing a modular vessel consisting of a propulsion module and a cargo module which can decouple outside of territorial waters.
The issue with accidents will be addressed using high impact load modelling and risk analysis

3. Modular Ship Concepts:

Five preliminary concept designs were developed for a modular nuclear merchant ship. Figure 2 and 3 illustrate two of these concepts.

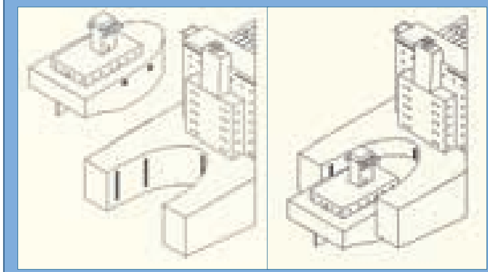


Figure 2: Pusher-barge modular ship concept

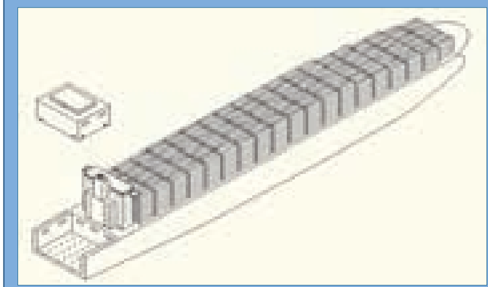


Figure 3: Floating 'dock' modular ship concept

4. Further Work:

- High level risk assessment to select the best performing concept. This will include an attempt to carry out some aspects of a Formal Safety Assessment as well as the use of a preliminary HAZID analysis.
- Development of the best performing concept including routine naval architecture (hydrodynamics, ship structures ...) and an FEA model.
- Service factor analysis with a 3D hydroelastic model to obtain the long term bending moments and assess the modular coupling in open waters for unrestricted service.
- Grounding and collision analysis applied to the structure in way of the Nuclear plant using nonlinear structural dynamics software.

5. References:

JENKINS, V. 2011. Risk and Classification Rules for Nuclear Powered Ships. *Ship Power Forum*. London: IMarEST

EPSRC Engineering and Physical Sciences Research Council

FSI Away Day 2012

Lloyd's Register

Professor P Lewin

UNIVERSITY OF Southampton

The Tony Davies High Voltage Laboratory

Laboratory Overview

The Laboratory has been active on its present site since being constructed in 1991 with funding from STC Submarine Cable Systems. While primarily the Laboratory is a research facility, commercial testing and consultancy are undertaken on a regular basis.

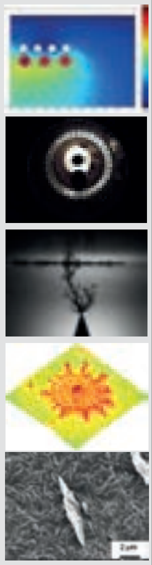
Personnel:

- 7 academic staff
- 5 full-time research staff
- 25 full-time postgraduate students
- 3 laboratory technical staff

Expertise in the laboratory covers the full spectrum of high voltage engineering, from dielectric materials science to condition monitoring and testing of high voltage plant.

Research Areas

- Condition Monitoring of HV Plant, particularly cables/transformers
- Environmental Modelling using techniques such as FEA and CFD
- HTS Power Apparatus, notably cable terminations/generators
- Liquid Dielectrics, including both conventional and novel oils
- Plasma & Space Technology, focusing on electric propulsion
- Solid Dielectrics, especially complex polymeric systems
- Space & Surface Charge, as applied to HV cable and GIS systems



Facilities & Testing Capabilities

The Laboratory has a wide range of HV facilities which we use for both research and commercial testing to a range of BS and IEC standards:

HV Facilities

- Up to 1MV/50kJ impulse generator
- Up to 300kV AC - pd free to less than 1 pC
- Up to 600kV DC
- Environmental chamber for fog, salt fog and rain tests on live components
- Screened room for low noise measurements
- Partial Discharge testing to IEC 60 270

Materials Analysis

- Characterisation using UV/Vis and IR spectroscopy, Differential Scanning Calorimetry (DSC) and Raman microscopy
- X-ray analysis
- Dielectric spectroscopy - Capacitance and Tan Delta measurements

Numerical Modelling

- A range of finite element/CFD tools, plus the development of bespoke codes

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Gyroscopic Energy Harvesting

N Townsend

ER25

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Gyroscopic Energy Harvesting

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Background

This research is investigating the potential of harvesting energy from the ambient vibrations and motions of a body (e.g., wave induced roll and pitch motions of a boat) using the reaction of a spinning wheel (gyroscopic precession).

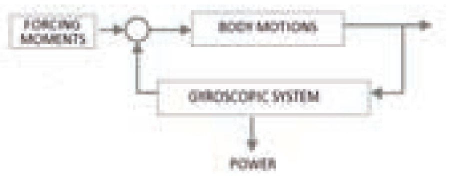


Fig 1: Block diagram representation of a gyroscopic energy harvester

Motivation and Aims

The motivation behind the project is to ...

... develop an understanding of the recoverable power from a gyroscopic system(s) on various marine vessels and structures.

The project aims to...

1.) Develop a theoretical model and verify the model through experimental testing,

2.) Identify the potential applications and system(s) design requirements and,

3.) Develop the system commercially.

Modelling Methodology

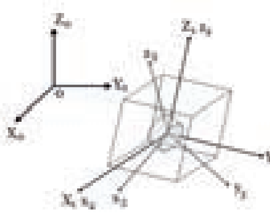


Fig 2: Coordinate frames

1, 3 and 6 degree of freedom (DOF) models based a momentum (Newton-Euler) method have been developed and are under investigation.

The models are based on the following governing equations of motion ;

Gyroscopic Moments

[illegible]

Coupled gyroscopic and body equations of motion

[illegible]

Equation of motion about the precession axis

[illegible]

Available instantaneous power

$P(t) = B_g\dot{\beta}^2$

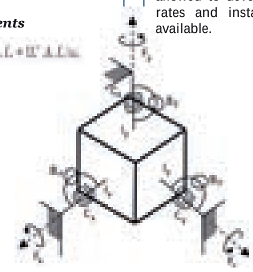


Fig 3: Rotational 3DOF body model

Findings

Lower gyroscopic damping can lead to nonlinear gyroscopic motion responses.

The initial onset of nonlinear gyroscopic precession begins with a period doubling.

Provided nonlinear motions are allowed to develop, greater precession rates and instantaneous powers are available.

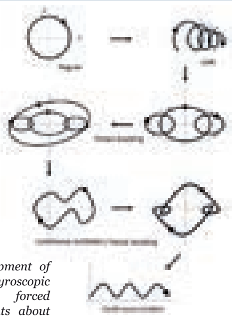


Fig 4: The development of nonlinear gyroscopic precession (to forced harmonic moments about one axis)

To maximise power, the spin rate and gyroscopic damping are required to be adequately matched for a given body, flywheel design (mass moment of inertia) and forced excitation (frequency and magnitude).

Experimentation to validate the numerical models is planned for 2012.

Conclusions and Further Work

Potentially, the system could be applied to any moving object or vehicle to enable energy recovery.

Lloyd's Register Educational Trust

Acknowledgement: This project is supported by **The Lloyd's Register Educational Trust.**

FSI Away Day 2012

Power Flow Active Control of Aeroelastic Flutter for a Nonlinear Airfoil with Flap

Dr Y Xiong

ER26

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Power Flow Active Control of Aeroelastic Flutter for a Nonlinear Airfoil with Flap

N.Zhao[1,2], Supervisors – Dr. Y.P.Xiong[1] and Prof. D.Q.Cao[2]
[1] School of Engineering Sciences, University of Southampton
[2] School of Astronautics, Harbin Institute of Technology

Background

• The flutter phenomenon of aeroelastic system is one of the most important issues in many areas, especially in aircraft structures. It is very dangerous when aircraft flutter happens because its vibration amplitude and dynamic stress will increase dramatically. The flutter may lead to rapid structural damage in flight within a few seconds as shown in Fig. 1,2.

• Nonlinear flutter happens with a phenomenon of limit cycle oscillations (LCOs) when the flight speed reaches the critical speed. The most concerned way to suppress flutter is to change the aerodynamic loads by changing the deflection of control surface. The flap as control surface in aeroelastic control system can be driven by an actuator.

• Various modern control methods have been widely used in the design of a control law for active flutter suppression, such as the LQR, adaptive control, robust control, etc. The information is insufficient to determine the pathway of the vibration transmission by the transfer function measurement method.

• Power flow control method takes into account both force and velocity information. Therefore, it is a better control parameter and the impedance characteristics of the structure is considered. It provides an effective measure to evaluate and improve the control performance of complex nonlinear systems.

Aims

• Active flutter control to suppress airfoil flutter by driving the control surface as the aerodynamic shape altered.

• Power flow analysis of the nonlinear coupling dynamic system and active control to optimize the vibration control performance.

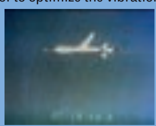


Figure 1: Video frame of DAST just after structural failure of right wing (1984)

Figure 2: The crash of a F117 Stealth Fighter in 1997 was linked to flutter

Modelling Methodology

• A typical supersonic/hypersonic airfoil model with a control surface is shown in Fig. 3. It has two degrees of freedom, i.e., plunging, pitching displacement denoted by h and α, respectively.

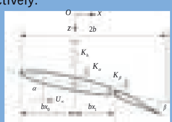


Figure 3: Sketch of a supersonic 2-D (two-dimensional) airfoil-flap system

• Governing Equations of Motion

$$\begin{cases} m\ddot{h} + S_\alpha\ddot{\alpha} + C_h\dot{h} + \left(K_h h + e_1 K_h h^3\right) = -q_h \\ S_\alpha\ddot{h} + I_\alpha\ddot{\alpha} + C_\alpha\dot{\alpha} + \left(K_\alpha\alpha + e_2 K_\alpha\alpha^3\right) = q_\alpha \end{cases}$$

• The bending and torsional stiffness of the airfoil are equivalent to the bending and torsional springs K_h and K_α at the elastic axis E, and the torsional stiffness of the flap is determined by the torsional spring K_β at the hinge H. And cubic nonlinear stiffness is considered in both the bending and torsional springs. b is half chord of the 2-D airfoil and β is the flap displacement. q_h and q_α are the aerodynamic lift and moment in the corresponding degree.

• Thin wings have hard cubic nonlinear characteristic which means stiffness increases gradually as the plunging gets bigger. The torsional stiffness, however, may take soft nonlinear characteristics.

• Active Flutter Control Strategy:

The control objective is to design a control strategy to heighten the critical flutter speed and depress the vibration amplitude of post-flutter oscillation. Toward these goals, a combined control law is proposed to suppress the flutter and it is described as $u = u_1 + u_2$, where the linear control force $u_1 = -K_1 Y$ is designed by using the LQR method for the corresponding linearized model of the system, and the nonlinear feedback control force $u_2 = -K_2\alpha^3$ is designed to suppress the amplitude of the post-flutter oscillation.

Results

• Dynamic Response: Parameters used is shown in the Table 1.

Table 1: Key parameters for 2-D airfoil

[illegible]

• Critical Flutter Speed: $\mu(V) = \max_i[\mathrm{Re}(\lambda_i)]$

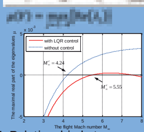


Figure 4: Relationship between μ and M_∞

where μ is the maximal real part of all the eigenvalues of system matrix, with respect to flight Mach number, M_∞, is shown in the Fig. 4.

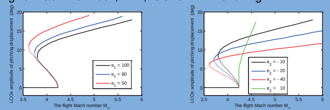


Figure 5: The effect of the nonlinear stiffness coefficients e_1 and e_2 on the amplitude of the limit cycle oscillations.

where e_1 and e_2 are nonlinear coefficients of stiffness in the plunging and pitching, respectively.

• Active Flutter Control Strategy:

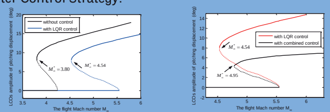


Figure 6: The amplitudes of limit cycle oscillations for the uncontrolled, LQR controlled and combined controlled system.

• Both the structure and aerodynamic nonlinearities have effect on the dynamic behavior of the airfoil. At the linear critical flutter speed, the equilibrium state of the system becomes unstable and a Hopf bifurcation occurs.

• Both subcritical Hopf bifurcation and supercritical Hopf bifurcation were observed in the system. Using the LQR control strategy, not only both the linear and nonlinear critical flutter speeds can be heightened but also the amplitude of LCOs can be suppressed for the airfoil in the supersonic/ hypersonic airflow.

Conclusions and Further Work

• The flutter, post-flutter and active control of a 2-D airfoil with control surface operating in supersonic/hypersonic flight speed regions is investigated first. For the combined controlled system, not only the nonlinear critical flutter speeds can be further increased but also the amplitude of LCOs can be further suppressed in comparison with the LQR controlled system.

• Further study will focus on the development of power flow based optimal active control strategy for the complex nonlinear coupling system and analysis of energy dissipation mechanism.

• Comparative study will be performed to evaluate the cost-effectiveness of the power flow control approach and the combined active control method. Optimal control parameters will be determined to reduce the input and transmitted power to the structure.

References:

1: Y.P. Xiong, J.T. Xing and W.G. Price and X.P. Wang, Hybird active and passive control of vibratory power flow in flexible isolation system. *Shock and Vibration.* 7(2000). pp. 139-148.
2: Y.P. Xiong, J.T. Xing and W.G. Price, Xiong, A general linear mathematical model of power flow analysis and control for integrated structure-control systems. *Journal of Sound and Vibration.* 10(2003). pp. 301-334.
3: D.Q. Cao and N. Zhao, Active control of supersonic/hypersonic aeroelastic flutter for a 2-D airfoil with flap. *Science China: Technological Sciences.* 8(2011). pp. 1943-1953.
4: D. Tang, E.H. Dowell and L.N. Virgin, Limit cycle behavior of an airfoil with a control surface. *Journal of Fluids and Structures*, 12(1998). pp. 839-858.

National Natural Science Foundation of China
China Scholarship Council

FSI Away Day 2012

Dr D Hudson

ER27

UNIVERSITY OF Southampton

Trade / Environment

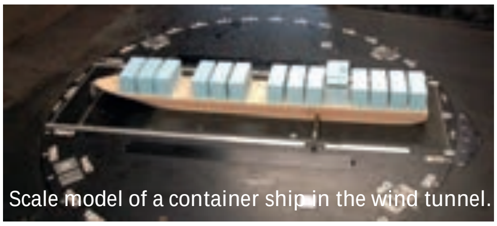
Low Carbon Ship Design

Research purpose

Shipping represents the most efficient means to transport raw materials and manufactured goods from both a financial and environmental perspective. The CO2 emitted per tonne.km for shipping is lower than for any other mode of transport.

Sheer volume of trade means, however, that global shipping accounts for 1.12 billion tonnes of CO2 emissions per annum, equivalent to ~3% of global emissions and surpassing the emissions of all but 5 industrialised countries.

There is thus an urgent need to reduce the greenhouse gas emissions of the industry.



Scale model of a container ship in the wind tunnel.

Collaborations

Lloyds Register
Hart, Fenton and Co. Ltd.
Prof. R. A. Shenoi
Dr. S.R. Turnock
Dr. D.A. Hudson
Prof. A. F. Molland

Research description

Several research projects aim to reduce the greenhouse gas emissions of the shipping industry through improvements in ship design.

- Development of a quantified method of relating improvements in the efficiency of specific ship design features directly to reductions in CO2 emissions.
- Reduction of the aerodynamic drag of container ships using wind tunnel experiments to investigate cost–effective means of drag reduction – including container stacking arrangements and superstructure shape.
- Performance prediction for auxiliary kite propulsion of merchant shipping, using theoretical and experimental methods to determine potential CO2 emissions reductions for realistic shipping routes.
- Investigation of viable alternatives to the diesel engine for propulsion - a case study designing an environmentally sustainable vessel for Lundy Island.

Beluga Projects was one of the first ships equipped with a full-scale site propulsion system.

www.southampton.ac.uk

Society and Government

By 2020, it is predicted that more than four billion people - or around 75 per cent of the global population - are expected to live within the world's coastal zones. The study of people and their welfare is critical to the welfare of our society. Maritime connections between individuals and societies have always been crucial to global trade, governmental networks and cultural and technological innovations. Empires and systems of commerce have been consolidated; traditions of social exchanges are continued; and new forms of communications are still emerging from these maritime connections.

Our interests and expertise in this domain includes the evolution of port cities, the planning of governance and planning in coastal regions owing to climate change patterns, and technological innovations in ensuring the safety of people, tourism and leisure activities.

Dr G Earl

UNIVERSITY OF Southampton

Communities

The Portus Project

Arts & Humanities Research Council

Portus was the port of Imperial Rome and during the 1st - 6th centuries AD was one of the most important commercial centres in the Roman Empire. The Portus Project is using archaeology and related disciplines to find out more about the nature, development and functions of this unique site and the people that lived and worked there, and passed through on their way to and from Rome.

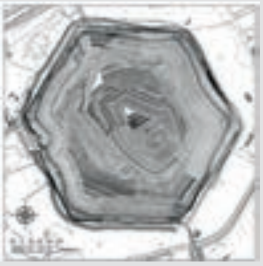
The site of Portus is huge - well over 3km² - and consists of a network of basins, canals and river ports, as well as a multitude of streets, warehouses, temples and administrative buildings. One of the only ways of adequately recording and visualizing the large amount of archaeological information generated during the fieldwork is through using the latest techniques in archaeological computing. These include processing and visualising data from a range of types of land and underwater survey, computer reconstructions, and innovative object recording methods.

This research is having considerable impact across a number of disciplines. Within the humanities our understanding of the scale and character of the port is helping us gain a clearer understanding of the involvement of the Roman state in the development of maritime and commercial infrastructure in the Roman empire, and the range and volume of traded goods moving between Rome and the Mediterranean in antiquity. This will provide an important perspective from which to gauge the achievements of other maritime powers in promoting Mediterranean wide trade, such as Medieval Venice, Genoa and Ottoman Turkey. Within the realm of the sciences our growing understanding of the development of the port is helping us better understand processes related to the development of the Tiber mouth and Tyrrhenian coast in historical periods.

Plan of the site in the 2nd Century AD

The techniques that we are applying and developing in the field of computer-based detection and recording, which derive from a range of disciplines, are making it easier for archaeologists to both create a more permanent record of the site and web-based access for specialists and general public at large – both of which will have important implications for the treatment of other large-scale archaeological sites across the world. It is also a very high profile site that is shortly to be opened to a paying public and whose continued protection for future generations is the subject of considerable debate amongst Italian authorities in their attempts to ensure better conservation and public enjoyment of major heritage sites.

Traded amphora recovered at Portus, with writing indicating its origin



Interim results of the side-scan sonar analysis of the Trajanic basin

Since very little is known about what lies underwater at the bottom of the enormous hexagonal Trajanic basin a side scan sonar and sub-bottom profiler survey has been undertaken by Dr Justin Dix of the School of Ocean and Earth Science.

This work is helping to determine the profile of the bottom of the basin and to create a map of the current harbour bed in order to identify any archaeological material on and within it. It is hoped that future work in concert with palaeo-environmental coring by colleagues from Aix-en-Provence, will also identify the thickness of sediments overlying the Roman harbour.

Excavations showing harbour mole and amphitheatre

Computer generated reconstructions produced by the Archaeological Computing Research Group at Southampton

The Portus Project is funded by the Arts and Humanities Research Council, the Soprintendenza per i Beni Archeologici di Ostia, the University of Southampton, with support from the British School at Rome and the University of Cambridge. It brings together experts in archaeology, classics, oceanography, sedimentology, electronics and computer science from across the world to study the site. The Portus Project is directed by Simon Keay, with Graeme Earl and Martin Millett. It is a collaboration between many partners including the British School at Rome, the Universities of Southampton, Cambridge, Oxford, Warwick, Bath, Aix-en-Provence and Seville, and the Institut Català d'Arqueologia Clàssica. Thanks are also due to Parsifal Cooperativa Di Archeologia (Rome), L-P Archaeology and Opti-cal Survey Equipment Ltd. The project is also grateful to the Duke Sforza Cesarini for continued access to his land.

www.portusproject.org

The Parkes Institute for the study of Jewish/non-Jewish relations

UNIVERSITY OF Southampton

JEWISH MARITIME HISTORY

The Rev. Dr James Parkes (1894-1981) formally created The Parkes Library in 1961 with the aim of providing: *a centre for research by non-Jewish and Jewish scholars and students… into the whole field of relations between Judaism and other religions.* James Parkes was an extraordinary person; a volatile non-conformist, a creative force and a person who confronted antisemitism head-on. He demanded a world in which it was safe to be a Jew. The Parkes Institute is a community of scholars, curators, librarians, students, Friends of Parkes and activists, whose work is based around the rich resource of the library and archive. Through our research, publications, teaching and conservation work we provide a world-class centre for studies of Jewish/non-Jewish relations throughout the ages; the experience of minorities and outsiders and the examination of the power of prejudice from antiquity to the contemporary world.

Transmigrancy
From the late 19th century, Southampton rivalled Liverpool as the main centre of transmigrancy in Britain. It was big business for shipping companies, railway companies and the ports themselves. Tens of thousands of immigrants passed through, staying up to two weeks before continuing their journeys and would have been a common sight in Southampton before 1914. Many were E. European Jews. From Southampton they moved on - North America, South America and South Africa amongst other destinations. There were many such Jews on board the Titanic never to make it to the 'golden medina' of America.

Atlantic Hotel, in Albert Road Southampton c. 1900 (now converted into apartments) where transmigrants were housed while awaiting passage

Seafaring Jews
A "mock trial", organized in 1938 by members of the German-speaking Jewish Community in Palestine, discussed the "lack of seafaring" among the Jews in Palestine – at the same time the city of Tel-Aviv was creating its own port. The Parkes Institute is developing a new project on Jewish seafaring which starts with a one day conference on 26 October 2009.

Port Jews
The Parkes AHRC Port Jews research project (2001-2005) which identified the "Port Jew" (in contrast to the "Court Jew" and their role in history) as a distinctive character who was active and self-conscious in a broad network of economic and cultural relations across Europe; studied cosmopolitan port cities and their Jewish communities in Early Modern and Modern History. The Parkes Institute is opening this research to a transnational perspective to study Jewish communities in Mumbai, Shanghai, Cape Town and Buenos Aires.


The port of Tel Aviv (photo: J. Schlör)

IMPACT
Publications: David Csearani (ed.), *Port Jews: Jewish Communities in Cosmopolitan Maritime Trading Centres, 1550-1950* (2002), David Cesarani and Gemma Romain (eds), *Jews in Port Cities, 1650s to the Present* (2006), Tony Kushner, David Cesarani and Milton Shain (eds), *Place and Displacement in Jewish History and Memory* (2009), Tony Kushner, *Anglo-Jewry since 1066: Place, Locality and Memory* (2009), James Jordan, Sarah Pearce and Tony Kushner (eds), *Jewish Journeys: From Philo to Hip Hop* (2010 forthcoming)

Joachim Schlör is working with Ingo Haar in Vienna, Leo Lucassen in Leiden and Carl Henrik Carlsson in Uppsala on a joint research project "Migration and Integration". The comparative study analyses "Jewish Spaces" in port cities such as Amsterdam, Antwerp, Oslo, London, and Southampton.

The Parkes Institute has carried out extensive dialogue at a public level with regards to diversity, tolerance and intolerance all of which have been played out on a spectacular level in maritime settings.

Events: Conference: "Jewish Families and Migration", January 2009, Cape Town; in which maritime themes were strongly represented. From this another international gathering will be held in 2011 in conjunction with local heritage bodies in the city of Cape Town, on the concept of the "archive" and migration with maritime themes being of central significance .

One day International Jewish Maritime Conference 26 October 2009 at NOC– with: Rebecca Wolpe, (Ben Gurion University) on "Jerusalem: Seafaring Narratives in Jewish Literature".and Naor Ben Yehoyada, (Harvard), "Jaffa Fishermen and the Zionist Project" among the speakers.

www.southampton.ac.uk

Dr S Jones

SG3

UNIVERSITY OF Southampton

Humanities: Communities

The study of people is central to research in the Humanities. Maritime connections between individuals and societies have always been crucial to global trade, governmental networks, and cultural and technological innovations. Empires and systems of commerce have been consolidated; traditions of social exchange are continued; and new forms of communication are still emerging from these maritime connections. By highlighting these issues, research in the humanities demonstrates that it is impossible to understand economies, politics and cultures without an understanding of the development of communities across oceans.

Networks

Maritime global networks were essential to the expansion of trade, colonisation and empires in the period after the famous 'voyages of discovery' of the fifteenth century. They made possible new trans-oceanic communities, linking people on the shores and hinterlands of distant continents. Nowhere was this more apparent than in the 'Atlantic world', a geographical region that developed as a result of new connections of commerce and colonisation around the rim of the Atlantic Ocean.

Sugar and slavery were of huge importance to the British Atlantic world. Ships left Liverpool, London and Bristol, to trade for enslaved people along the coast of West Africa before shipping them to work on plantations in the Americas and returning home laden with American staple products, such as sugar, rum, tobacco and rice. This relied on Atlantic communities of merchants, entrepreneurs, colonists and investors, who created new ways of extending credit, managing risk and extracting profit from the mass movement of people and goods. It also required close communication, and British slaveholders in the colonies kept in constant touch with merchants, friends and family 'at home'. Many of them also retired to the British Isles once they had made their fortunes, managing their colonial plantations from the other side of the Atlantic and further strengthening the far-flung links that bound Britons into global communities.

Colleagues in history and other humanities disciplines at Southampton research these Atlantic and other maritime global networks. Their work has been funded by grants from sources such as the AHRC and the British Academy, and their publications have addressed themes such as cultural identities, migration, slaveholding, refugees and port cities. They have also developed links with the National Maritime Museum, helping to create a new 'Atlantic Worlds' gallery.

ZBA1586: Attack and Capture of the rebels' positions near Montego Bay by boats from HMS Blanche (Repro ID: F7405 © National Maritime Museum)

Coasts

Beach Idols, Southern India. © Lucy Blue

Located in antiquity at boundaries between 'the known' and 'the unknown worlds', maritime communities were the interface between emerging networks of people. Maritime archaeology attempts to access, understand, and explore the role of these communities in maritime contact, and ultimately discover the connection they have with people today.

Coastal communities are subject to both social and environmental change. Geological and Geophysical work in the Solent Estuary region has enabled the mapping of submerged landscapes that were inundated due to Holocene sea-level rise. This work addresses the impact of environmental change on people from the Mesolithic through to present day. The Chumash 'maritime' communities of south central California faced similar challenges with changing hydrological conditions throughout the later Holocene. Research funded by the University of Southampton, UCLAN and UCLA has revealed how relationships between interior highland zone, lake dwellers and coastal communities shifted with a move to a more arid climate during the medieval epoch. In both the Solent and South Central California, changes in hydrological regimes altered how people interpreted the world around them, on both functional and spiritual levels.

In more recent history, 'port cities' have been the point of arrival and departure for countless millions of migrants. The experiences of these migrants raise a number of important questions. For example, how do these groups interact with 'host' communities and with what consequences? In what ways is the host community – in this context, the port city – shaped by migrants? Members of the Parkes Institute for the study of Jewish/non-Jewish relations are researching the life experiences of 'port Jews', while other scholars in the School of Humanities are asking similar questions in relation to Asian and African diasporas.

Ships

Communities and their relationship with the sea, the technology of their boats, and the choices they make in the selection of the vessels they construct, is the focus of ethno-archaeological work conducted in the Indian sub-continent, supported by the *British Academy funded Society for South Asian Studies*. Maritime ethnography examines the boats in a modern day context, acquiring an insight into the practice of maritime communities of the past.

Shipboard experiments in a sixteenth-century Italian woodcut., proving the curvature of the sea. *Liber Pompilii Azalii Placentini* (Venice: Scoto, 1544) fol. 80r. © The British Library Board. London, British Library, 536.l.7.

Complementing work on the significance and influence of boat technologies, research in English is focused on how the maritime connections experienced by navigators were 'translated' by writers of texts and cartographers between the twelfth and the fifteenth-centuries. How does a practical understanding of the Ocean translate into bookish and cartographic knowledge? Measurement was by time travelled more often than by units of distance; space was marked out by what one does to get to it, rather than according to geometry. Communities of geographers and cartographers wrestled with whether and how the space of communities of travellers, explorers and navigators should be incorporated into the image of the world.

Other work in the School of Humanities is directed towards different questions of legitimacy, and different types of community forged aboard boats. The AHRC funded project on *The Indian Ocean: narratives in literature and law* supports research into recent and historical narratives of piracy. Current stories of Somali pirates (by others and themselves, as communities of criminals and heroes, as nation builders and nation breakers) have both continued and altered stories of pirate communities begun in the late 17th century by travellers, journalists, lawyers, and writers of fiction.

Outputs

Stephanie Jones, 'Colonial to postcolonial ethics: Indian Ocean "belongers ", 1668-2008', *Interventions,* 11.2 (2009),1-23.

A Historical Companion to Postcolonial Literatures in Continental Europe and its Empires, eds. Prem Poddar, Lars Jensen and Rajeev S. Patke (Edinburgh: Edinburgh University Press, 2009).

Boats of South Asia, eds. Sean McGrail, Lucy Blue, Eric Kentley and Colin Palmer (London: Routledge, 2003).

Christer Petley *Slaveholders in Jamaica: Colonial Society and Culture during the Era of Abolition* (London: Pickering and Chatto, 2009).

Christer Petley '"Home" and "This Country": Britishness and Creole Identity in the Letters of a Transatlantic Slaveholder', *Atlantic Studies* 6:1 (2009), 43-61.

Fraser Sturt 'Fishing for meaning: lived space and the early Neolithic of Orkney', in *Set in Stone: new approaches to Neolithic monuments in Scotland,* eds. V. Cummings and A. Pannett (Oxford: Oxbow, 2005), 68-80.

Collaborations **Our partners include:** AHRC (Arts and Humanities Research Council), National Maritime Museum, Open University, Southampton Archaeology Museum, UCLAN, UCLA, University of Cambridge, University of Liverpool.

Dr C Petley

UNIVERSITY OF Southampton

Humanities: Trade

Oceans are important areas of contest, trade, and war. They are also cultural spaces in which identities are shaped and re-shaped, sometimes willingly but sometimes, as in the case of transatlantic slavery, through force and coercion. Ships were the platforms that facilitated maritime trade, and harbours the interface that linked different cultures. Since prehistory, these and other technologies have linked people in ways that have facilitated exchange, commerce and trade. Researchers in the humanities are interested in all of these themes as well as the human stories of those traders, workers, and migrants who moved across and within the ocean world.

Human Voices

One of the issues that researchers in the humanities focus on is the lived experience of those who were involved in trade, whether as traders, pirates, migrants or enslaved workers. The Arts and Humanities Research Council (AHRC) funded project on The Indian Ocean: Narratives in Literature and Law is designed to interrogate how the Ocean has been presented in various popular and institutional, creative and regulatory 'stories' over the past five hundred years. Other researchers in Humanities are looking in detail at the transatlantic slave trade. We are also interested in areas of contest – for example, how abolitionist and pro-slavery advocates 'imagined' slavery – and the representation of colonial elites, both in the Caribbean and North America.

Swahili Man and Gujarati Woman, Zanzibar, circa 1910, Royal Commonwealth Society Collection, Cambridge University Library. The photo is emblematic of the busy Indian-Ocean trading connections between East Africa and the Indian subcontinent, which went on alongside cultural exchange, travel and migration.

Trade and Technology

Ships are floating pieces of technologies as well as social worlds, and researchers in the humanities focus on these interconnected elements of ocean travel. The study of shipwrecks contributes towards our understanding of maritime trade. At the University of Southampton, the Centre for Maritime Archaeology explores the construction of ships by investigating shipwrecks as well as examining the nature of their cargoes. Research beneath the icy waters of the Baltic and in the depths of the Mediterranean has revealed well preserved ships still laden with the goods they set sail with centuries ago, providing previously unseen insight into historical trade patterns between parts of Europe, North Africa and the world beyond. As well as researching ships, colleagues in the humanities are interested in port cites, another collection of sites in which the technologies of trade intersect with rich and varied social and cultural encounters created by ocean travel and commerce. At the University of Southampton, the Port Networks Project engages colleagues working on Roman ports throughout the Mediterranean in order to further understand the nature of Roman trade, and the Portus Project funded by the AHRC lies at the centre of this work. Meanwhile colleagues in History and in the Parkes Institute have furthered our understanding of Jewish port communities and of the many ways in which modern Britain has been forged through its relationship with the sea, including the impact and legacies of global trade and a maritime empire.

Some contacts

Prof. Jon Adams (Archaeology), Dr Lucy Blue (Archaeology), Dr Stephanie Jones (English), Dr Marianne O'Doherty (English), Prof. Tony Kushner (History and Parkes), Prof. John Oldfield (History), Dr Christer Petley (History)

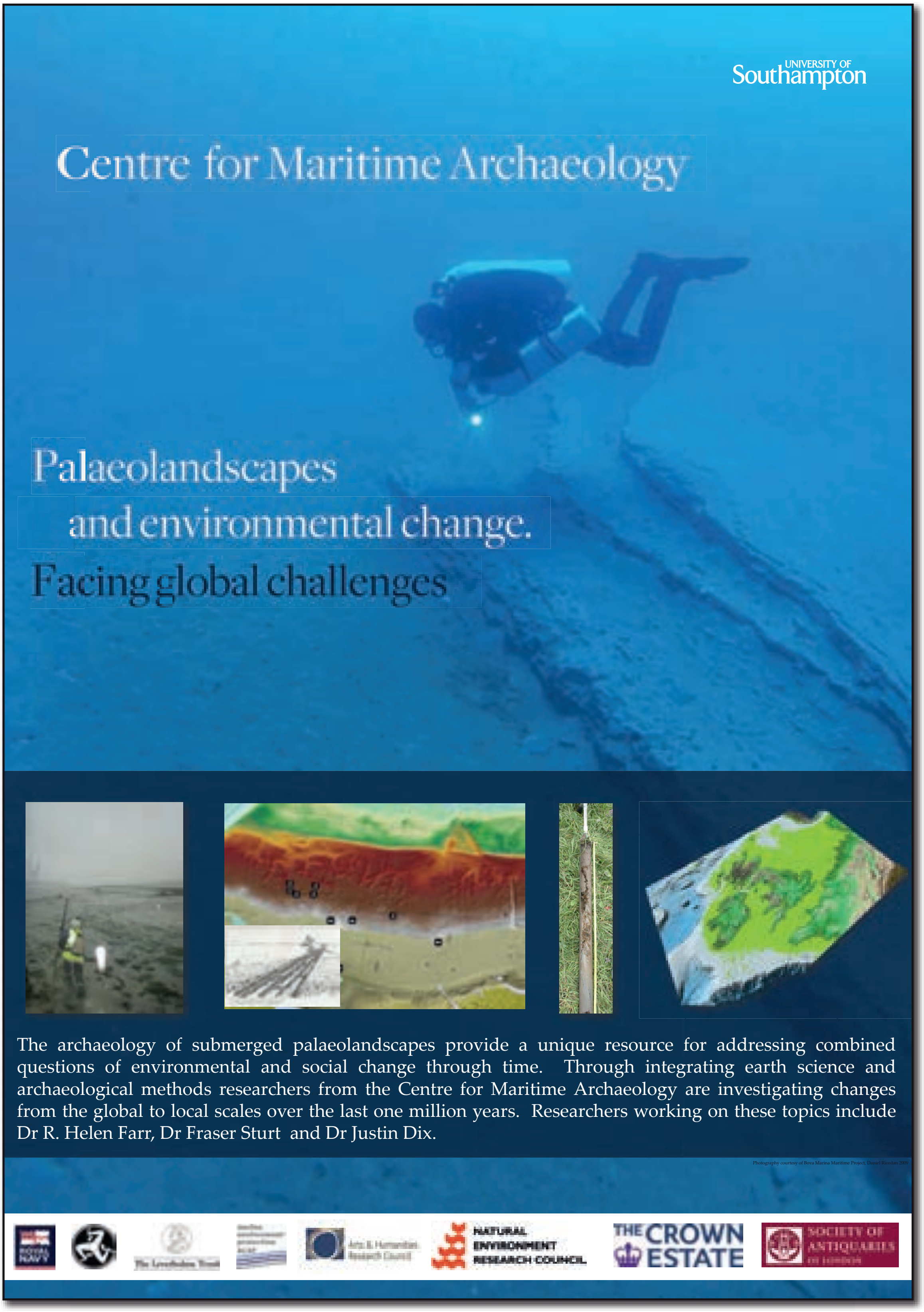
For contact details and more information about the many colleagues working on maritime-related projects in Humanities, please visit our website at www.southampton.ac.uk/humanities

www.southampton.ac.uk

Centre for Maritime Archaeology - Palaeolandscapes and Environmental Change

Dr L Blue

SG5



Centre for Maritime Archaeology - Reconstructing Wrecks - Technology, Innovation and Social Change

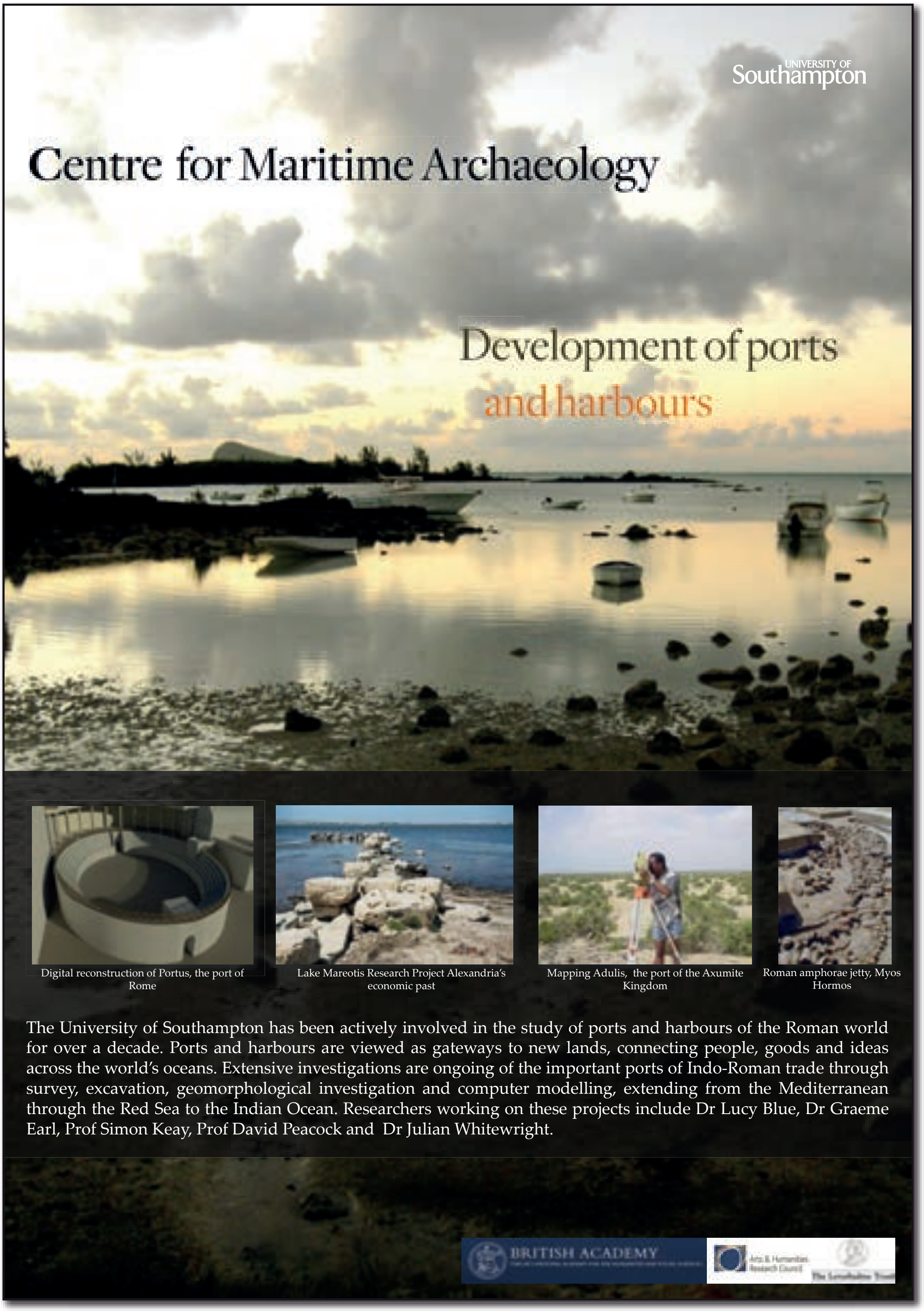
Dr L Blue

SG6

Centre for Maritime Archaeology - Development of Ports and Harbours

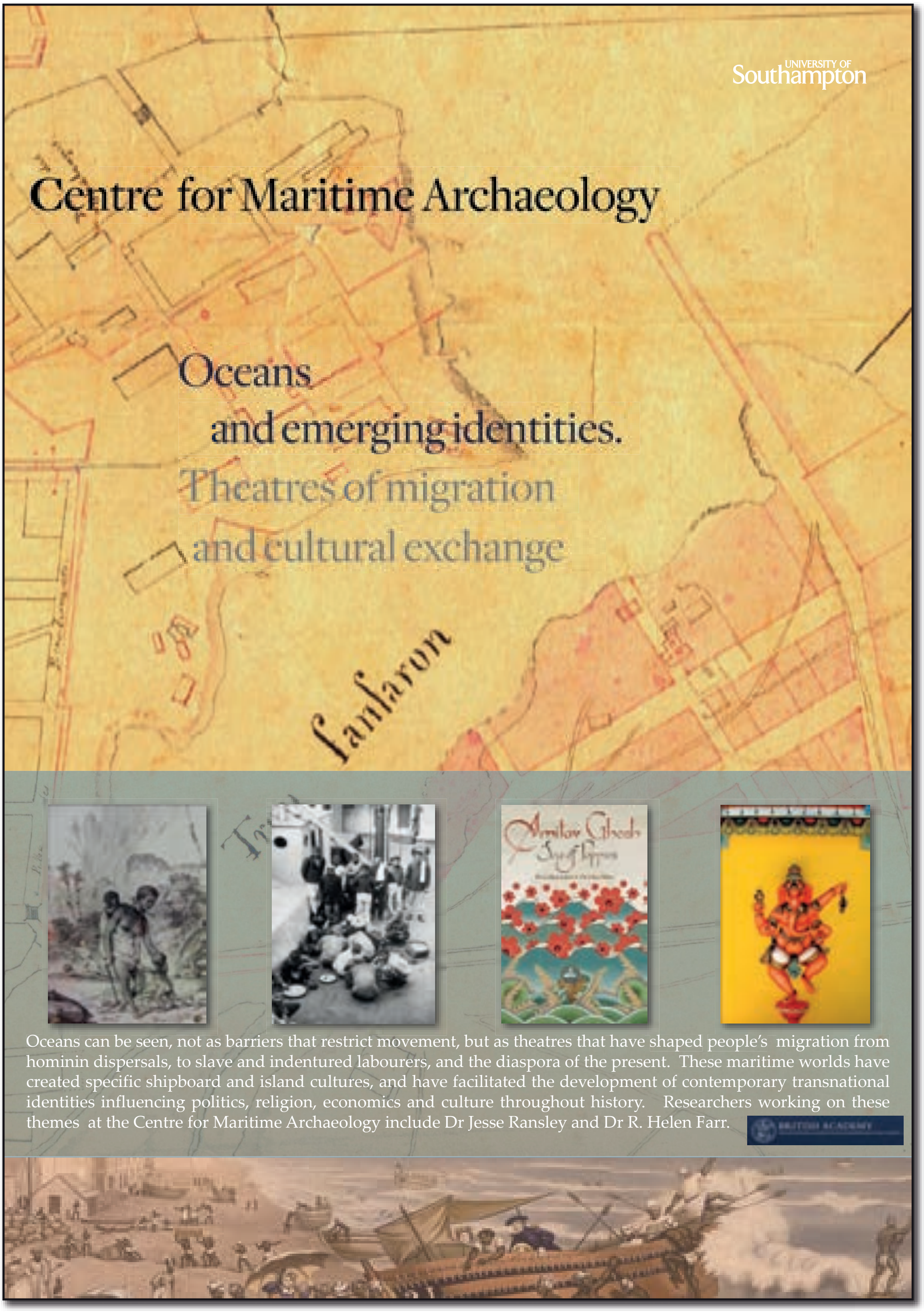
Dr L Blue

SG7



Centre for Maritime Archaeology - Oceans and Emerging Identities

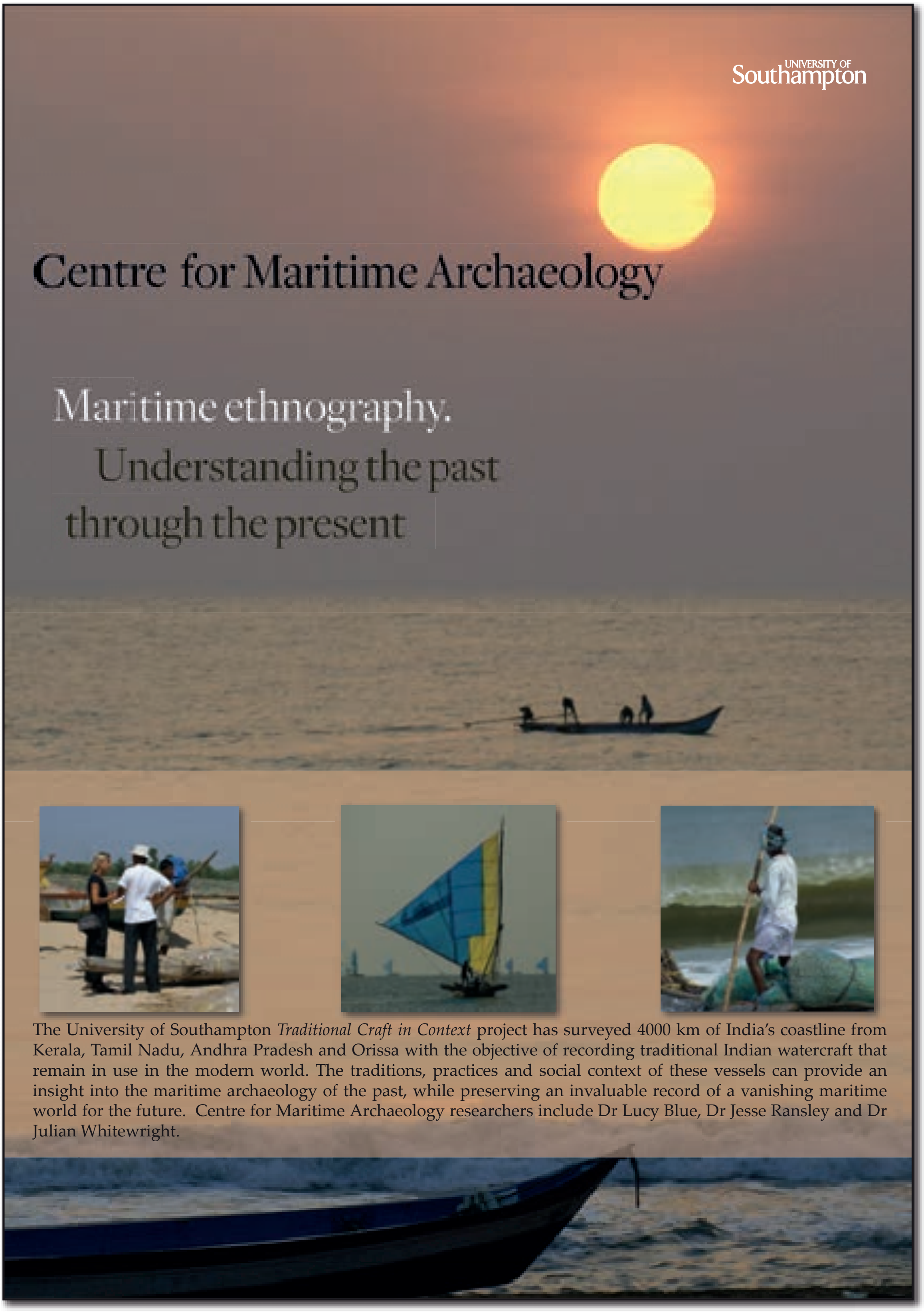
Dr L Blue **SG8**



Centre for Maritime Archaeology - Maritime Ethnography - Understanding the Past through the Present

Dr L Blue

SG9



Centre for Maritime Archaeology - Heritage Management and Outreach

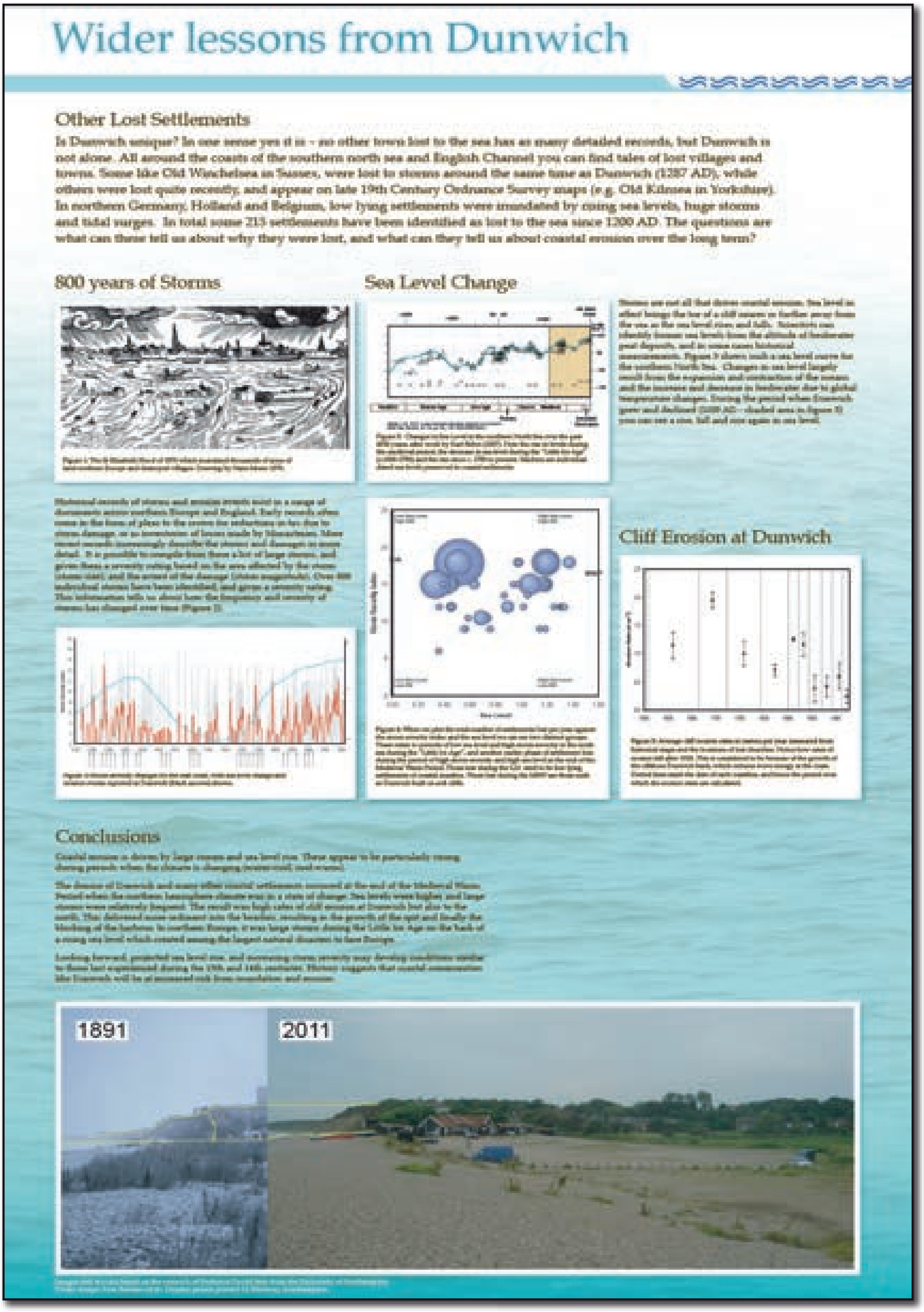
Dr L Blue

SG10

Wider Lessons from Dunwich

Professor D Sear

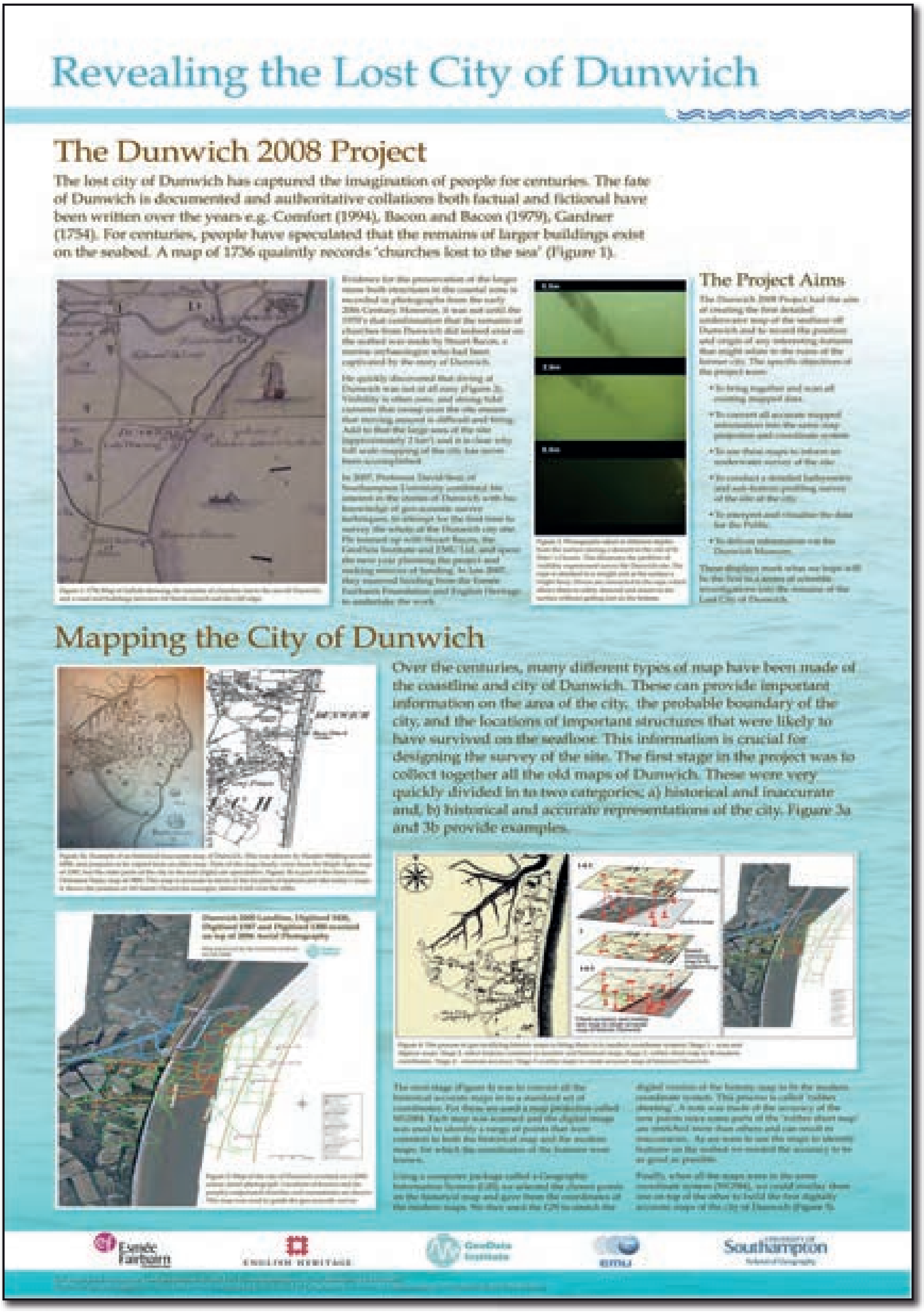
SG11



Revealing the Lost City of Dunwich - The Dunwich 2008 Project

Professor D Sear

SG12

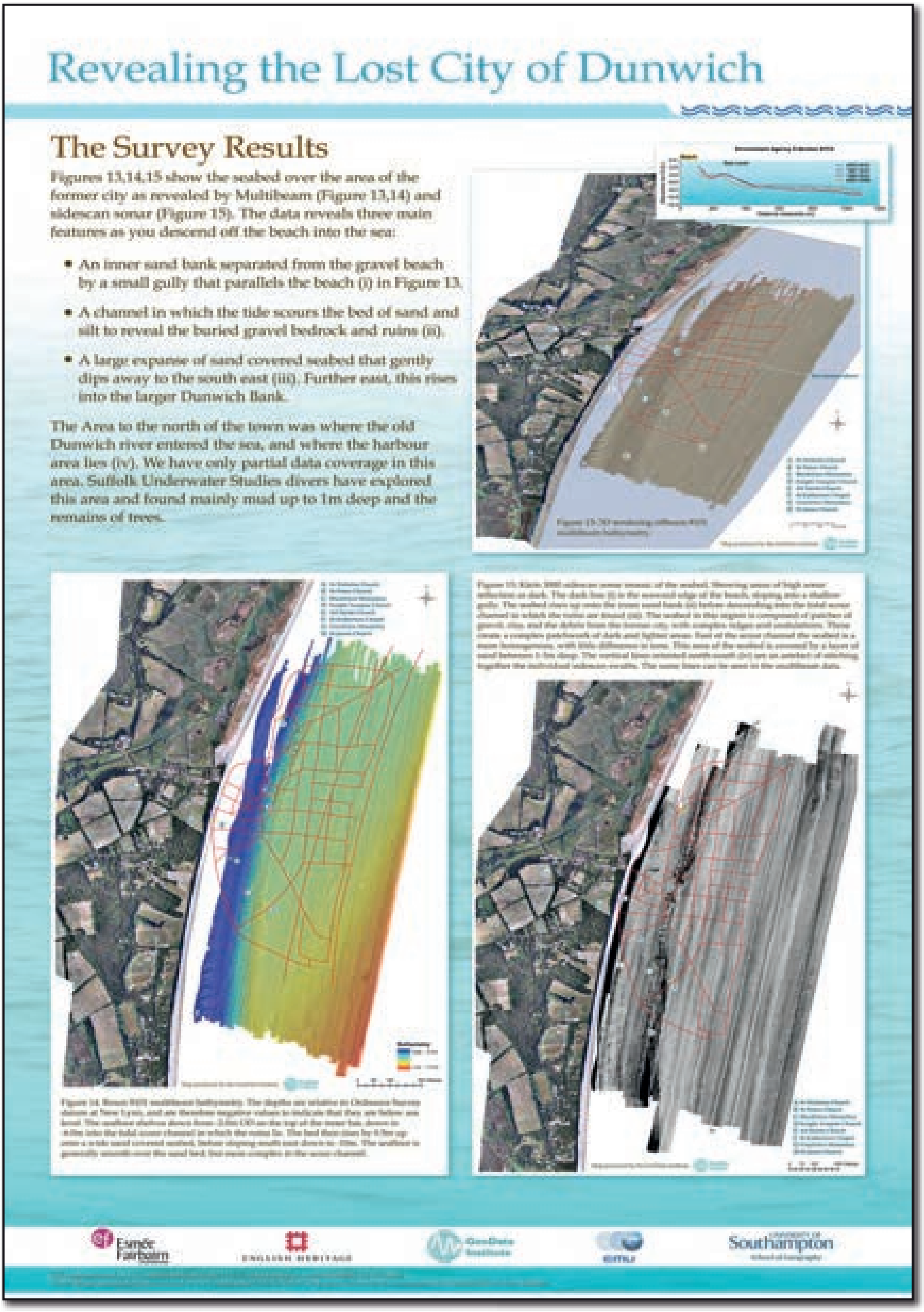


The 2008 Underwater Survey

Professor D Sear SG13

Revealing the Lost City of Dunwich - The Survey Results

Professor D Sear **SG14**



Dr D Hudson

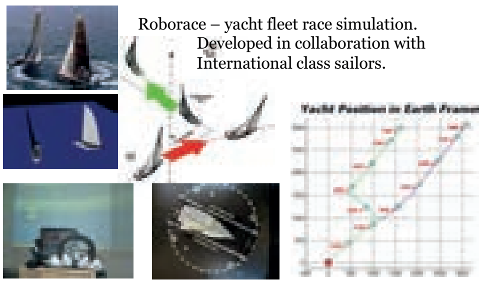
UNIVERSITY OF Southampton

Communities

Maritime Sport and Leisure

Research Purpose

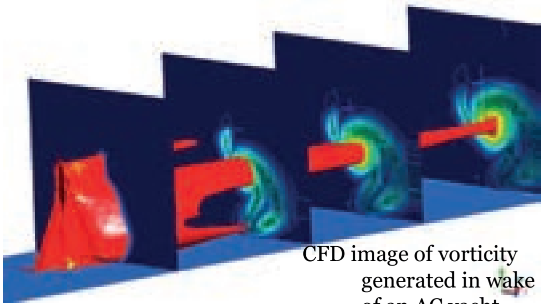
Achieving top performance in highly competitive maritime sports such as sailing, rowing or canoeing requires the synthesis of the best athlete tailored equipment, knowledge of the most effective strategies and tactics, a suitable training regime and the desire to win. Conventional approaches to performance enhancement have partitioned developments or indeed ignored specific aspects all together. As the human factor is integral to the performance of marine sport or related leisure activities a whole engineering systems approach is required that can include that interaction.



Roborace – yacht fleet race simulation. Developed in collaboration with International class sailors.

Impact

The engineering challenges in events such as the America's Cup, round the world yacht races are a large driver in improving performance of computational and experimental fluid dynamic analysis tools, real time instrumentation systems and smart materials fro the maritime sector. The many thousands of people who enjoy watersports and the millions who will watch Olympic events are influenced by the innovations in maritime technology led by many Ship Science graduates.



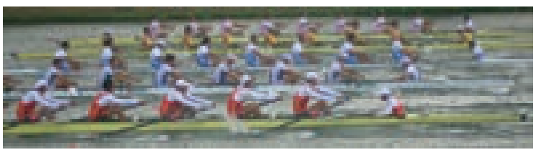
CFD image of vorticity generated in wake of an AC yacht

Research Description

Yachts and small craft design encompasses all aspects of Naval Architecture from high performance materials for sails to the latest in optical fibre sensors embedded in the mast. An area of expanding interest is in exactly how sailors or rowers make tactical and strategic choices. Success or failure can often be dictated by split-second decisions. Simulation tools have been developed that

(1)capture the complexity of the whole physical system and enable human-in-the-loop control to improve training or

(2)development of 'robotic' craft that capture the behaviour of real sailors so that the design of a new boat can be assessed under realistic conditions



Collaborations

TNZ, Luna Rosa, Alinghi, UK Sport, British Marine Federation, and many other SME

www.southampton.ac.uk

Professor S Pinch

SG16

UNIVERSITY OF Southampton

Port Cities

Remembering the Titanic in 2012: 'City Branding', Civic Identity and Local Economic Development

Description of the research

The sinking of the Titanic acts as a potent symbol that has persisted well beyond the particular event in 1912. Titanic can be said to epitomize disaster and catastrophe, serve as a warning to blindly trusting technology, symbolize the active role of nature in the form of the (Atlantic) ocean, and necessarily bring up feelings of nostalgia, perhaps as a result of its periodic retelling as a movie. For all these reasons, the Titanic continues to fascinate and enthral academics and the public alike.

This research project will use the forthcoming 100th anniversary of the sinking of the Titanic in April 2012 to examine how this event is memorialized in the five cities most touched by the disaster: Belfast, Halifax, Liverpool, New York City and Southampton. The Titanic was conceived and financed in Liverpool, built in Belfast, and officially set sail from Southampton. The majority of victims of the Titanic were buried in Halifax (Canada), and its ultimate destination was New York City. We are interested in examining the meanings attached to Titanic memorials in each of these cities.

The project will also investigate how the processes of Titanic memorialisation are integrated into strategies for economic development and the extent to which these formal promotional activities by civic authorities accord with local understandings of this powerful event. We will use a variety of methods to investigate these research interests, including archival research into the memorials themselves, setting the memorials into historical and political context, interviewing important image-makers on their strategies for using the Titanic for city development, and speaking to tourists and local residents to understand how they view the Titanic legacy in terms of their attachment to their locality.

Impact of the research

The results of this research will help municipal decision-makers, citizens and academics interested in the place-memory relationship better understand the links between the Titanic legacy and their city image. More specifically, we plan to offer the following real-world benefits:

* knowledge of the different ways cities are memorializing the sinking of the Titanic;

* evaluation of the economic success of different city-based strategies, including links between the Titanic and city-imaging/branding;

* understanding the interpretations of the Titanic memorialization made by local citizens;

* and insights into the Titanic 'tourist experience' in different cities.

Collaborations

We are seeking to collaborate with a variety of city officials and cultural leaders from across the five Titanic Cities. These will include interviewing city officials such as the cultural committee, town/urban planning and development, and *Titanic* Cities contact person, complemented by members of the 'growth coalition': politicians, local media, tourist boards, museums, and heritage associations

Researchers

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S Hall

SG17

National Oceanography Centre, Southampton
University of Southampton and Natural Environment Research Council
The Marine and Coastal Access Act
How do you use the Sea?
Introducing the Marine and Coastal Access Act
Almost everyone in the UK lives within a short drive of the coast – we do after all live on an island, even if that's easy to forget in a world of air travel and the Channel Tunnel.
The waters and seabed that surround our island are the source of many resources, worth billions of pounds to our economy. Direct marine-related activities comprise over 4% of the UK Gross Domestic Product, nearly £50 Billion. At a more local level, Southampton is a major player. Our busy port handles over 42 million tonnes of cargo per year and is the main gateway for trade with the Far East.
Marine resources include the sands and gravels used by the construction industry, the almost constant wind and waves that can provide a huge resource of renewable green energy, fish, shellfish and edible seaweeds, not to mention the leisure resources and transport corridors afforded by the sea.
Until now, there have been few if any rules and regulations concerning how the various users of the sea coordinate their activities, or ensure that what they are doing has no undue impact on other users or the health of the ecosystem. At long last Government have recognised that the sea requires a much higher level of protection, and new laws are being prepared to help manage the UK's coastal waters. NOCS has played a strong part in helping to formulate the new system.
In England and Wales the Marine and Coastal Access Act is designed to establish a system of marine spatial planning and stewardship which will provide an essential first step in looking after our marine environment. Much of the work will be overseen by the new Tyneside-based 'Marine Management Organisation' but with a network of local offices and close contacts with the marine science community including NOCS.
A series of Marine Conservation Zones, including some fully protected areas, will give marine life the protection from fishing, dredging or construction activities that are needed to allow ecosystems a chance to recover from the damage inflicted by careless human use.
Planning of activities will ensure that the needs of industry are combined with the protection of ecosystems and the freedom of other users to engage in their own activities.
For more information about the Marine and Coastal Act see:
www.defra.gov.uk/marine/legislation/
National Oceanography Centre, Southampton
European Way, Southampton SO14 3ZH, UK
Tel: 023 8059 6666
www.nocs.ac.uk
Stephen Hall,
National Marine Coordination Office
NATURAL ENVIRONMENT RESEARCH COUNCIL

N Foster

SG18

Southampton
UNIVERSITY OF

Sustainable mudflats and saltmarshes

Research context

Intertidal mudflats and saltmarshes comprise the sedimentary shores of estuaries and other sheltered areas in temperate and high latitude regions (Figure 1). They are increasingly valued for their biodiversity and their role in sustainable coastal erosion and flood defence.

Figure 1: Mudflats and saltmarshes in Yarmouth Estuary, Isle of Wight, UK

However, these habitats and their tropical equivalent, mangroves, are globally in decline. This is predominantly attributed to land claim for agriculture, industry and waste disposal; vegetation die-back; and sea-level rise. This puts their services and the species that depend on them at increasing risk.

Research description

This research aims to design and validate a systemic-level decision-support system (DSS) to facilitate concerted actions to better mitigate and manage intertidal mudflat and saltmarsh degradation and loss.

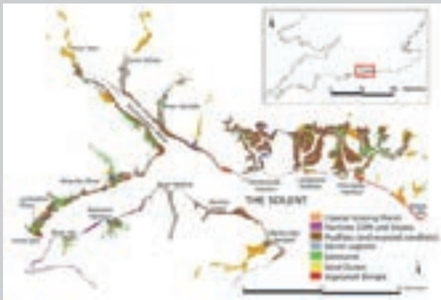

Figure 2: Solent coastline (Cope et al., 2008)

The Solent region, where mudflat and saltmarsh loss presents a significant challenge to decision makers, will be used as a case study. The objectives are: to ascertain the context which frames the decision-making situation through desk studies and in-depth interviews; to design a DSS based on the learning from the above; and to validate the DSS via action research.

Cope et al. (2008) Solent Dynamic Coast Project: Summary Report. New Forest District Council / Channel Coast Observatory.

Research impact

The outcomes of this research will be an improved understanding of the concerted actions to mitigate and manage mudflat and saltmarsh degradation and loss in the Solent region; a better understanding of the historical, environmental, socio-economic, legislative and political factors that influence concerted actions to realize sustainable mudflats and saltmarshes; and a DSS for use in similar future complex decision-making situations across the UK.

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SG19


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UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL
Marine & Coastal Access Act: Impacts
Marine & Coastal Access Act - Impacts
Marine leisure contributes £millions to the Southampton economy. The Marine and Coastal Access Act will help shipping companies and port operators
The Marine & Coastal Access Act, coupled with the European Marine Framework Strategy Directive, will provide extra resources to keep our seas & coasts clean, healthy and thriving with diverse marine life.
The Royal Navy helps
What's nicer than some tasty seafood overlooking our beautiful coast? New rights to coastal access will allow walkers to explore extensively the UK coastline.
Anglers is a popular sport in the UK.
their needs are
account with the new planning
system.
The Marine and Coastal Access Act will be informed and
Marine Science from the UK's community of ocean research
NOCS has a central role in providing the knowledge that will be used by the marine planning community, and training the next generation of marine and earth scientists.
WWW.NOC.SOTON.AC.UK
National Oceanography Centre, Southampton
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Tel: 023 8059 6666
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Stephen Hall
National Marine Coordination Office
NATURAL ENVIRONMENT RESEARCH COUNCIL

Design of High Speed Craft from a Human Factors Perspective

Dr D Taunton

SG20

UNIVERSITY OF Southampton

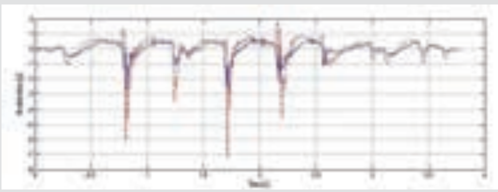
Communities

Design of High Speed Craft from a Human Factors Perspective

Research description

Several inter-linked research programmes aimed at determining the effect of hull design and operation on the performance of the crew of high speed craft, such as the rigid inflatable boats used by the RNLI and interceptor craft used by the MOD.

Full-scale measurements onboard RNLI rigid inflatables and model experiments in towing tanks were conducted. These results were used to develop novel design methods allowing boats to be designed for improved coxswain and crew, or passenger, performance.



Vertical acceleration record from tank tests

Human trials subject

Research impact

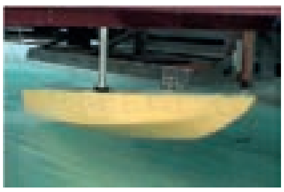
Design guidelines produced for RNLI for rigid inflatable lifeboats.

New design methods incorporating human responses can be used to improve operator performance.

Lessons learnt:
1) Motions and accelerations are so severe that the EU limit for whole body vibration is normally exceeded in a matter of minutes.
2) Vibration reducing technology, such as suspension seating, has little effect on the whole body vibration limit and thus work continues on crew workload assessment, training and operator guidance as a means to improve performance.

Collaborations

Royal National Lifeboat Institution (RNLI)
Institute of Sound and Vibration Research
University of Chichester
Prof. R.A. Shenoi
Prof. P.A. Wilson
Dr. D.A. Hudson
Dr. D.J. Taunton



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National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

National Marine Coordination Office

The **National Marine Coordination Office** (NMCO) is part of NERC's **National Marine Capability** and is working with the marine science community and a variety of marine and maritime partners to improve dialogue and to sustain interactions in an inclusive, impartial way.

We are raising awareness of the contribution that marine science can make to society in key policy areas such as climate change, biodiversity and effective, science-informed environmental management. NMCO encourages and coordinates contributions to government consultations, stimulates knowledge exchange between marine scientists and policy makers and provides support to the wider marine science community.

NMCO provides the NERC contribution to the Defra-led secretariat for the Government's **Marine Science Coordination Committee** (MSCC) and its associated working groups such as the **Underwater Sound Forum** and the **Marine Environmental Data & Information Network** (MEDIN). MSCC was set up in response to the former House of Commons Science and Technology Committee report 'Investigating the Oceans' to help the UK to face up to future marine science challenges. Its first task is to develop the **UK Marine Science Strategy**.

NMCO provides the secretariat for NERC's Strategic Marine Science Programme **Oceans 2025** and its associated advisory board.

Internationally, NMCO represents NERC at the **European Science Foundation Marine Board**. NMCO staff lead the UK input to the **Intergovernmental Oceanographic Commission**, and chair the **UK Argo Expert Group**. We host the CLIVAR International Project Office (Climate Variability and Predictability) – part of the World Climate Research Programme, which coordinates science and administration under oversight of the CLIVAR scientific steering group. We are continually strengthening our international links and welcome visitors from overseas institutes and universities.

NMCO provides a focus for joint actions to foster a strong marine science community and raise the profile of marine science. Our partnerships include:
Challenger Society for Marine Science – Learned Society for the marine science community.
European Science Foundation Marine Board – Supporting marine science in the EU.
Institute for Marine Engineering Science and Technology – Professional Institution.
Marine Southeast – Marine grouping addressing needs of the marine sector in South-East England.
Passenger Shipping Association – Enables links to ships of opportunity for scientific instrumentation.
SeaVision UK – Organisation that promotes the importance & diversity of the marine sector.
Society for Underwater Technology – Learned Society supporting subsea technology and education.
Subsea UK – Trade body for the offshore technology sector.

NMCO widely to inform science policy

2008 Intergovernmental Oceanographic Commission Executive Council

NMCO stresses the importance of sustained observations, like the ones above from Oceans 2025, when responding to UK Government consultations

NMCO supports a range of partnerships with the community, helping to give a stronger voice for marine science.

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Stephen Hall
National Marine Coordination Office

NATURAL ENVIRONMENT RESEARCH COUNCIL

Professor H Staniland

SG22

UNIVERSITY OF Southampton

Institute of Maritime Law

Established in 1982, the Institute of Maritime Law is a leading world centre for teaching, research and consultancy in maritime law.

The Institute seeks to be a focal point for maritime law research, and to form a bridge between academics and practitioners.

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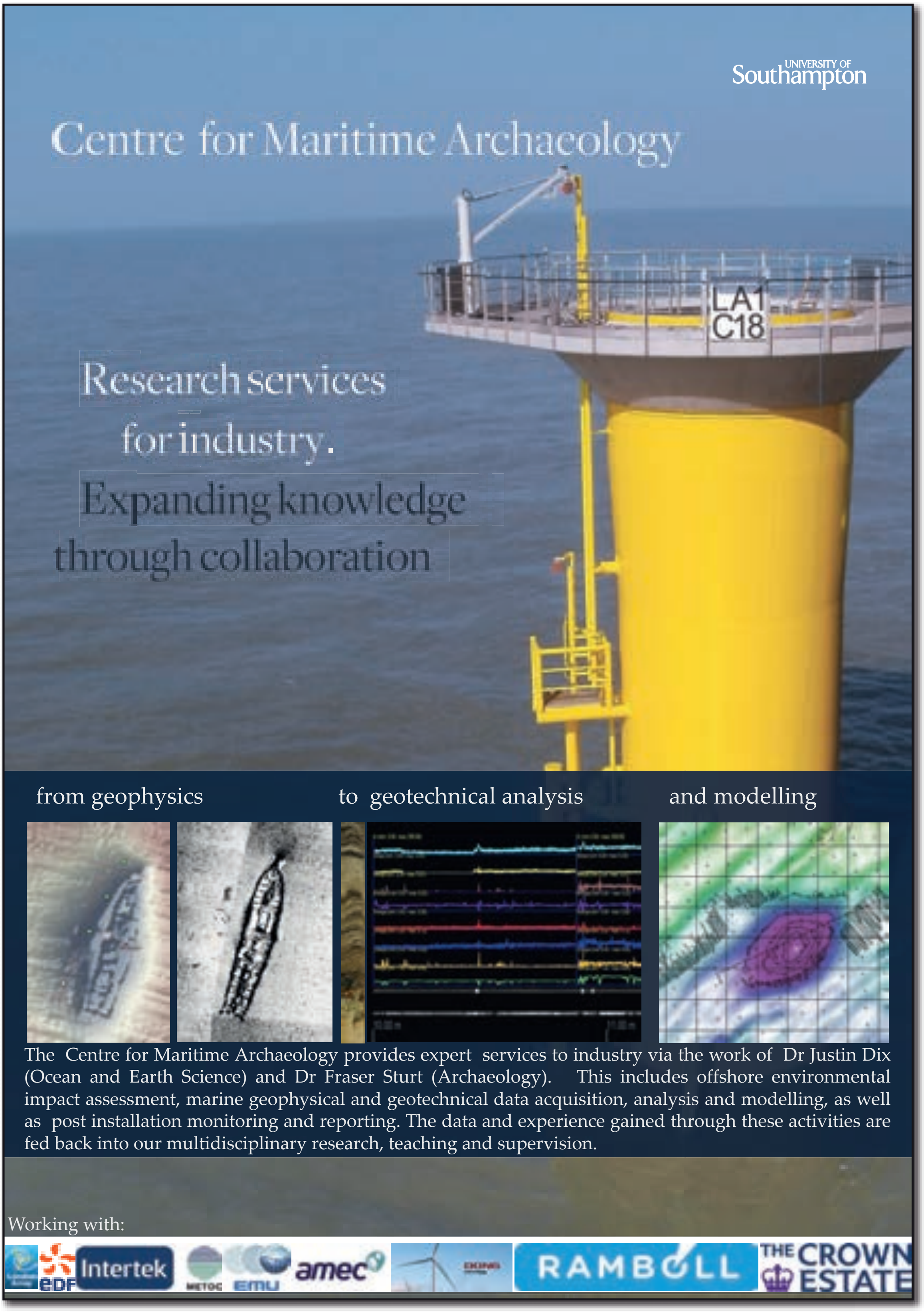
Centre for Maritime Archaeology - Research Services for Industry

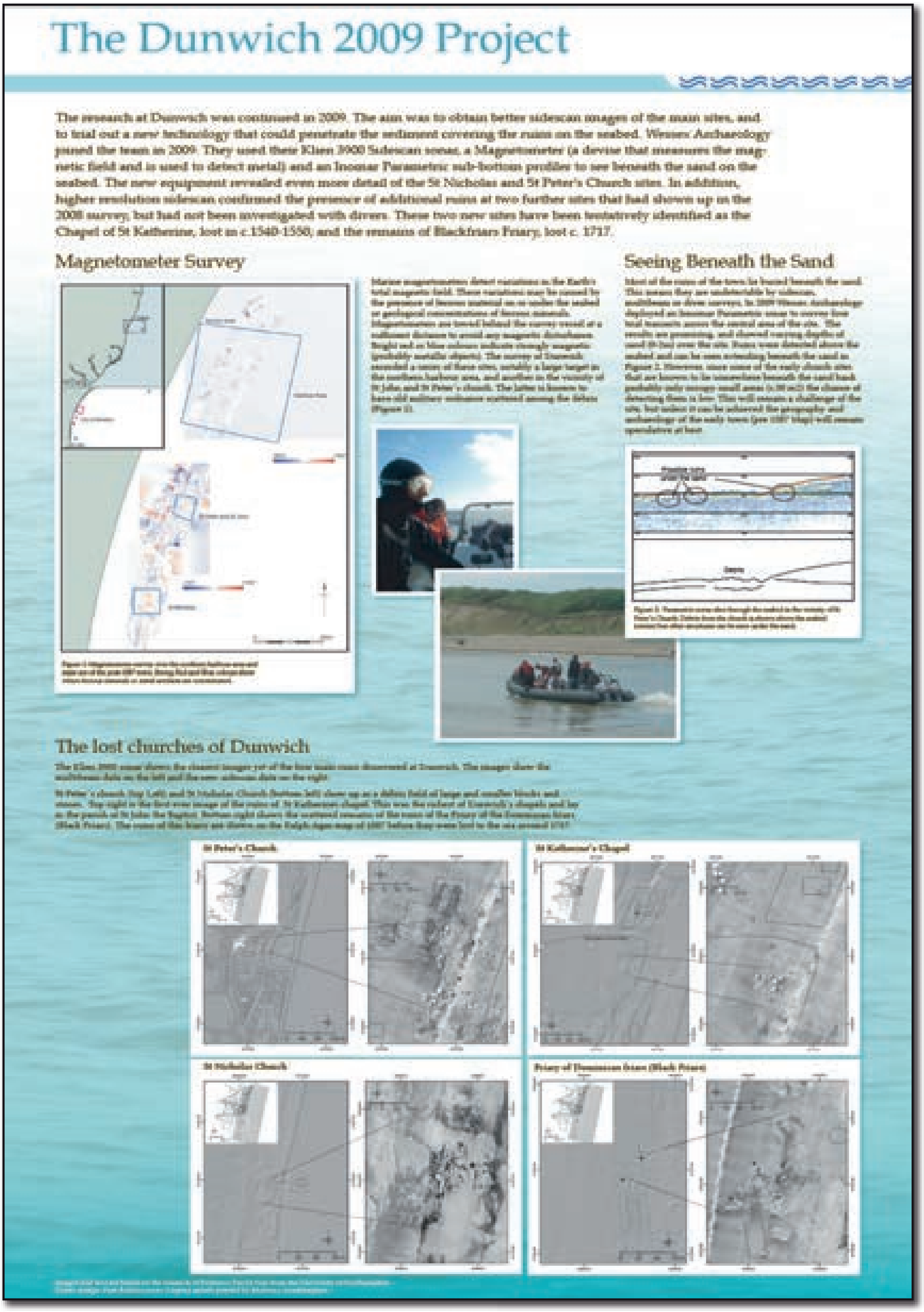
Dr L Blue

SG23



Professor D Sear

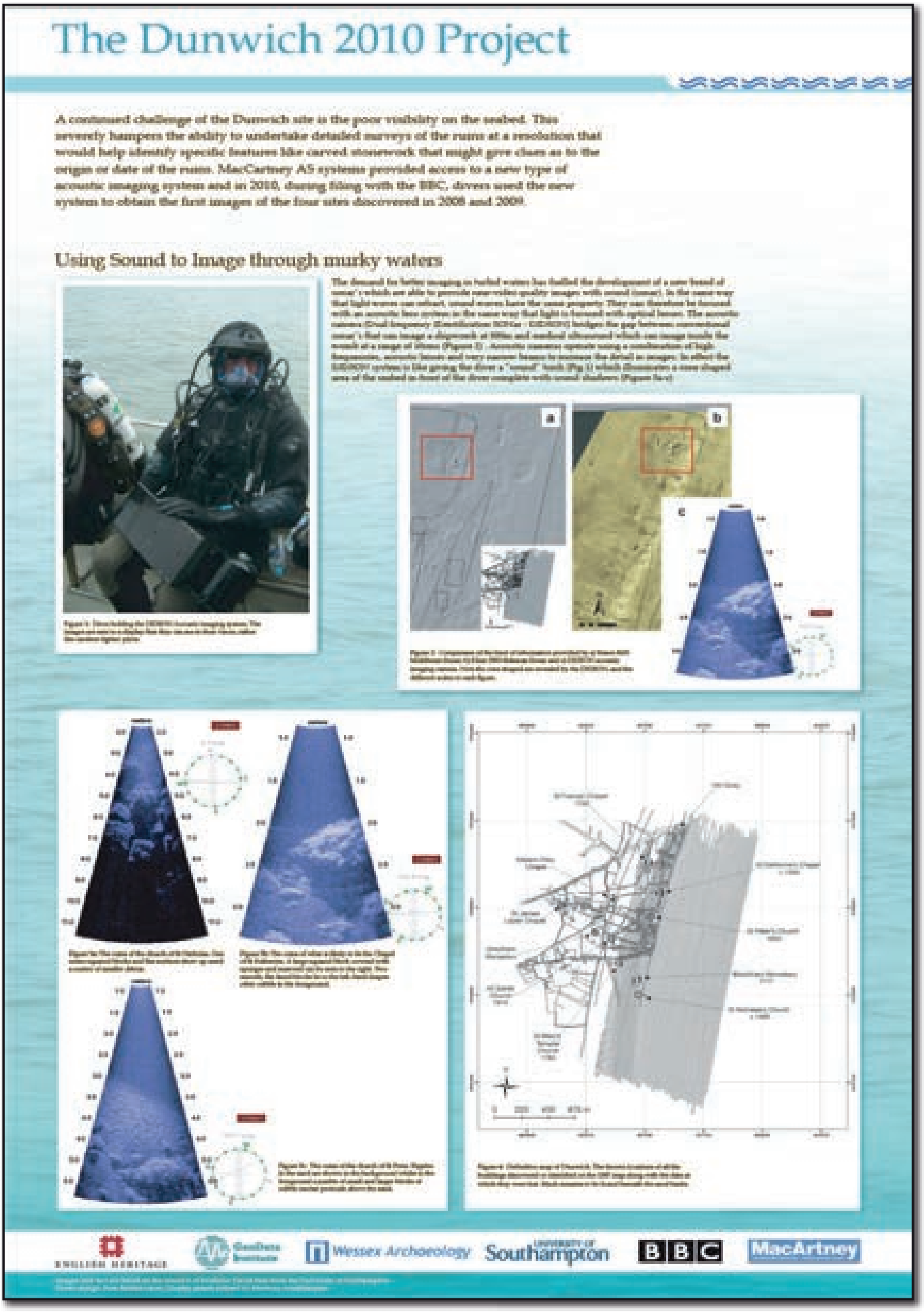
SG24



The Dunwich 2010 Project

Professor D Sear

SG25



Effects of Vibration and Low-Frequency Motions on Passengers and Crew

Professor M Griffin

SG26

Effects of vibration and low-frequency motions on passengers and crew

UNIVERSITY OF Southampton

Institute of Sound and Vibration Research

The Human Factors Research Unit conducts basic and applied research in human responses to vibration, including health effects, discomfort, performance, biodynamics, seating dynamics and motion sickness.

Dependence of motion sickness on low-frequency motions

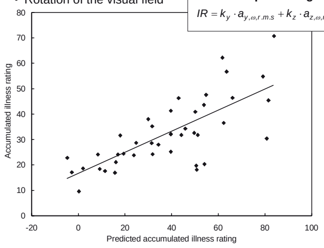
Using unique simulators, laboratory experimental research has explored effects of motion and vibration on human comfort, performance, and health.

Motion sickness studies have included:

- Fore-and-aft oscillation
- Lateral oscillation
- Roll oscillation
- Combined lateral and roll oscillation
- Combined fore-and-aft and pitch oscillation
- Vertical oscillation
- Rotation of the visual field

Model for predicting illness ratings (*IR*):

$$IR = k_y \cdot a_{y,\omega,r.m.s} + k_z \cdot a_{z,\omega,r.m.s} + k_{\dot\theta} \cdot \dot\theta_{\omega,r.m.s} + k_{y\times\dot\theta} \cdot a_{y,\omega,r.m.s} \cdot \dot\theta_{\omega,r.m.s}$$



The model produces useful predictions of the accumulated illness ratings reported by persons exposed to combinations of lateral oscillation, roll oscillation and vertical oscillation in the ISVR laboratory studies

Supported by:
EC Project no. G3RD-CT-2002-00809
A Rational Approach for Reduction of Motion Sickness & Improvement of Passenger Comfort & Safety in Sea Transportation (COMPASS)

Effects of Deck Motions on Postural Stability

Treadmill mounted on 6-axis simulator

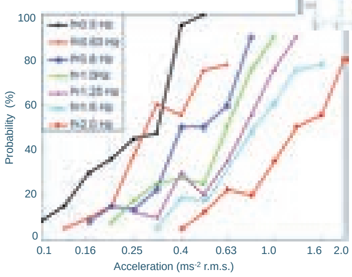
Independent variables

- Magnitude
- Frequency
- Direction of the oscillatory motion

Dependent variables

- Subjective measurements (estimated probability of losing balance)
- Objective measurements (forces applied by feet during gait)

Time-history of perturbation



Subjective Measurements – Estimated probability of losing balance

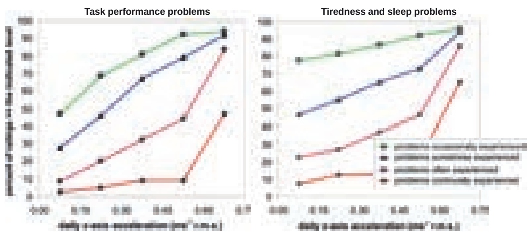
- At a specific frequency, estimated probability of losing balance increases as the perturbation magnitude increases
- At a specific acceleration, fall probability decreases with increasing frequency
- At a specific velocity, fall probability is almost independent of frequency

Supported by: Société Nationale des Chemins de fer Français (SNCF)

Crew Response to Motions of an Offshore Oil Production and Storage Vessel

Effects of motions on crew members of an FPSO (floating production and storage offshore) were studied over a five-month period

- Vessel motions were continuously monitored during winter months (October to March)
- A questionnaire survey in the form of a "daily diary" was completed by crew members for each day offshore



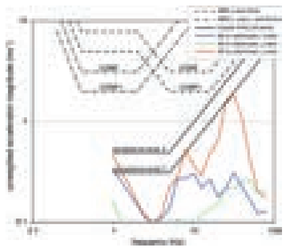
Conclusions

- Problems with physical tasks involving balancing, moving and carrying were most strongly associated with motion, followed by sleep problems
- Physical and mental tiredness, and cognitive aspects of task performance, were significantly associated with motions, but correlations were less strong than with physical tasks
- There was a rapid increase in great or severe problems (ratings of 3 or 4), when the daily average vertical acceleration increased above 0.6 ms^{-2} r.m.s.

Supported by an offshore oil production company:

Haward B, Lewis C, Griffin, M (2009) Motions and crew responses on an offshore oil production and storage vessel. *Applied Ergonomics 40, 904-914.*

Development of standards and guides for evaluation of human response to shipboard whole-body vibration



Comparison of 1/3 octave band spectra of 3-axis deck accelerations on a 36-m catamaran with Lloyds and ABS vibration limits for high-speed craft.

Seat and deck-mounted accelerometers

Collaborations:

American Bureau of Shipping

- Whole-body vibration class guides for crew habitability and passenger comfort on ships, yachts and HSCs

Maritime and Coastguard Agency

- Codes of practice for noise and vibration in ships

European Commission

- Non-binding guide to good practice for implementing Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (VIBGUIDE)
- Risks of Occupational Vibration Exposures (VIBRISKS)
- A Rational Approach for Reduction of Motion Sickness & Improvement of Passenger Comfort & Safety in Sea Transportation (COMPASS)
- Evaluation and Improvement of Suspension Seat Vibration Isolation Performance (VIBSEAT)

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Human Factors in the Design of High Speed Marine Craft

Dr D Nikolić

SG27

UNIVERSITY OF Southampton

Trade

Human factors in the design of high speed marine craft

D.Nikolić[1], R.Allen[1], R.Collier[2], L.Collier[2], D.Taunton[3], D.Hudson[3], R.A.Shenoi[3]

Description of the research

Aim of the study

The main objective of this study was to establish if there is a relationship between boat motion during transits and measures of human physiology.

A secondary objective was to establish if exposure of a human to random and shock vibration affected a measure of spinal muscle fatigue and a participant's rating of perceived exertion (RPE).

Methodology

An experiment was conducted in order to establish if synchronised measures could be used to establish relationships between boat motion during transits and measures of human physiology during exposure to random whole-body vibration in a dynamic environment and to analyse its influence on human physiology.

The experiment was undertaken during a sea trial with a RIB-X Expert XT650. A male participant (26 years old, 170 cm tall and 72 kg weight) participated in this study. The time duration of the trial was approximately 30 minutes at an average boat speed of 25 knots. Sea conditions were moderate (sea state 3) with the average wave height of 0.84 m and zero-crossing period of 4 s taken at the closest wave recorder.

The data measured during the trial (Figure 1) were:

- boat vibration and motion (LCG acceleration and heading),
- human whole-body vibration (head and seat acceleration),
- human physiological data (electromyography (EMG) activity of spinal muscles and electrocardiographic (ECG) changes).

Perceived exertion using the Borg Rating of Perceived Exertion (RPE) scale was recorded following the trial.

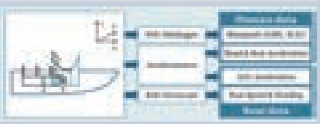

Figure 1. Experimental setup (A – LCG Accelerometer, G – LCG Rate Gyroscope, H – Head Accelerometer, S – Seat Accelerometer)

Impact of the research

Designers of high speed marine craft, biomedical engineers and human performance specialists aim to establish guidelines for design of such craft that take into account the need of the crew to maximise performance.

It is anticipated that this translational methodology could be used to enable a better understanding of:

- how fatigue develops as a result of exposure during transits,
- fatigue characteristics of spinal muscles,
- how fatigue impacts human performance,
- how to reduce fatigue through preventative exercise measures.

Results and discussion

Whole-body vibration

The total Vibration Dose Value (VDV) of 12.28 calculated from seat acceleration was dominated by y-axis (12.19) with a contribution from x and z-axes (2.08 and 4.92). This exceeded the Exposure Action Value (EAV) of 9.1 $m \cdot s^{-1.75}$ 19 minutes into the trial. Plot of the frequency-weighted seat acceleration in the most prominent axis along with the corresponding VDV is given in Figure 2, where the EAV and Exposure Limit Value (ELV) are marked by dotted lines.

Figure 2. Vibration dose value in y-direction for sitting posture

ECG analysis

Plots of boat speed, normalised frequency-weighted LCG and seat rms acceleration magnitudes with a plot of normalised instantaneous heart rate recorded during the trial are given in Figure 3. Results showed a statistically significant correlation between boat vibrations and the heart rate variations. The relationship is evident in the three vibration axes. The influence of the boat vibration with the correlation coefficient of 0.52 is larger than the seat vibration with the correlation coefficient of 0.45. The delay between the heart rate and vibration signals was estimated to be approximately 2 s.

EMG analysis

Median frequencies (MDFs) calculated for the whole duration of trial are shown in Figure 4. It can be seen from these plots that the MDFs of the lower back spinal muscles, i.e. *Left Multifidus* and *Right Multifidus*, decrease with time showing a cumulative effect consistent with muscle fatigue.

Summary

The EMG and ECG changes during vibration exposure were used as a basis for evaluation of fatigue. RPE measures indicated that the participant rated the exertion as "*somewhat hard*" during the transit and changes in the EMG and ECG signals indicated that fatigue was associated with the transit. This experiment demonstrated that it is feasible to simultaneously measure human performance and boat data, and that there is a relationship between the boat motion and subsequent fatigue.

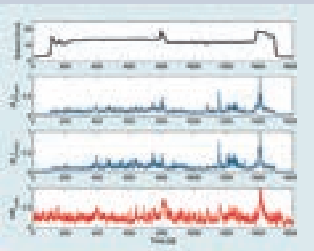

Figure 3. Boat speed, frequency-weighted seat and LCG rms acceleration magnitudes and heart rate during trial

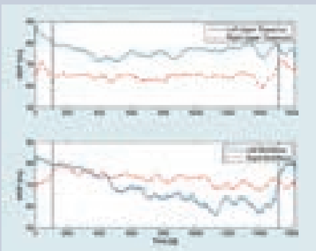

Figure 4. Median frequencies of the four EMG signals recorded during trial

Collaboration

This multi-disciplinary project was carried out as a collaborative endeavour involving:

1. Institute of Sound and Vibration Research (ISVR), University of Southampton
2. School of Health Sciences, University of Southampton
3. School of Engineering Sciences, Ship Science, University of Southampton
4. The Royal National Lifeboat Institution (RNLI)
5. University College Chichester

The research was funded by EPSRC (grant no. EP/C525728/1).

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Trade and Transport

With a global value worth £2 trillion, the marine market continues to grow across continents. In the EU, 90% of external trade and 40% of internal trade is seaborne; 1200 ports cater for 3.5b tonnes of cargo and 350 million passengers. UK´s maritime sector is the second largest in Europe; with contribution to the world maritime economy at about 3.1% the UK is placed in the top six, together with USA, China, Japan, India and Germany.

Our work encompasses technological aspects, working towards safe shipping and ship designs, legal instruments governing commercial and seabed management, logistics and supply chain management and the underlying impact of the maritime trade driven economics on the nation states´ welfare.

Delphin2: An Over Actuated Autonomous Underwater Vehicle for Manoeuvring Research

Dr D Taunton

TT1

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITY OF Southampton

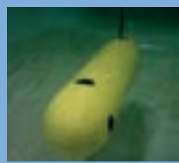
Delphin2: an over actuated autonomous underwater vehicle for manoeuvring research

Introduction

The Delphin2 Autonomous Underwater Vehicle (AUV) is a small (<2m) highly manoeuvrable submersible, designed to undertake complex missions which require it to autonomously interact with the subsea environment with no external connections for power or control. It is the culmination of six years of work by PhD and Masters level students at the University of Southampton (UoS) under the supervision of researchers at the UoS and the National Oceanography Centre, Southampton (NOCS). The AUV has been designed to both compete in the Student Autonomous Underwater Challenge – Europe (SAUC-E) and to provide a research platform to investigate AUV manoeuvring and control.

Student Autonomous Underwater Challenge - Europe

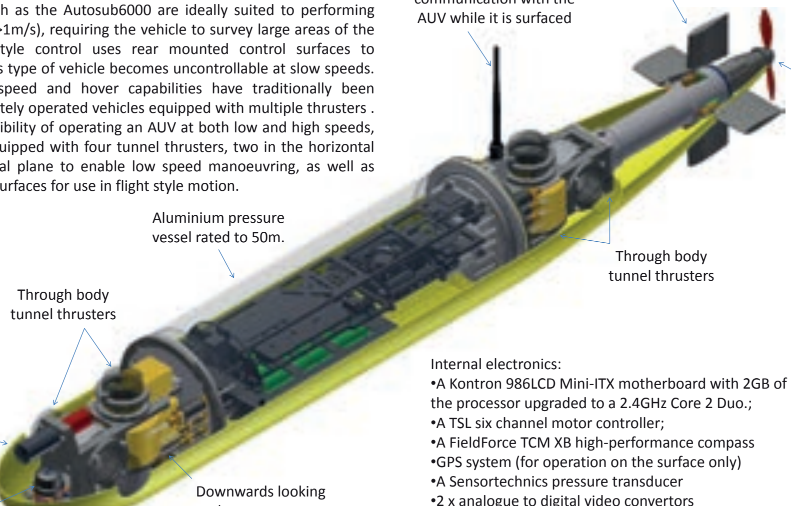
Held since 2006, SAUC-E challenges the next generation of engineers to design and build an autonomous underwater vehicle (AUV) capable of performing realistic missions. The event is designed to encourage students to think about underwater technology and related applications while fostering innovation and technology.



Underwater shot of the Delphin2 AUV

Vehicle Description

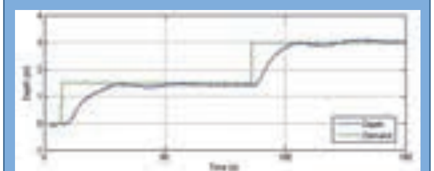
Delphin2 is based on a scaled version of the NOCS Autosub6000. Conventional survey style AUVs such as the Autosub6000 are ideally suited to performing high speed missions (>1m/s), requiring the vehicle to survey large areas of the seabed. This flight style control uses rear mounted control surfaces to manoeuvre and so this type of vehicle becomes uncontrollable at slow speeds. Tasks requiring low speed and hover capabilities have traditionally been performed using remotely operated vehicles equipped with multiple thrusters . To investigate the feasibility of operating an AUV at both low and high speeds, Delphin2 has been equipped with four tunnel thrusters, two in the horizontal and two in the vertical plane to enable low speed manoeuvring, as well as movable rear control surfaces for use in flight style motion.



Internal electronics:
- •A Kontron 986LCD Mini-ITX motherboard with 2GB of RAM with the processor upgraded to a 2.4GHz Core 2 Duo.;
- •A TSL six channel motor controller;
- •A FieldForce TCM XB high-performance compass
- •GPS system (for operation on the surface only)
- •A Sensortechnics pressure transducer
- •2 x analogue to digital video convertors
- •An ACKSYS (WLg-LINK-OEM) Wi-Fi module
- •A Nickel Metal Hydride (NiMH) battery pack comprising of three 21.6 V (nominal) 10Ah cells.

Vehicle Control

An open-source robotic control package called ROS is used onboard the Delphin2 AUV. Within the control system are high-level decision making controllers and low-level manoeuvring controllers. The low-level controllers adjust the onboard actuators to maintain certain high-level demands such as depth, example below.



Depth control performance of Delphin2

Ongoing Research

Development of the vehicle is ongoing with the development of low-level control systems and vehicle hydrodynamics being the current focus.

Due to the increased capability of the vehicle, field trials are now being conducted at large lakes in Hampshire with a long two week test being scheduled at Lough Neagh in Northern Ireland. This will test the vehicles navigation systems as the missions could be up to several hours and tens of kilometres in length.

Delphin2 AUV at Eastleigh Lakes

Nature in Manoeuvrable Bio-Locomotive Engineering (NIMBLE)

Dr J Blake

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Nature in Manoeuvrable Bio-Locomotive Engineering (NIMBLE)

S.G.K. Man s.k.man@soton.ac.uk , Dr J.I.R. Blake, Dr S. Boyd, and Dr A. B. Phillips
Faculty of Engineering and Environment

1. NEMO Project Background

Nature in Engineering for Monitoring the Oceans (NEMO) is an EPSRC funded joint project between University of Southampton, Newcastle University, and National Oceanographic Centre, Southampton.

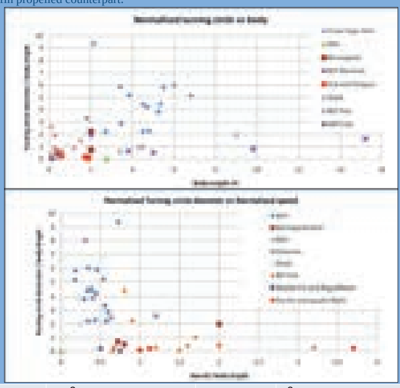
The aim of the NEMO project is to use inspiration from nature to improve performance of the next generation Autonomous Underwater Vehicle (AUV).

The NEMO project can be separated into two work packages. One involves the development of a soft body deep diving vehicle. The other, as discussed here, involves development of the next generation propulsion and manoeuvre platform.

2. Manoeuvrability of Bio-inspired Propulsion

In a database study of various marine animal species and AUVs. It was found the overall efficiency (based on cost of transport calculation) of AUV were actually higher than many animals, contrary to the common believe that animals were more efficient. Much of these inefficiency in animals were caused by inefficient linear actuators, ATP conversion and the hotel loads associated with the animal's base metabolism.

However, the same study also found animals were significantly more manoeuvrable than AUVs. Most AUV required 5 body lengths (BL) to make a complete U-turn where as most animals can achieve this in less than 1 BL. The turning rate of animals are also much higher than AUVs. The study also found those animals using pair fin aquatic flight propulsion showed significantly better performance than their body and caudal fin propelled counterpart.

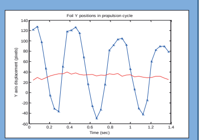


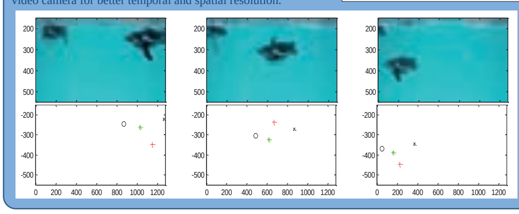
Bottlenose Dolphin	252°/s, 0.44BL @2.12BL/s	REMUS 100	5°/s, 2.9 BL @ 0.5BL/s
Tuna	0.94BL @ 0BL/s	MIT VCUUV	75°/s, 2BL @0BL/s, 16.9°/s, 3.7BL @ 0.5 BL/s
Penguin	550°/s, 0.24BL	MIT Finnegan	0.77BL @ 0.72BL/s
Seals	690°/s, 0.1BL @ 1BL/s	Odyssey ROV	120°/s, >1 BL @0 BL/s

3. Video Motion analysis

In order to get a better insight into the swimming mechanics of paired fin propelled animals. Video motion analysis were carried out on penguins and marine turtles.

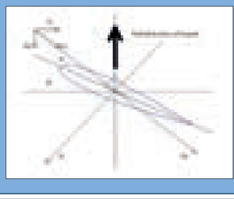
Permission were granted by Paultons Park in Southampton to film their Humboldt penguins in their enclosure. The analysis confirmed reports in the literature that penguins and seals flipper motion is not restricted to two axis. There is a third component in yaw. The future plan will be to employ multiple high speed video camera for better temporal and spatial resolution.

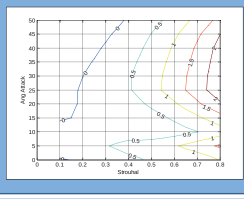




3. Simple Quasi Steady Modelling

The video motion analysis cannot tell us how much force is generated by the flapping flipper. However, the video analysis can measured speed, flapping amplitude, Strouhal numbers, and flapping frequency. The forces can be calculated through mathematical modelling. The first attempt at modelling used a simple model presented by Licht (2004) The model treated the foil as a translating foil, with calculation carried out at 0.7 span. This model was used for producing specifications for the NIMBLE actuator.



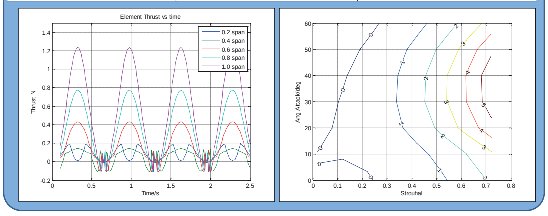


3. Blade element modelling

The simple model treated the flapping foil as though the whole span of the foil behaved in the same way as 0.7 span. Obviously this is not true, so a more advanced model based on blade element theory was developed. The blade element model divide the foil into a number of sections (blade elements) and evaluate individual sections independently. Since the pitch angle of a rigid foil is constant across the span, the foil angle of attack would vary along the span. In some cases the angle of attack at the tip could be so large that the foil stalls while the angle of attack at the root could be so small that it becomes negative and generate negative thrust.

A number of other hydrodynamic effects were modelled in addition to the basic hydrodynamics. The other effects modelled included added mass, foil inertia and rotational lift.

However, the current model is not yet able to account for tip losses which resulted in a gross over estimate of the thrust coefficient.



5. NIMBLE actuator

The NIMBLE flapping foil actuator was developed in parallel to the BET model. This actuator was design to actuate a hydrofoil in three axes; pitch, roll and yaw. It was designed to be operated in a towing tank and recirculating water channel environment.

The NIMBLE actuator is controlled by a National Instrument CompactRIO controller controlling three servo motors of various sizes.

In stage one, only the pitch and roll axis will be active and the aim was to calibrate the platform. It will also attempt to verified results in the BET model as well as comparing against experimental results reported in the literature.

In stage two, the yaw axis will be added. The aim will be to study the effect of three axis actuations and how that will affect agility and manoeuvrability compared to normal two axis actuations.

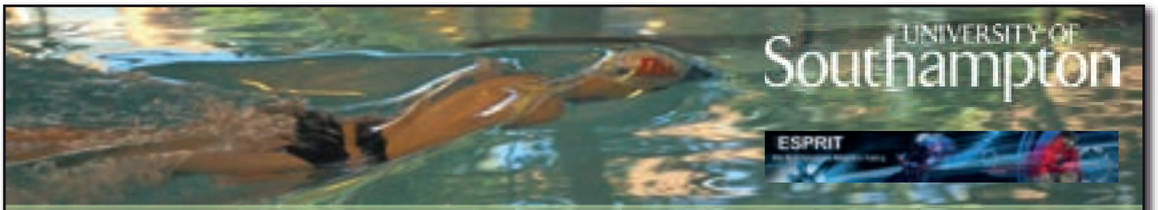
Acknowledgement

This project is supported by funds from the **EPSRC** and in collaboration with Prof. G. Griffiths of **National Oceanographic Centre, Southampton** and Dr A. Murphy and Miss M. Haroutunian of **Newcastle University**

FSI Away Day 2012

Newcastle University

National Oceanography Centre, Southampton



Swimming data capture

Optimized athlete body sensor networks for simulation-based performance analysis *ESPRIT* PoC
AIJ Forrester, CJ Brooks, SR Turnock, DJ Taunton, DA Hudson, K Takeda, JIR Blake, MP Prince, CWG Phillips, AP Webb, J Banks, Faculty of Engineering and the Environment
MJ Stokes, M Warner, Faculty of Health Sciences

The objective for this PoC is the accurate simulation of swimmer performance in the competition environment. In order to understand the factors that influence performance, we obtain qualitative and quantitative data using specially designed equipment and techniques. Subsequent data analysis enables us to focus on the various components of an individual swimmer's technique, and provide useful feedback for both coach and athlete.

Our data acquisition experience

Testing has been conducted on 35 elite athletes in 43 testing sessions, culminating in 575 measurement runs. An intensive feedback environment has been achieved on poolside incorporating force/speed measurement and video analysis. Data from these sessions is stored and used for further post analysis to increase understanding of the swimming problem.

Recently flow visualisation of underwater dolphin leg kick has been achieved using a bubble sheet. This enables the flow features of a successful technique to be identified.

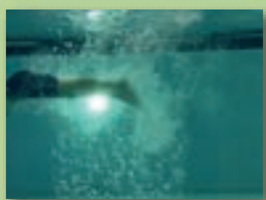


Figure. Bubble screen to aid flow visualisation

Tow rig

A tow system has been designed and manufactured allowing swimmers to be towed actively and passively at a range of depths and speeds.

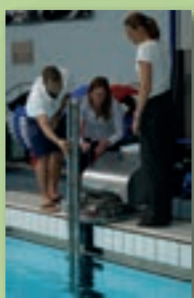


Figure. The latest tow system for British Swimming

Assistive software

The i-DAQ software is able to simultaneously record force and video data. The data is processed and synchronised with the video. Shortly after each run this information is able to be displayed to the athlete and coach. They can step through the video frame by frame and gain an insight into how the force changes through a stroke cycle.

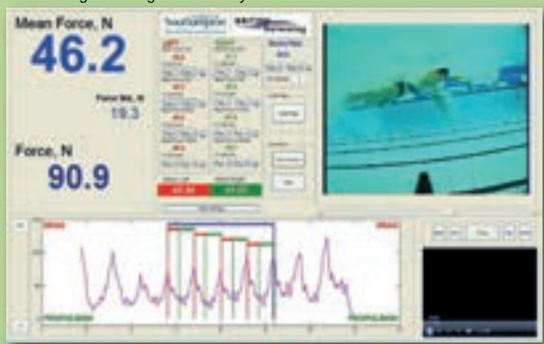


Figure. The i-DAQ tow rig data acquisition system.

Wireless sensors

A practical and efficient wireless Body Sensor Network (BSN) has been developed enabling us to capture body orientation and linear motions in a non-intrusive manner. Data from the onboard inertial sensors on each unit can be streamed via Bluetooth, or logged to a miniSD card for later wireless download, to a host PC. Host software has been developed for wireless operation of the sensor units, and for performing post-processing of the data. A number of metrics, including swimmer pitch and roll, propulsive efficiency, joint angles and linear acceleration are available for use in both musculoskeletal and hydrodynamic simulation, and as a real-time training aid.

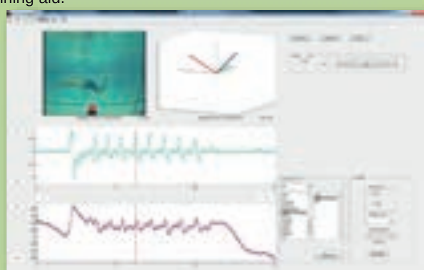


Figure. Orientation and linear motion from a lower back mounted sensor

http://www.soton.ac.uk/engineering/research/groups/ced.page | email: Alexander.Forrester@soton.ac.uk
Computational Engineering & Design Group, University of Southampton, SO17 1BJ, U.K.

Professor P Temarel

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

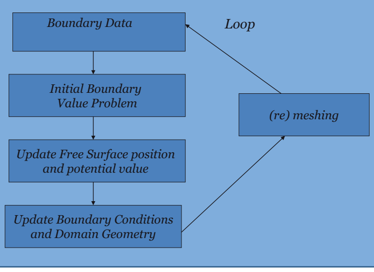
UNIVERSITY OF Southampton

Unstructured MEL modelling of 3D ship Hydrodynamics

Alberto C. Chapchap – acc1e09@soton.ac.uk - Ship Science
Supervisor – **Professor Pandeli Temarel**

Description and Goal

Under the potential flow assumptions the so called geometric non linear effects are intimately associated with the instantaneous wetted surface variations, higher order hydrodynamic actions and non linear free surface boundary conditions (kinematic and dynamic).
In order to address these issues, and their influence on wave-induced motions and loads, the Mixed Eulerian Lagrangian scheme is investigated and the feasibility of a modified version of it, using Level Set Theory and distance functions to represent the geometric domain, is currently being tested. The main features, per time step, can be summarized as follows:



3D Potential Flow model in time domain for FSI (Mixed Eulerian Lagrangian)

1- Each time step the flow is described by the solution of the Boundary Value Problem (BVP) using the rankine source as Green's function.

$$\iint_{Body} \phi(\vec{y}) G_n(\vec{x},\vec{y})\, ds(y) - \iint_{FS} \phi_n(\vec{y}) G(\vec{x},\vec{y})\, ds(y) = -\alpha(x)\phi(x) - \iint_{FS} \phi(\vec{y}) G_n(\vec{x},\vec{y})\, ds(y) + \iint_{Body} \phi_n(\vec{y}) G(\vec{x},\vec{y})\, ds(y)$$

2-Free surface potential and position are then updated in a Lagrangian fashion this is written as:

$$\frac{D(x(t))}{Dt} = \nabla\phi \qquad \frac{D(\phi)}{Dt} = \frac{1}{2}\nabla\phi\cdot\nabla\phi - gz$$

Partial Results – Radiation Problem of a forced hemisphere

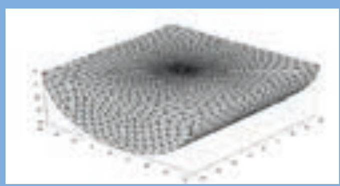


Figure 2 :Crude mesh consisting of 3217 triangles used to perform forced heave oscillations of the hemisphere

Time series of heave force

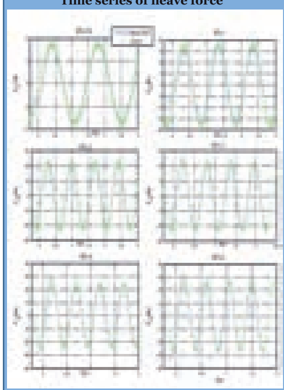


Figure 3 :Heave hydrodynamic force of a heaving hemisphere time series for different normalized frequencies (kRs) using linear free surface boudary conditions , compared with the analytical results from Hulme (1982)

Hydrodynamic Coefficients

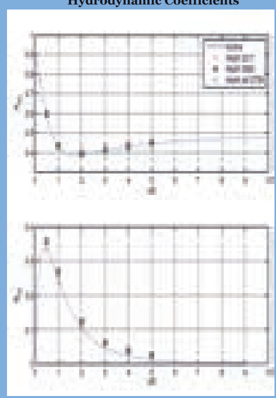


Figure 4 : Hydrodynamic coefficients obtained from the time series by means of a Fourier transform as function of kRs.

Applications

- *Seakeeping analysis in time domain to study the effects of geometric non linear boundary conditions on wave-induced motions*
- *Non Linear hydroelasticity analysis (effects of the geometric non linear free surface boundary conditions on the radiation potential of flexible floating structures are of particular interest)*
- *Linear / Non linear wave generation*

Partial Results for a wigley hull performing forced heave oscilations

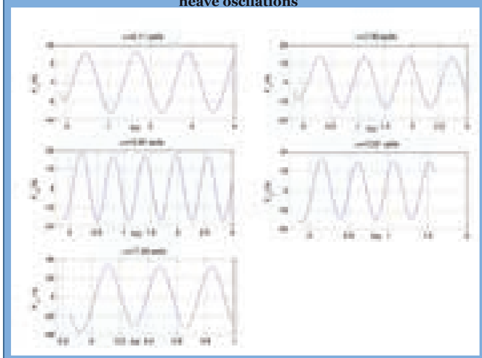


Figure 1: Heave hydrodynamic force of a Wigley hull undergoing forced oscillations without forward speed.

Future Work

- Replace the linearised form of the kinematic and dynamic free surface boundary conditions for their exact versions, in order to take into account to the so called non linear geometric potential flow effects.
- Extend the methodology to hydroelasticity and to free floating bodies in the presence of incident waves

Lloyd's Register

Acknowledgement
This project is supported by funds from Lloyd's Register, Strategic Research Group.

FSI Away Day 2012

Nonlinear Hydrodynamic Analysis of Floating Structures Subject to Ocean Environments

Dr Z Chen

TT5

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Nonlinear Hydrodynamic Analysis of Floating Structures Subject to Ocean Environments

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Background

- An accurate prediction of wave-induced motions and loads is vital in ship and offshore structure designs.
- Practical nonlinear environments, especially the second-order factors, generate significant load effects on the floating structures.
- Several numerical methods and commercial software are available but not robust enough particularly for the nonlinear analysis.

Objectives

- To understand the mechanism of wave-body interaction based on the potential theory.
- To predict hydrodynamic loads and responses of a floating body in nonlinear waves.
- To develop an efficient numerical algorithm and Fortran codes using Rankine source technique and Euler-Lagrangian formulation.

Figure 1: Nonlinear wave excitations on floating structure

Problem Formulation

- The governing equation for the motion of a rigid body in the time domain can be expressed as follows:

$$(M+m)\ddot{x}(t)+\int_0^t K(t-\tau)\dot{x}(t)d\tau+Cx(t)=F_e(t)$$

- The dynamic and kinematic nonlinear free-surface boundary conditions are listed below:

$$\frac{\partial\eta}{\partial t}+\frac{\partial\phi}{\partial x}\frac{\partial\eta}{\partial x}+\frac{\partial\phi}{\partial y}\frac{\partial\eta}{\partial y}-\frac{\partial\phi}{\partial z}=0$$

$$\frac{p}{\rho}+g\eta+\frac{1}{2}v^2+\frac{\partial\phi}{\partial t}=C(t)$$

- Euler-Lagrange time stepping procedure

1. A mixed boundary value problem is solved for velocity potential at a fixed instant .

2. The free surface boundary condition can then be stepped forward in time by Lagrangian formulation:

$$\frac{D\phi}{Dt}=\frac{\partial\phi}{\partial t}+v\cdot\nabla\phi,\quad \frac{dX}{dt}=v(X)$$

Numerical Methodology

- The Rankine source method can be extended to simulate nonlinear surface waves by distributing desingularized sources on the free surface.
- The body surface boundary condition varies nonlinearly with time step to capture the nonlinear effect of body condition.
- The free-surface is divided into inner and outer domain where source is evenly distributed in the former and exponentially increased in the latter. The nondimensional desingularized distance is given by:

$$L_d = D_m^{0.5}$$

Figure 2: 2-D Rankine source method computation model

Initial Result

The initial results for a 2-D circular cylinder in unbound domain show a good agreement between the panel method and analytical expression which can be expressed as:

$$\phi = -UR\sin\theta$$

The cylinder is divided into 12, 24 and 36 panels respectively.

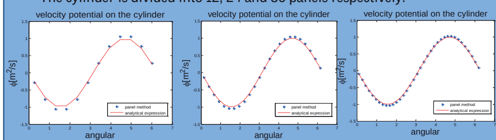

Figure 3: The comparisons of panel method and analytical expression

Under the effect of free-surface, the computation of the added mass of a semi-circular cylinder is quite stable. The convergence phenomenon is illustrated in Figure 4, where x-axis represents the number of nodes distributed on the free surface.

The results indicate that 200 nodes are enough for convergence.

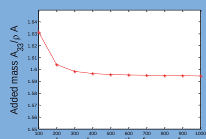

Figure 4: Convergence of added mass

Future Work

- 2-D floating body hydrodynamic evaluation will be extend further to consider nonlinear free-surface and body-exact condition effects.
- Rubber-band numerical method and Euler-Lagrange time stepping procedure will be applied in the numerical simulation.
- A further numerical method will be developed to simulate 3D wave-body interactions.

References

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2. Longuet-Higgins, M.S., Cokelet, C. D., *The deformation of steep surface waves on water, I a numerical method of computation*, Proceedings of the Royal Society A350,(1976), 1-26.

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Numerical Investigation into Potential Flow Around High-Speed Hydrofoil Assisted Craft

Professor G Hearn

TT6

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Numerical Investigation into Potential Flow Around High-speed Hydrofoil Assisted Craft

ZHONGYU YANG –zy1c08@soton.ac.uk , supervised by Prof G.E HEARN and Dr Z CHEN

Background

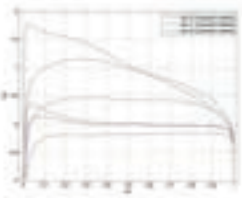
Currently, hydrofoils are an important element for some high-speed crafts. The role of a hydrofoil is to lift a part or the whole hull above the free surface at a sufficiently accelerated speed so that the waves normally generated by a displaced hull no longer exist. Consequently, with the same engine power, crafts equipped with hydrofoils travel much faster than conventional displacement hulls. Hydrofoils may be ***surface piercing*** or ***fully submerged***.

Surface piercing hydrofoil Bras-D's Or in Canada (60 knots)

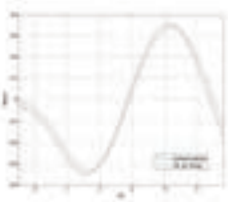
Fully submerged hydrofoil craft PC(H) High Point produced by U. S. Navy (45 knots)

The surface piecing system provides good roll, heave and pitch stability because the lifting foil area automatically changes as the craft attitude varies, which makes it self-stabilizing with no control required. The fully submerged foil system offers better sea keeping performance since it suffers much less free surface losses and this makes it more steady in rough seas. The fully submerged hydrofoil is adopted in this investigation to improve potential flow based calculations and numerical simulations around hydrofoil assisted crafts during the transitional take-off stages whilst considering free surface effects. Instead of applying a time dependent simulation, a specific number of quasi-steady state flows are investigated.

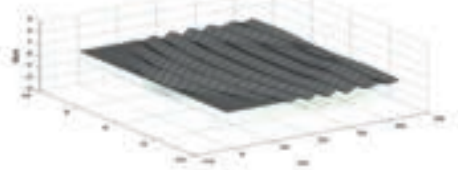
Results



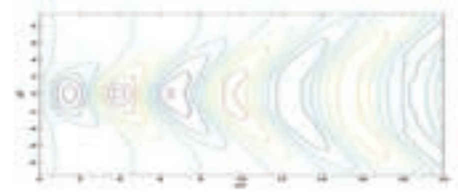
Comparison of pressure coefficients of a 2-D NACA4412 hydrofoil with different depths



Comparison of wave patterns of a 2-D NACA4412 hydrofoil



Numerical simulation of wave deformation of a 3-D NACA4412 hydrofoil considering the ***Linear*** free surface

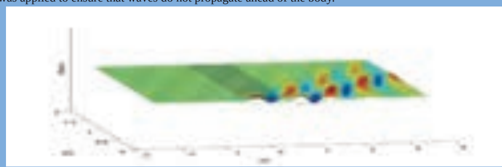


Numerical calculation of wave contour of a 3-D NACA4412 hydrofoil considering the ***Linear*** free surface

Proposed Numerical Method

➢ Panel (boundary element) Method

Panel, or boundary element method is adopted as the numerical simulation method in this investigation. It was developed during the late 1950's and early 1960's by Hess and Smith as a simple numerical tool for calculating potential flows about arbitrarily shaped bodies. The technique consists of discretising the boundary of the structure and associated wakes into a number of elements. From each element a simple flow field is considered to originate from an assigned fluid singularity. The strengths of the fluid singularities are determined by requiring continuity of velocity on the panels. By constraining the assumed complexity of variation of fluid singularity strengths over the panels, the fluid structure in each analysis may be reduced to a set of simultaneous equations solved for these unknown strengths. The panel method exploits the fact that potential fluid flows are governed by Laplace's equation. This feature and the linearity of the associated boundary value problem permits an equivalent integral equation formulation that does not require determination of flow within the interior of the fluid domain. Comparison with the finite element method and the finite difference method readily demonstrates the advantages of the panel method through discretisation of boundaries only. In practice this means that associated volume integrals associated with the Green integral identities used may be removed without introducing approximation. When considering the free surface effect (kinematic and dynamic free surface boundary conditions), the simple Rankine source method is applied instead of an all encompassing Green function which is computationally very complicated. However, the consequence of using the simple Rankine source method is that singularities have to be distributed on the all the boundaries including the free surface. This increases the number of unknowns and the approach is restricted to panel sizes that are small enough compared with the wavelength to ensure no useful information is lost. In addition, special attention has to be paid to guarantee that there are no waves in front of the body, which means no upstream waves. A one-sided, upstream, finite difference operator was applied to ensure that waves do not propagate ahead of the body.



Numerical simulation of wave deformation of a half 3-D Wigley hull considering the ***Non-linear*** free surface

➢ Mathematical Statement

Governing Equation:

•Laplace's Equation $\nabla^2\Phi = \Delta\Phi = \frac{\partial^2\Phi}{\partial x^2} + \frac{\partial^2\Phi}{\partial y^2} + \frac{\partial^2\Phi}{\partial z^2} = 0$

where Φ is the total velocity potential.

Boundary Conditions:

•Steady state body boundary condition $\nabla\Phi \cdot \mathbf{n} = \frac{\partial\Phi}{\partial n} = 0$

where **n** is a unit outward normal vector on the surface.

•Kutta condition $\mu_w = \mu_u - \mu_l$ It requires the velocity on the wake to be finite and in the selected implementation the doublet strength on the wake equals the difference of doublet strengths on the first and the last hydrofoil panels.

•Non-linear free surface boundary condition

[illegible]

Perturbed Velocity Potential:

[illegible]

Future work

Numerical investigation considering the non-linear free surface effect remains a challenge when hydrofoil assisted craft go through the take-off stage. It is necessary to implement a numerical simulation of the hydrofoil assisted craft as it picks up the speed to reach full speed with considering the interactions between multiple foils and the displacement hull under the non-linear free surface formulation.

FSI Away Day 2012

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Numerical Investigations on Fluid-Structure Interactions Using Particle Based Methods for Marine Applications

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Supervisors –**Dr. Mingyi Tan** and **Professor Jing Tang Xing**
Faculty of Engineering and the Environment

Introduction & Motivation

• Many fluid-structure interaction problems often involve violent fluid motions in marine engineering field, such as slamming and green water when a ship travels in rough seas which can produce overall momentum change and deformation of the hull. It is important to understand the interaction between fluid and structure to avoid damages caused by dynamic loads on the structures.

• Traditional grid-based numerical methods like FEM and FVM built on continuous assumption are not efficient for large deformation problems involving F-S separations, breaking waves, etc. Particle based methods like Smoothed Particle Hydrodynamics (SPH) are an alternative approach to simulate rough fluid motion because of their Lagrangian descriptions and meshless properties. It also has been developed to model solid motions to improve numerical efficiencies for nonlinear violent fluid-structure interactions.

Objective

To apply and improve the Smoothed Particle Hydrodynamics (SPH) method to simulate violent fluid-structure interactions.

Theory

- A general function f(x) and its gradient can be approximated by SPH in the forms:

$$< f(x_i) >= \sum_{j=1}^{N} \frac{m_j}{\rho_j} f(x_j)\cdot W_{ij} \quad \text{and} \quad < f'(x_i) >= \sum_{j=1}^{N} \frac{m_j}{\rho_j} f(x_j)\cdot W_{ij}'$$

here the smoothing function W_{ij} depends on the smoothing length h.

- Governing equations normally include (1) continuity equation and (2) momentum equation

$$1).\ \frac{D\rho}{Dt} = -\rho\frac{\partial v^{\beta}}{\partial x^{\beta}} \qquad 2).\ \frac{Dv^{\alpha}}{Dt} = \frac{1}{\rho}\frac{\partial \sigma^{\beta}}{\partial x^{\beta}}$$

SPH form for these equations can be easily derived

$$a).\ \frac{D\rho_i}{Dt} = -\rho_i \sum_{j=1}^{N}\frac{m_j}{\rho_j} v_i^{\beta}\cdot\frac{\partial W_{ij}}{\partial x_i^{\beta}} \quad \text{and} \quad b).\ \frac{Dv_i^{\alpha}}{Dt} = \frac{1}{\rho_i}\sum_{j=1}^{N} m_j \frac{\sigma_j^{\alpha\beta}}{\rho_j}\frac{\partial W_{ij}}{\partial x_i^{\beta}}$$

Boundary treatment

- Using repulsive force on wall particles
- Using denser wall boundary particle

Figure 1. Using repulsive force on wall particles

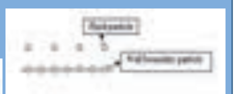

Figure 2.Using denser particles on wall surface

Examples of fluid-structure interaction simulations with SPH

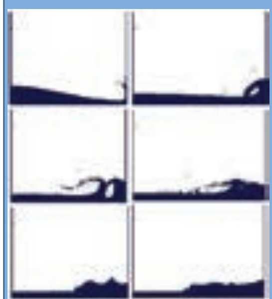

Figure 3. Flow impacts onto a fixed wall boundary using ISPH

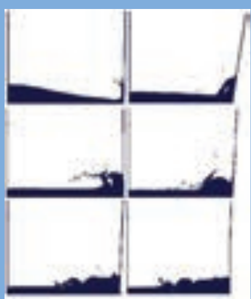

Figure 4. Flow impacts onto a spring supported wall using ISPH

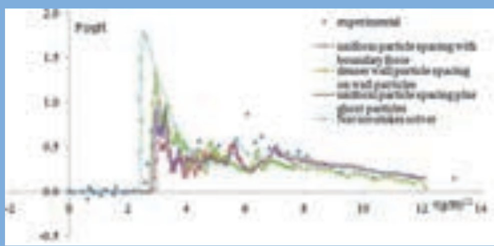

Figure 5. Analysis of pressure values on point (3.22,0.16) in the case of water impacting onto a fixed wall shown in Figure 3.

Figure 6. Water entry of a wedge using ISPH

Figure 7. Wave pattern comparison between simulation and experiment

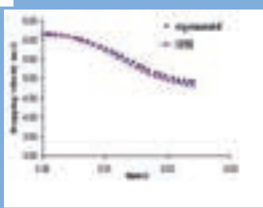

Figure 8. Dropping velocities of wedge obtained by simulation and experiment

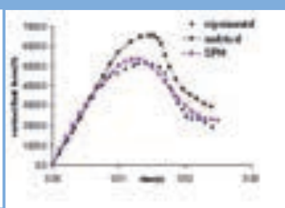

Figure 9. Impacting force on the wedge shown in Figure 6.

Conclusions

- Incompressible SPH method gives reliable pressure values
- Instead of traditional ghost particle boundary treatment, repulsive boundary force and denser wall particles are two alternative treatments incorporated with ISPH which improve the simulation efficiency
- SPH can be developed to create a powerful tool for fluid-structure interaction problems with large motions and deformations.

FSI Away Day 2011

Hydroelastic Inflatable Boats: A Possible Design Methodology.

Professor P Wilson

TT8

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Hydroelastic Inflatable Boats: A Possible Design Methodology

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1. Introduction

The Royal National Lifeboat Institution (RNLI) use a 5 m inflatable boat (IB), called the IB1, for search and rescues in littoral waters. Anecdotal evidence has indicated, but not proved, that the hydroelasticity of the IB1 improves the performance, especially in waves or surf. The RNLI require scientifically-based design guidelines for the IB. Current designs are based on designers' experience and trial and error for a rigid vessel.

Figure 1: In the foreground is the RNLI IB1 and in the background is the RNLI Atlantic 85 RIB. [Website]

Project Aims

- Divide the entirely hydroelastic boat into manageable hydroelastic problems
- Create a design methodology for the manageable hydroelastic problems
- Develop design tools for each hydroelastic problem

2. Current Aspects of Hydroelasticity

The majority of ships are considered rigid when they are designed. If hydroelasticity is considered during the design stage it is primarily used to calculate the stresses and strain within the structure so that the structural weight can be minimised [Hirdaris and Temarel (2009)].

Hydroelasticity consists of two main research areas: global hydroelasticity and slamming (or local) hydroelasticity. **Global hydroelasticity** studies the longitudinal bending and torsional twisting within the boat [Bishop and Price (1979)], see figure 2. **Hydroelastic slamming** investigates the local deformation caused by a wedge impacting a free surface [Faltinsen (1997)], see figure 3. These provide two manageable hydroelastic problems.

Figure 2: Global hydroelasticity

Figure 3: Hydroelastic Slamming

Rigid structure
Elastic structure
Water surface

3. New Aspect of Hydroelasticity

The IB1 has a fabric hull which as able to deform when the vessel is planing, see figure 4. This defines a practical hydroelastic problem called a **hydroelastic planing surface**.

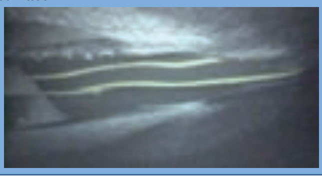

Figure 4: An underwater photograph of the hull deforming at 19 knots

[Dand et al (2008)]

References:

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HIRDARIS, S. E., TEMAREL, P., 2009, Hydroelasticity of ships: recent advances and future trends, *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment 223, (3), pp. 305-330*

WEBSITE viewed on 22/08/2011, image of IB1 and Atlantic 85. http://www.rnlisunderland.org/information/lifeboats/pg18.html

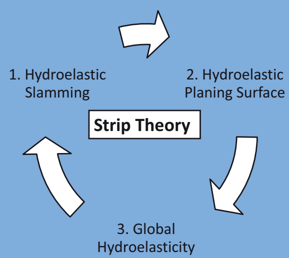
4. Design Methodology

Three practical hydroelastic problems have now been described (global hydroelasticity, hydroelastic slamming and hydroelastic planing surface) but how do they link them together?

A key design tool in naval architecture is strip theory. Strip theory involves solving the forces on transverse slices of the boat and then integrating over the length to find the forces and moments over the length of the boat. Strip theory provides an order to studied the aspects of hydroelasticity. This is because the hydroelastic slamming aspect can be compared to the transverse slices of strip theory. Then the forces on the hydroelastic transverse slices can be integrated to find the forces on a hydroelastic planing surface. Finally, wave loads can be applied to the forces on a hydroelastic planing surface to solve the global hydroelastic forces.

Hydroelastic Slamming

Hydroelastic Planing Surface



Global Hydroelasticity

5. Conclusion

An entirely hydroelastic boat has been subdivided into manageable hydroelastic problems. The hydroelastic problems have been linked together using strip theory. Further work will include the development of design tools for each hydroelastic aspect.

Lifeboats

EPSRC Engineering and Physical Sciences Research Council

Acknowledgement: This project is supported and funded by the University of Southampton, EPSRC and the RNLI

FSI Away Day 2012

A Sobey

TT9

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Damage Assessment Tool for Marine Structures

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MoD\Lloyd's Register Centre of Excellence in Marine Structures

Motivation

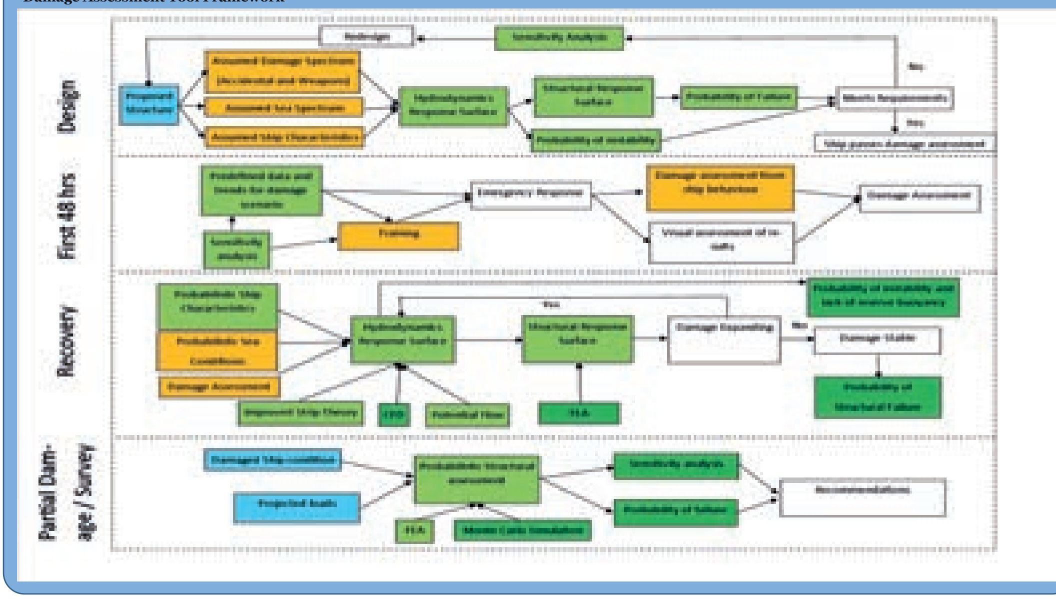
Each year ships sustain damage through collisions, groundings and other reasons but relatively few are lost. During emergencies where the vessel remains afloat the safety of the crew and cargo are put into danger. It is therefore key that advice is based on accurate modelling. Current assessment tools have ensured safety but are conservative. The ability to rapidly model the damage in an emergency scenario will lead to savings in cost and reduce the environmental impact of these occurrences.

Aims and Objectives

The aim of the project is to develop an improved methodology for damaged ship assessment and design. This aim will be completed through a number of objectives:

- Develop methodologies to aid each stage of the damage scenario
- Determine the applicability of each framework
- Investigate the use of FEA within damage scenarios
- Investigate the use of CFD and potential flow within damage scenarios
- Validate the modelling of these tools
- Investigate the use of faster tools against experiments or more computationally expensive techniques
- Model damage situations

Damage Assessment Tool Framework



Methodology

The project is developing research in the area of damaged structural analysis. This research has been split into four main stages of a vessels life:

1. Design– Vessels are analysed for damage tolerance which is then optimised.

2. First 48 hrs Emergency Response – At this stage little is known about the damage that has occurred. Information is scarce and crews and emergency response must react quickly to secure the safety of the crew and cargo. There is limited time for modelling but advice must be accurate.

3. Recovery of the Vessel – This stage can last for a period of a couple of weeks. More knowledge is known about the vessel and decisions are being made about whether to tug the boat to safety, the cheapest and most environmentally friendly option, to ferry it home or to scrap it, the least desirable option. Rapid modelling techniques will allow the investigation of a number of "what if" scenarios.

4. Partial damage of the structure – It is possible that the damage that occurs may not penetrate the structure but may lead to total failure through use. This is common in composite materials.

These areas all rely on the use of response surfaces as metamodels to represent more complex modelling. This allows a rapid yet accurate analysis of the damaged structure. The tool relies on a hydrodynamic response surface that will feed into a structural response surface determining the probability of a total failure.

Diagram Key:

- Modelling currently under way
- Modelling Completed and validated
- Input Data
- Potential areas of work
- Outputs

Collaboration

The project is split between the University of Southampton and University College London. In total 7 PhDs have worked or are working on the project covering areas of hydrodynamics, both experimentally and through modelling, structural analysis of steel and damage tolerance of composite materials.

Conclusions

Damage to ship hulls represents a threat to the safety of crews and cargo and can lead to environmental and economic impacts. Current levels of structural modelling represent methods that have ensured safety but are conservative in how they assess the collapse of damaged structures. This research combines a number of specialist areas to develop models that are rapid enough to be used in emergency response but are more accurate than those currently in use.

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Strength Assessment of Damaged Steel Ship Structures

Professor RA Shenoi

TT10

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

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Strength Assessment of Damaged Steel Ship Structures

Mr J.M.Underwood[1], Prof. R.A. Shenoi[1], Dr J.I.R.Blake[1], Mr C. Snell[2], Mr P. James [3]
[1] Fluid Structure Interactions Research Group, University of Southampton
[2] UK MoD, [3] Lloyd's Register EMEA,
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Introduction

Damage continues to occur to ships across the world (*Figure 1*). Many events leave the vessel damaged but afloat and in need of assistance on how to salvage the vessel, ensure safety of the crew and prevent potentially catastrophic environmental impact.

Shore based emergency response services exist to provide guidance to the owner and crew during a damage incident. To do so they perform residual or damaged strength assessments of the vessel through the use a simplified structural modelling procedure termed Progressive Collapse Analysis. The method divides the structure into individual stiffened plate elements whose strength is assessed against pre-calculated stress-strain curves, summed to ascertain the overall strength of the vessel. (*Figure 2*)

Figure 1: *Damaged Container Ship (Image by USCG)*
http://www.portstrategy.com/features101/legal-and-insurance/coping_with_the_crash

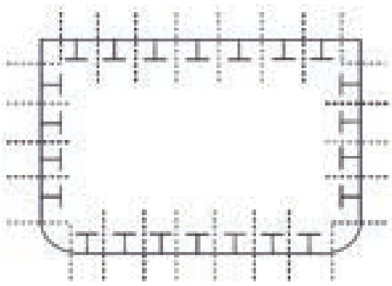

Figure 2: *Progressive Collapse Analysis Structural Idealisation*

Current Limitations

Whilst the method is fast, Progressive Collapse Analysis has the following weaknesses:

1. Interframe collapse due to bending is the only mode of failure assessed;
2. Only intact structure is modelled, no residual strength of damaged structure is accounted for;
3. Stress-strain curves used to capture the structural data are limiting;
4. Physical separation of elements does not allow the influence of damage on surrounding structure to be captured;
5. Pre-stressing of the structure due to the damage event is neglected.

Research Aim

To develop a method, procedure or collection of data that can be used to assess, or aid in the assessment of, the residual structural strength of a damaged vessel.

Modelling Methodology

To overcome the weaknesses of the current progressive collapse analysis, a new method is proposed which utilises Response Surface Method (RSM) to capture the required structural data. (*Figure 3*)

The response surface is created from a number of finite element analysis (FEA) cases and has the advantage of being able to capture additional variations in the structure. The method will also allow the use of larger structural elements.

Development of the method is supported by a study into the effect of damage on local ship structural arrangements to determine what factors should be included in or excluded from the response surface, to simplify and speed up the calculation process.

Figure 3: *Flow Diagram of New Progressive Collapse Analysis Method Using Response Surface Method*

Conclusions and Further Work

The work completed to date has shown that RSM is able to capture damaged strength data for peak stress and ultimate collapse of stiffened plates whilst accounting for variations in geometrical arrangement including damage position and size, plate thickness and material properties.

It has also been shown that the implementation of Progressive Collapse Analysis in its current form can lead to overly pessimistic prediction of the damaged strength of a vessel. This can be resolved by including the residual strength of damaged structure in the analysis.

Investigating the effects of damage induced holes in stiffened panels, it has been shown that the damage itself can influence the failure modes in surrounding undamaged structure. This could lead to modes of failure developing that span multiple frames prior to interframe collapse, demonstrating the need to use larger structural elements to assess the damage strength via a new Progressive Collapse Analysis methodology.

Future work will continue to develop the proposed method and investigate the effects of damage on the strength of steel ship structures.

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Integrated Design for Production to Ensure Sustainability in Marine Transportation

Dr J Blake

TT11

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Integrated Design for Production to Ensure Sustainability in Marine Transportation

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Sponsors: Princess Yachts International

Background

Princess Yachts International (PYI) are one of the UK's leading leisure boat builders, producing 14-40m composite luxury powerboats. In 2006 a closed mould infusion process was introduced, improving health and safety, weight, quality, repeatability and emissions.

Optimization of the infusion process is now required to continue PYI's development and growth as the boundaries of the resin infusion process are pushed with the production of 40m plus hull forms. Voids are a common defect in fibre reinforced resin matrix composites, forming and growing during the fabrication process, leading to a higher level of parameter control to avoid these occurrences[1].

Residual stress development during the curing phase is critical to the resulting composite quality. Residual stresses tend to develop at 2 key stages of the curing process, firstly during polymerisation which causes a chemical and physical transformation, and secondly curing cooling, where the shrinkage of the laminate creates a complex stress field[2]. Understanding and control of these residual stresses is critical in the further improvement in efficiency and sustainability of composite marine vehicles.

Research Methodology

- A field survey has been carried out to assess the quantity, location and severity of voids at PYI. An acceptable and unacceptable level has been chosen based on ALARP principle, established on PYI's desire to remain leaders in the luxury powerboat production sector. The resulting histogram can be seen in figure 1.
- Subsequent to identification of the void and imperfection locations shown in figure 1, a chine mould section has been taken from the A2 stern mould. Flow and cure cycle experiments will be carried out at PYI and at the University of Southampton, figure 4.
- Computational flow front analysis using PAM-RTM will be used to assess the injection strategy, moulding temperature's, injection pressure's and key injection gate, vents and vacuum ports. The result will be validated against full scale measurements and the chine section experiments, an example infusion model can be seen in figure 3.
- Thermal analysis of the cure cycle will be carried out computationally and validated against the through thickness cure temperature profiles attained at PYI and from the chine moulding.

Figure 4: Chine Section Flow Front Experiment

References

1-Gu, Y., Li,M., Zhang, Z., &Sun,Z. (2009). Measuring method and process analysis of void formation conditions for resin matrix composites. *ICCM 17*, Edinburgh

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3-ESI Group. (2006). *PAM-RTM, simulation software for resin injection and infusion on fibrous reinforcements is enabling Poncin Yachts to optimize its manufacturing processes*. Available: www.esi-group.com. Last accessed 27th November 2011

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Objectives

1. Identify key locations for void and imperfections in large scale infusions.
2. Identify the key sources of residual stress in a typical large scale composite infusion.
3. Model, both computationally and experimentally, the infusion process used at PYI.
4. Design residual stress alleviation mechanisms that are not detrimental to the desired material properties or dimensional constraints by PYI.
5. Create a user friendly methodology for identifying and reducing residual stresses in composite components to be incorporated in to the design process.

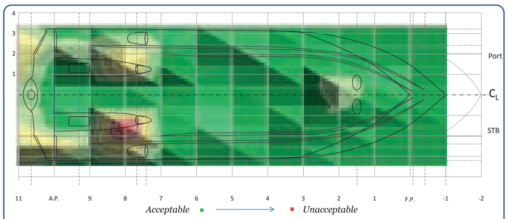

Figure 1: Histogram Presenting Voiding Distribution

Figure 2: PYI Infusion

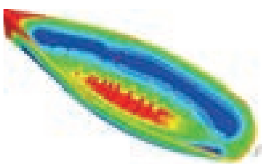

Figure 3: PAM-RTM Injection simulation For Harmony Yachts[3]

Conclusion

All composites exhibit some form of imperfections and voiding due to residual stresses. A large level of research has been carried out on small scale infusions, however little information is available for large scale infusions such as those undertaken at PYI. This research will generate the required tools to identify the sources and control measures required to reduce voids and imperfection in large scale composite components. The implementation of such tools will lead to an increased understanding of the resulting laminate properties allowing for tighter tolerances at the design stage and further optimization of the structure.

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Acknowledgement: This project is supported by funds from the **Engineering and Physical Sciences Research Council** and **Princess Yachts International**

Damaged Composites - Marine Structures

Professor RA Shenoi

TT12

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Damaged Composite Marine Structures

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Supervisors – Professor R. A. Shenoi, Dr J. I. R Blake, Dr A. J. Sobey,
Mr P. James (Lloyd's Register), Mr C. Snell (UK MoD)

Background

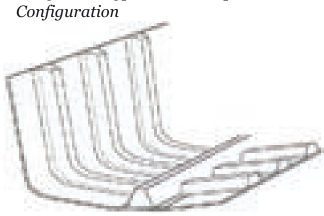
Composites are used in engineering applications due to their ability to tailor properties to a specific design. Stiffened shell laminates are used as the primary structure in the marine industry in deck and hull structures and increasingly in aerospace fuselage and civil applications. The UK MoD Single Role Mine Hunters (SRMHs), shown in figure 1, are constructed from single skin E-glass polyester hulls stiffened with longitudinal and transverse "top-hat" stiffened frames and girders, as shown in figure 2.

Collision and other impact events commonly occur in such vessels and can cause delaminations and de-bonding within the laminate and stiffener. Following a damage event it is critical to understand the residual capabilities of the structure to ensure the safety of the structure, the users, and for both environmental and financial considerations.

Under compressive loading the interaction of delamination growth, inter-frame and frame buckling leads to a complex interaction of damage mechanisms.

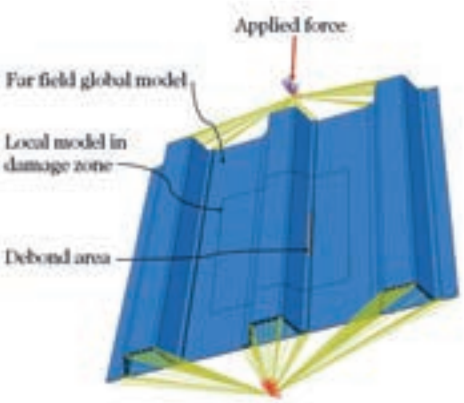
^ *Figure 1: MoD SRMH HMS Grimsby*

v *Figure 2: Typical Monocoque Hull Configuration*



Research Aim

"The aim of this research is to fully understand the effect of design and damage parameters on the residual capability of composite stiffened panels."



^ *Figure 3: Model configuration*

Methodology

In order to achieve the research aim a detailed non-linear finite element model has been generated utilising a global-local approach and the virtual crack closure technique to accurately assess the crack propagation, progressive damage and ultimate collapse of multi-stiffened panel under compressive and in-plane loads.

The model configuration is shown in figure 3. A global-local model utilises shell elements in the far field structure which approximates the displacement and stress fields to a suitable accuracy and utilises solid elements in the region the damaged zone.

This model will be verified by full scale experimental data and material characterisation tests for both tensile and fracture material properties

Future Work

- Development and validation of a finite element model capable of representing idealised delamination damage
- Assessment of collapse mechanisms and progressive damage of stiffened panels including initial damage.
- Sensitivity analysis investigating the effect of damage parameters on residual capabilities.
- Comparison of damage models allowing realistic damage patterns and associated damage.
- Assessment of the effect of design and manufacturing parameters on the residual capability and damage tolerance.
- Development of guidance for damage vessels and design guides to aid a damage tolerant design.

Conclusion

This research aims to increase the understanding of the residual capability of stiffened panels containing de-bond and delamination damage as seen in in-service damage incidents. This will be achieved through a validated non-linear finite element model to replicate buckling modes and using the virtual crack closure technique to model crack propagation. This model will be used to conduct parametric studies on geometric, material and damage parameters and therefore help to develop guidance for damage vessels and design guides to aid a damage tolerant design.

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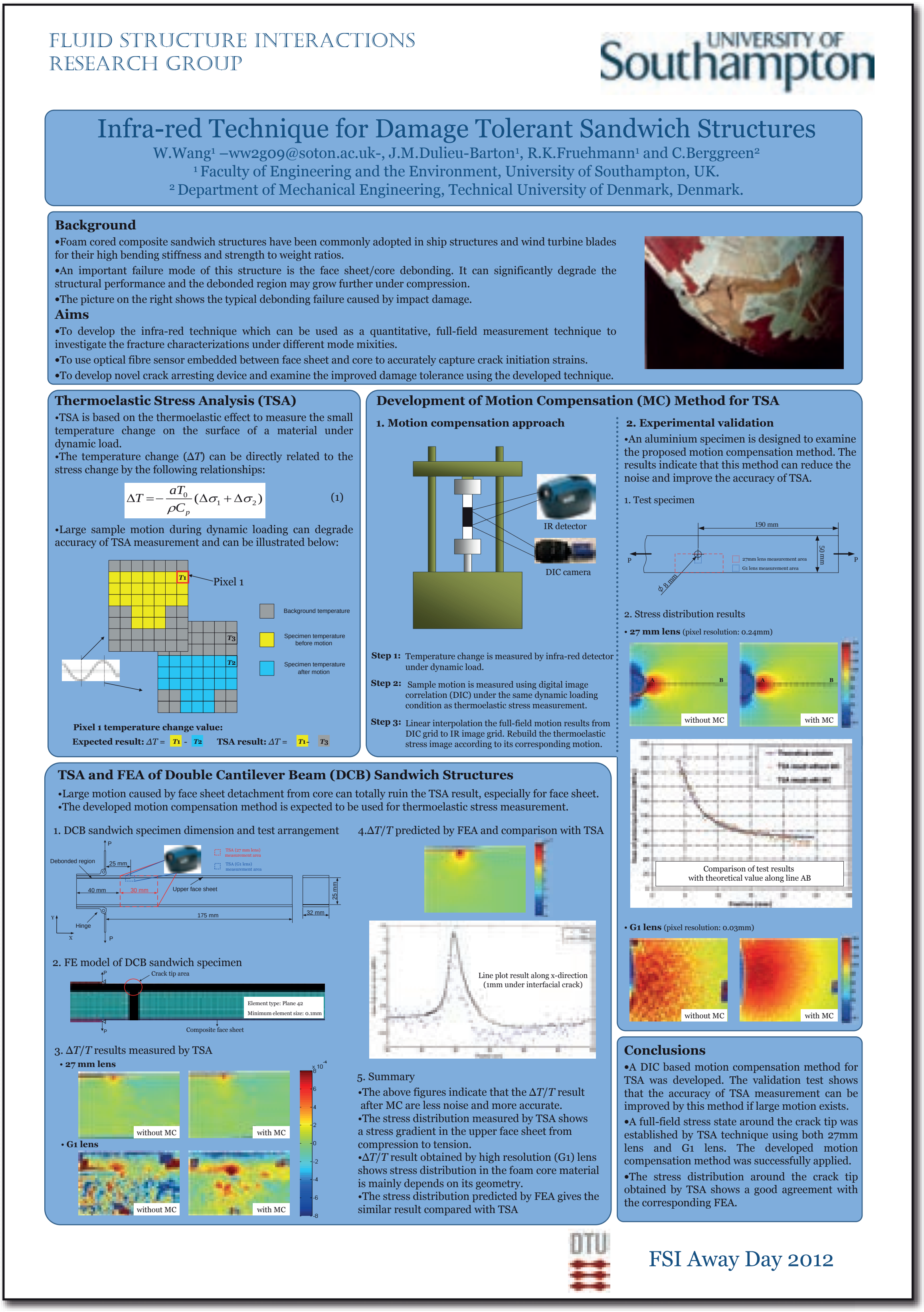
Acknowledgement:
This project is supported by funds from the Engineering and Physical Sciences Research Council and the MoD/Lloyd's Register Centre of Excellence in Marine Structures

Infra-Red Technique for Damage Tolerant Sandwich Structures

Professor J Barton

TT13



FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Infra-red Technique for Damage Tolerant Sandwich Structures

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[1] Faculty of Engineering and the Environment, University of Southampton, UK.
[2] Department of Mechanical Engineering, Technical University of Denmark, Denmark.

Background

•Foam cored composite sandwich structures have been commonly adopted in ship structures and wind turbine blades for their high bending stiffness and strength to weight ratios.

•An important failure mode of this structure is the face sheet/core debonding. It can significantly degrade the structural performance and the debonded region may grow further under compression.

•The picture on the right shows the typical debonding failure caused by impact damage.

Aims

•To develop the infra-red technique which can be used as a quantitative, full-field measurement technique to investigate the fracture characterizations under different mode mixities.

•To use optical fibre sensor embedded between face sheet and core to accurately capture crack initiation strains.

•To develop novel crack arresting device and examine the improved damage tolerance using the developed technique.

Thermoelastic Stress Analysis (TSA)

•TSA is based on the thermoelastic effect to measure the small temperature change on the surface of a material under dynamic load.

•The temperature change (ΔT) can be directly related to the stress change by the following relationships:

$$\Delta T = -\frac{aT_0}{\rho C_p}(\Delta\sigma_1 + \Delta\sigma_2) \quad (1)$$

•Large sample motion during dynamic loading can degrade accuracy of TSA measurement and can be illustrated below:

Pixel 1 temperature change value:

Expected result: $\Delta T = T_1 - T_2$ **TSA result:** $\Delta T = T_1 - T_3$

Development of Motion Compensation (MC) Method for TSA

1. Motion compensation approach

Step 1: Temperature change is measured by infra-red detector under dynamic load.

Step 2: Sample motion is measured using digital image correlation (DIC) under the same dynamic loading condition as thermoelastic stress measurement.

Step 3: Linear interpolation the full-field motion results from DIC grid to IR image grid. Rebuild the thermoelastic stress image according to its corresponding motion.

2. Experimental validation

•An aluminium specimen is designed to examine the proposed motion compensation method. The results indicate that this method can reduce the noise and improve the accuracy of TSA.

1. Test specimen

2. Stress distribution results

• **27 mm lens** (pixel resolution: 0.24mm)

• **G1 lens** (pixel resolution: 0.03mm)

TSA and FEA of Double Cantilever Beam (DCB) Sandwich Structures

•Large motion caused by face sheet detachment from core can totally ruin the TSA result, especially for face sheet.
•The developed motion compensation method is expected to be used for thermoelastic stress measurement.

1. DCB sandwich specimen dimension and test arrangement

2. FE model of DCB sandwich specimen

3. $\Delta T/T$ results measured by TSA

• **27 mm lens**

• **G1 lens**

4. $\Delta T/T$ predicted by FEA and comparison with TSA

5. Summary

•The above figures indicate that the $\Delta T/T$ result after MC are less noise and more accurate.
•The stress distribution measured by TSA shows a stress gradient in the upper face sheet from compression to tension.
•$\Delta T/T$ result obtained by high resolution (G1) lens shows stress distribution in the foam core material is mainly depends on its geometry.
•The stress distribution predicted by FEA gives the similar result compared with TSA

Conclusions

•A DIC based motion compensation method for TSA was developed. The validation test shows that the accuracy of TSA measurement can be improved by this method if large motion exists.

•A full-field stress state around the crack tip was established by TSA technique using both 27mm lens and G1 lens. The developed motion compensation method was successfully applied.

•The stress distribution around the crack tip obtained by TSA shows a good agreement with the corresponding FEA.

DTU

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Analysis of Adhesively-bonded Composite Joints

Dr S Boyd **TT14**

Analysis of adhesively-bonded composite joints

George Crammond[1]
Supervisors – **Dr Stephen W. Boyd** and **Professor Janice M. Barton**

1. Motivation & Aim

There is increasing use of composites within the marine industry due to their beneficial specific materials properties. Yet the large size of marine structures makes it impractical and expensive for structures to be moulded as one continuous piece.

Figure 1: Internal structure of a typical composite vessel

Joining mechanisms are required either to assemble the structure from many smaller components or for the attachment of secondary structure. Significant weight savings and greater load transfer efficiency are possible when using the adhesively bonded joint

The project investigates the application of bonded joints in marine applications, specifically the through thickness load transfer mechanisms in the joint

Figure 2: Double butt strap joint geometry

2. Experimental approach

Non contact full field experimental methods used to assess the stress and strain fields within a double butt strap joint (DBSJ) using Thermoelastic Stress Analysis (TSA) and Digital Image Correlation (DIC).

TSA uses a highly sensitive infra-red (IR) detector to measure the temperature changes induced in a material as a result of the thermoelastic effect. The temperature change, ΔT, is directly related to the stress change, defined for orthotropic materials as

$$\Delta T = -(K_1 T \Delta\sigma_{11} + K_2 T \Delta\sigma_{22}) \quad (1)$$

DIC uses an image recognition algorithm to track the movement of a random speckle pattern on the surface from a sequence of recorded images, from which deformation and strain fields can be obtained

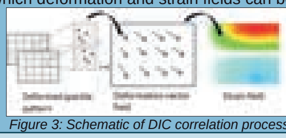

Figure 3: Schematic of DIC correlation process

3. Through thickness strain measurement

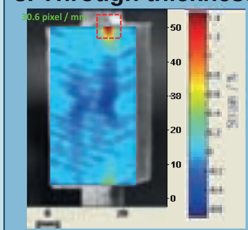

Figure 4: ε_{xx} strain in joint loaded at 17kN

Increased magnification

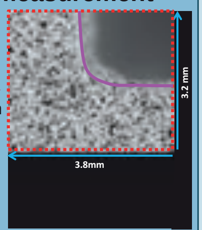

Figure 5: high magnification image of joint

Through thickness strain observed to concentrate at the discontinuity between the inner adherend and outer strap. Failure of the joint was seen to initiate from this high strain region is where failure is initiated.

Current analysis provides insufficient spatial resolution of data to understand mechanics in this region. Solution to increase the magnification up from 30.6 pixels/mm to 640 pixels/mm

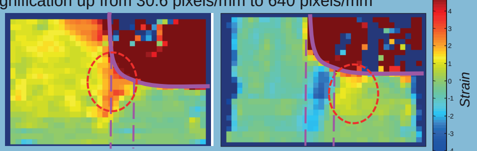

Figure 6a): ε_{yy} strain b)ε_{xx} strain at discontinuity in joint loaded at 12kN

Strains around the geometric discontinuity identified with much greater spatial resolution and strain precision.

Significant localised strain concentrations observed at the interface with adhesive in the outer strap (peel) and in the inner adherend (axial)

4. Thermoelastic Stress Analysis

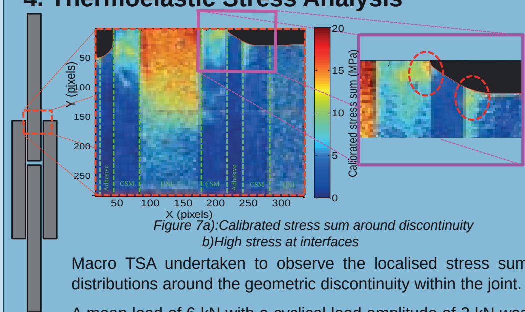

Figure 7a):Calibrated stress sum around discontinuity b)High stress at interfaces

Macro TSA undertaken to observe the localised stress sum distributions around the geometric discontinuity within the joint.

A mean load of 6 kN with a cyclical load amplitude of 3 kN was applied to the joint. Definitive bands of high and low stress can be seen, relating to the material and stacking sequence within the joint.

High stress sum regions present in the inner and outer straps at the interface with the adhesive at the geometric discontinuity.

Stress concentrations correspond to the areas of high axial and peel strains identified in the earlier analysis indicating maximal through-thickness load transfer

5. Conclusions

- Full-field, non-contact experimental techniques used to evaluate the stress and strain distributions within a double butt strap joint
- Stress field shows bands of high and low stress relating to the material and stacking sequence within the joint. High stress regions at the discontinuity between inner and outer adherend also visible
- Digital Image Correlation used to analyse the through thickness load transfer within the joint, identifying a complex strain field and the growth of cracks prior to failure

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Pulse Phase Thermography and its Application to Defects in Adhesively Bonded Joints

Professor J Barton

TT15

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Pulse Phase Thermography and its Application to Defects in Adhesively Bonded Joints

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Introduction

Adhesive joints are often preferred to their mechanical counterparts due to:

•Reduction in weight.

•Improved load transfer through the joint.

Adhesive joints are currently being used in the membrane style liquid natural gas (LNG) containment system used in carriers such as the Mk III, Fig. 1.

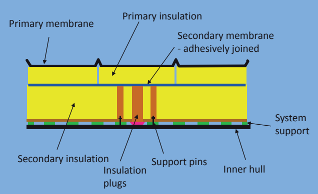

Figure 1: LNG MKIII carrier insulation construction.

Kissing Defects

Kissing defects are:

The improper adhesion at the adhesive/adherend interface without any identifiable void or volume associated with it.

The cause of kissing defects is unknown. Work here is based on a liquid layer approach to recreating kissing defects [1,2], which are made by introducing contamination to one of the adhesive/adherend interfaces in a joint, Fig. 2.

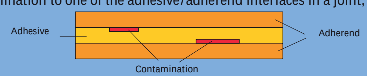

Figure 2: Liquid layer method of recreating kissing defects.

No current NDE methods are able to detect kissing defects.

Aim

To develop a non destructive method to assess the integrity of adhesive bonds using pulse phase thermography (PPT).

Pulse Phase Thermography (PPT)

•A heat pulse is applied to the surface of a sample and the thermal response of that surface is monitored using an infrared camera, Fig. 3.

•Variation in conductivity through the material where there is a defect will lead to an area of different temperature on the surface over the defect.

Figure 3: PPT set-up and equipment.

•Thermography data is recorded in a series of k thermal images over an observation period following the pulse.

•The data for is transformed from the time domain to the frequency domain using a 1D fast Fourier transform (FFT), (1).

$$F_n = \sum_{k=0}^{N-1} T(k) e^{-2\pi i k n / N} = Re_n + i\,Im_n \quad (1)$$

•Phase values for each pixel may then be calculated from these real and imaginary components, (2).

$$\phi_n = \tan^{-1}\left(\frac{Im_n}{Re_n}\right) \quad (2)$$

•Phase images can then be obtained [3].

Results and Discussion

Materials with inserts

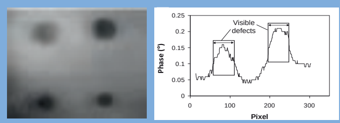

Figure 4: Phase image and phase profile plot across the upper two defects.

A carbon fibre reinforced plastic (CFRP) panel with polytetrafluoroethylene (PTFE) inserts between plies at various depths was tested. The defects were clearly visible to the maximum tested depth of 0.875 mm for the minimum tested defect diameter of 5 mm.

Tests were also carried out on glass fibre reinforced plastic (GFRP) with PTFE defects. A reduced phase contrast was found due to a reduced contrast in diffusivity between the sample and defect.

Bonded samples

Liquid layer defects were added to a CFRP lap joint along with PTFE inserts which were bonded using the normal curing cycle for the material.

The PTFE inserts are clearly visible in the PPT data whereas the petroleum jelly and silicon grease contaminations are only just visible as a slight variation in the phase contrast image, Fig. 5. The chalk dust and Frekote defects were not visible.

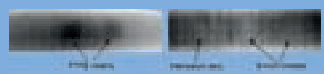

Figure 5: Phase images for PTFE and liquid layer defects in CFRP.

PTFE inserts were easily detected in a CFRP bonded joint constructed using epoxy film adhesive, which allows the adhesive thickness to be accurately controlled, Fig. 6. When this control is reduced by using spreadable epoxy adhesive the contaminations and inserts become much harder to distinguish. The silicon grease contamination used is visible in the phase values however other variations in the adhesive thickness are also causing a similar magnitude variation in the phase values, Fig. 7.

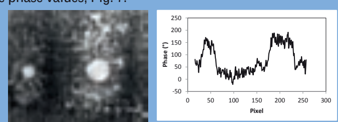

Figure 6: Phase image and profile plot for PTFE inserts in a CFRP bonded joint using film adhesive.

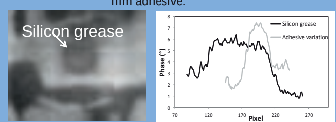

Figure 7: Phase image and profile plot for spreadable adhesive bond with silicon grease contamination.

Conclusions and Further Work

• Artificial insert defects were successfully identified in a range of materials including CFRP and GFRP. PTFE, silicon grease and petroleum jelly were all detectable in the CFRP lap joint sample.

•Defects in a film adhesive lap joint were found to be more detectable than in the spreadable adhesive.

• Artificial defects in the spreadable adhesively joined sample were found to be indistinguishable from other adhesive variations. Further investigation and development of the technique is required.

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1. Yan, D., Drinkwater, B.W. and Neild, S.A. NDT&E International, 2009. 42: p. 459-466.
2. Brotherhood, C.J., Drinkwater, B.W. and Guild, F.J. Journal of Nondestructive Evaluation, 2002. 21(3): p. 95-104.
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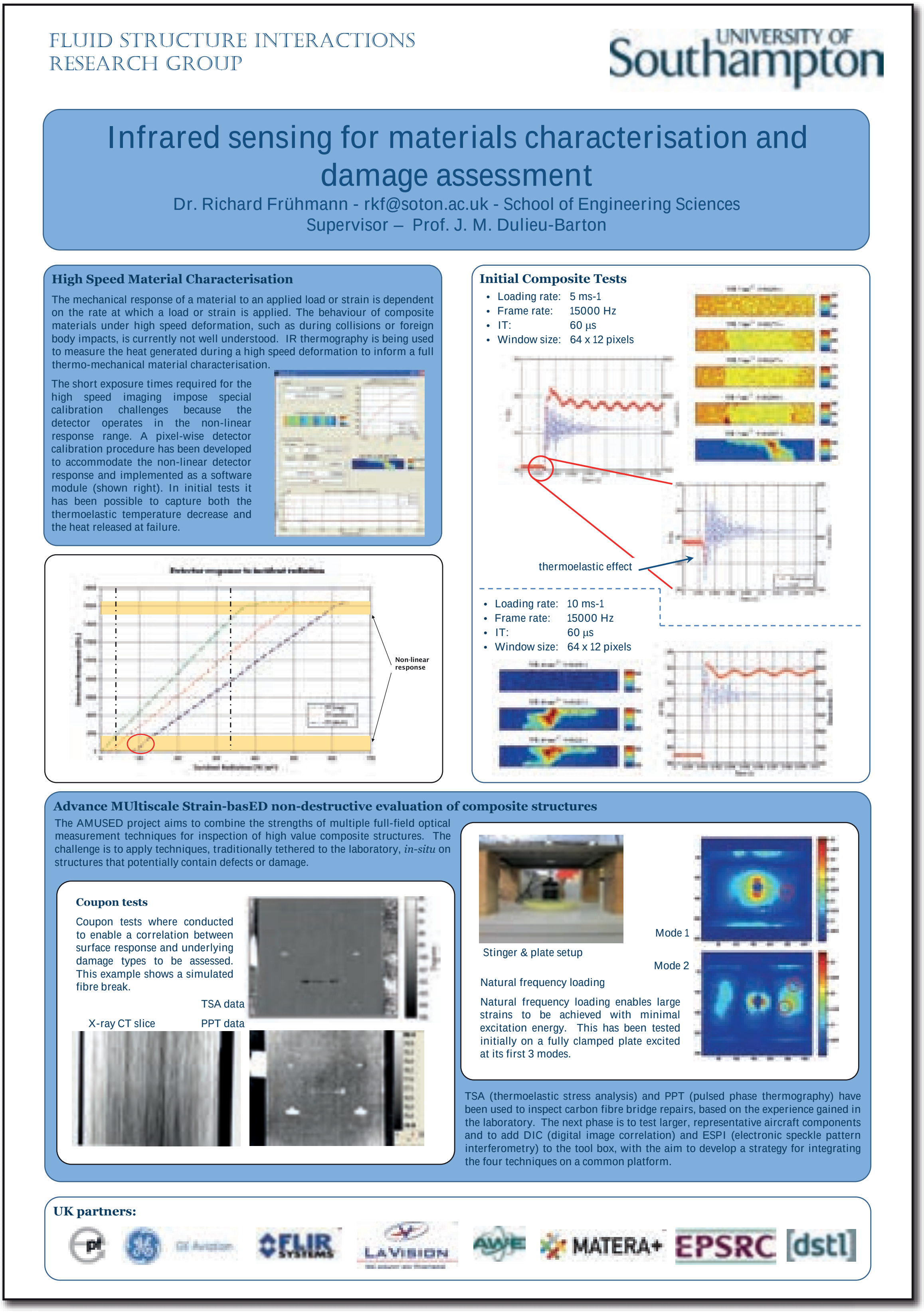
Infrared Sensing for Materials Characterisation and Damage Assessment

Professor J Barton

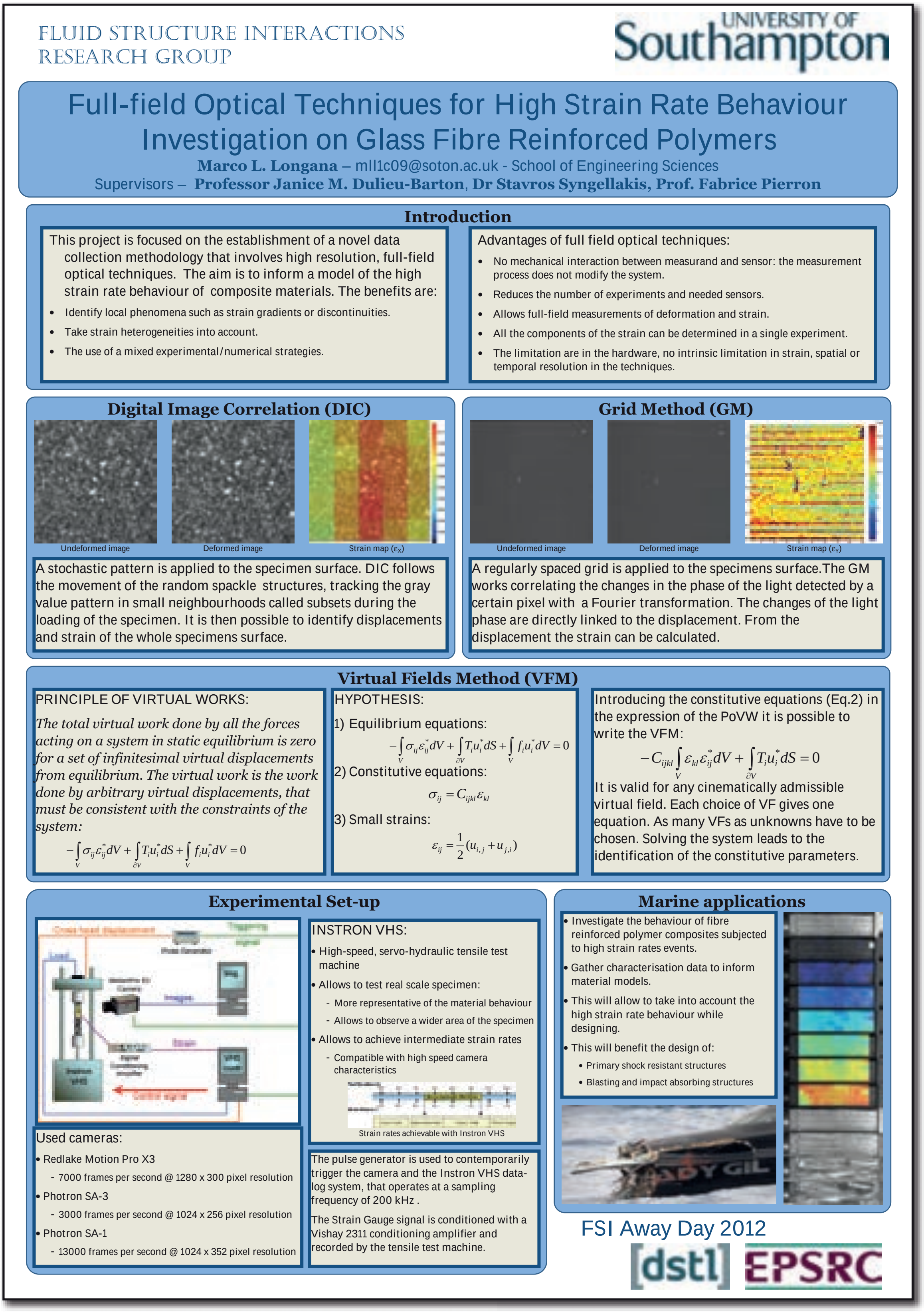
TT16



Full-Field Optical Techniques for High Strain Rate Behaviour Investigation on Glass Fibre Reinforced Polymers

Professor J Barton

TT17



The Use of Optical Techniques to Assess the Performance of Composite Materials under High Velocity Deformations

Professor J Barton

TT18

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The Use of Optical Methods for the Study of Composite Materials Under High Velocity Deformations

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G.Battams@soton.ac.uk

Motivation

- Composite materials are increasingly being used in a variety of land, sea and air applications where they are liable to encounter various types of high strain rate events, such as those shown in Figures 1 and 2.
- Such events may cause structural failure or cause damage which may reduce performance and service life.
- Modern advances in CCD technology have allowed the potential for optical techniques to be used to study high strain rate events.
- The purpose of this work is to develop a methodology for the high strain rate testing of composite materials using optical techniques with a focus on the subsequent study of damage propagation and remnant life.

Figure 1: Bird strike on a wind turbine

Figure 2: Hail impact on an aircraft nose

Objectives

- To investigate the variables and compromises required during high speed white-light imaging and their effect on data accuracy and quality
- To develop a rig that is capable of applying a known level of high strain rate damage to a composite specimen without total specimen breakage
- To determine the remnant life of such damaged specimens and to use this data to develop material models over a range of strain rates and materials
- To investigate high strain rate damage initiation mechanisms and the subsequent heat evolution and surface strain maps

Figure 3: Photron SA1 high speed white light camera and CEDIP Silver 480M infra red camera

High strain rate damage initiation

- A rig was designed to allow a high strain rate tensile load of known magnitude to be imparted to composite specimens.
- Shear pins of known geometry are loaded in series with a composite specimen such that damage is initiated but total failure does not occur.
- Calibration tests are required to determine the precise shear pin failure load according to actuator velocity and pin dimensions.
- Elastic springback was found to occur which loads the specimen in compression. A further rig design will be developed to prevent such behaviour.
- Damaged specimens will then be tested under cyclic loading to investigate the damage propagation response.

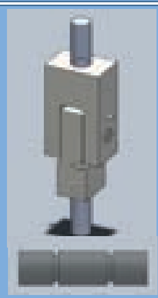

Figure 4: High strain rate damage initiation rig

Damage Initiation Tests

Initial tests have been conducted on assessing the viability of using high speed imaging and digital image correlation (DIC) to analyse the surface strains up to failure during quasi-static tensile tests.

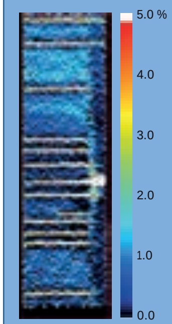

Figure 5: DIC derived longitudinal strain map

- DIC has been proven to be able to image the formation transverse cracking during the quasi-static tensile test of an [90,0,90,0]s specimen as shown in the strain map in Figure 5.
- Future damage initiation tests using the new rig design will aim to maximising the available sensor area to achieve similar spatial resolutions.
- Synchronous high speed infra red imaging will also be used to provide information on surface temperature increases, indicating the occurrence of damage.

Damage Propagation Tests

Tests will be conducted to use the full field techniques of DIC and thermoelastic stress analysis (TSA) to study how damage propagates in pre-damaged specimens.

- Damaged and undamaged samples will be placed under cyclic loading to propagate further damage.
- TSA will be used to provide a full field measure related to surface stress sum. Figure 6 shows how TSA has been used to image the progression of damage as the mean load is increased.
- DIC will be used to provide a surface strain map over the cyclic strain range.
- The two techniques will be combined to provide a full-field damage metric describing damage propagation across a range of composite materials.

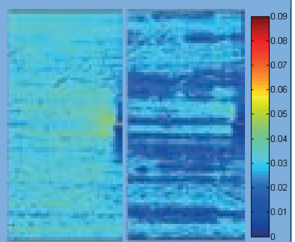

Figure 6: TSA images showing $\Delta T/T_0$ plots. A reduced thermoelastic output can be seen as damage progresses.

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Acknowledgement: This project is supported by funds from the **Engineering and Physical Sciences Research Council** and **Defence Science and Technology Laboratory**

Synchronised IRT and DIC capture to Measure the Strain Rate Dependency of Fibre Reinforced Composites

Professor J Barton

TT19

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Synchronised IRT and DIC capture to measure the strain rate dependency of fibre reinforced composites

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Motivation

- The military use composite materials in land, sea and air vehicles in high performance applications, to assist with speed and maneuverability.
- Collisions or blast loads (Figures 1 and 2) cause high strain rate events to occur, that may cause the composite structure to fail completely or to suffer damage that reduce service life
- To reduce the risk of catastrophic failure after a high strain rate event it is important to fully understand the structural performance of polymer composite materials and structures under such loading.
- It is known that the behaviour of composite materials is dependent upon the strain rate, and that during the formation of damage a temperature change occurs within the material.

Figure 1: Bird strike on aircraft nose

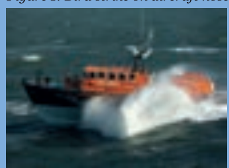

Figure 2: Slamming on RNLI lifeboat

Objectives

1. Develop high strain rate testing facilities at University of Southampton.
2. To develop digital image correlation (DIC) procedures for capturing deformations at high velocity based.
3. To obtain a full field picture of the temperature evolution during the high strain event using infra-red thermography (IRT).
4. Develop the use of simultaneous IRT and DIC at high framing rates.
5. To provide a thermomechanical characterisation of the material performance using experimental data to validate existing measured data and models.
6. To use full-field techniques to assess the performance and damage tolerance of materials after experiencing high strain rate events.

Intermediate strain rate – VHS Instron machine

Figure 3: VHS Instron test machine

- Tensile coupons up to 20 m/s
- Strain rates up to 10^2 s^{-1}
- Test times between 1 – 15 ms
- Load recorded using 80 kN Kistler load cell
- Inertia removed using slack adaptor designed in-house
- Enlarged protective enclosure allows several optical systems to be used simultaneously
- All optical and data acquisition systems triggered by central pulse
- GFRP crossply with 0° and 90° surface plies with wasted section to ensure failure capture
- High speed images at 5 kHz over 512 x 256 pixels
- IR images at 15 kHz over 64 x 12 pixels

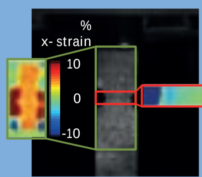

Figure 4: Example results from crossply GFRP specimen, DIC - green box and IRT - red box

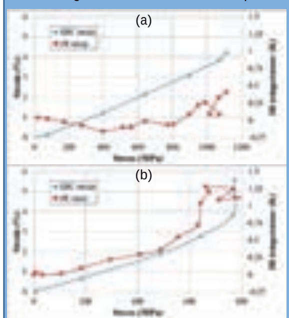

Figure 5: (a) 0° surface, (b) 90° surface ply

- Figure 4 shows high speed image of 0° specimen, with DIC and IRT data at 20 ms (14 kN) superimposed.
- Figure 5 plots DIC strain and IRT temperature vs stress at the image mid-point.
- DIC strain show linear relationship to stress for both specimens.
- IRT temperature both indicate an initial drop
- Towards failure temperature is higher for 90° specimen

High strain rate – Split Hopkinson pressure bar

Figure 6: Split Hopkinson pressure bar rig

- Striker velocity up to 30 m/s
- Strain rates in the 10^3 s^{-1}
- Designed around composites
- Strain gauge signal captured by Picoscope at 20 MHz.
- Five CFRP crossply specimens (10 x 10 mm) tested at ~13.5 m/s
- Strain rate of ~ 1000 s^{-1} achieved
- Using the Hopkinson analysis on signals from strain gauges mounted on the incident and transmission bars the stress/strain curves in Figure 7 were obtained.

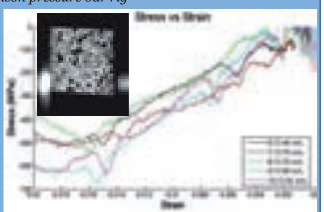

Figure 7: CFRP crossply at ~ 1000 s^{-1}, inset is an example of high speed image of speckled surface

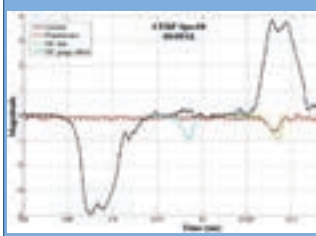

Figure 8: Example of incident, reflected and transmission pulses together with timing of DIC data

- Figure 8 demonstrates the ability to trigger high speed camera adequately to obtain DIC aligned temporally with testing pulse.
- Further work to improve specimen alignment and hence test consistency
- Extend the SHPB to soft materials such as foam with polymeric and hollow transmission bars

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Acknowledgement: This project is supported by funds from the **Engineering and Physical Sciences Research Council** and **Defence Science and Technology Laboratory**

Permeability and Cure Measurements in the Vacuum Assisted Resin Infusion Process for Validation of PAM-RTM Simulation

Dr S Boyd

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Permeability and Cure Measurements in the Vacuum Assisted Resin Infusion Process for Validation of PAM-RTM Simulation

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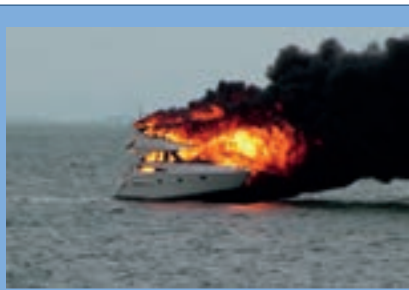
Background

This study investigates permeability and cure kinetics in the context of vacuum assisted resin infusion (VARI). The approach is taken as an alternative to the generally accepted permeability measurements based on the Resin Transfer Moulding (RTM) technology. This research forms part of an EPSRC project on novel fire resistant resin systems for the marine industry [1].

A multi-thermocouple system is presented and used to monitor the flow front advancement in the VARI process. The thermocouples are low-cost and durable; and demonstrated their ability to detect the flow front position without needing any temperature difference between the preform, the resin and the mould. Also, the thermocouples provide an in-built monitor of the cure period of the resin after the infusion process. PAM-RTM, a 3D simulation software package developed by the ESI Group, has been selected for simulating the resin flow and modelling the cure.



Analysis of the Vacuum Assisted Resin Infusion Process

The compaction pressure of the flexible vacuum bag and the resin pressure can significantly influence the resin permeability, fibre volume fraction (V_f) and the reinforcement properties.

Important parameters:

- Compaction of preform: dry and wet states
- Viscosity of resin
- Porosity of preform $(1 - V_f)$
- Flow front advancement
- Pressure gradient

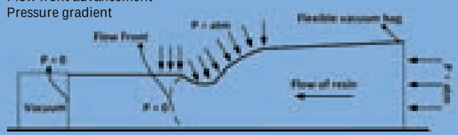


Figure 1: Compaction mechanism in the VARI process

PAM-RTM Simulation

The flow simulations are based on the classical Darcy`s law approach coupled with the continuity equation using a low Reynolds number Newtonian incompressible flow model under the isothermal conditions in the VARI module of PAM-RTM 2010 software.

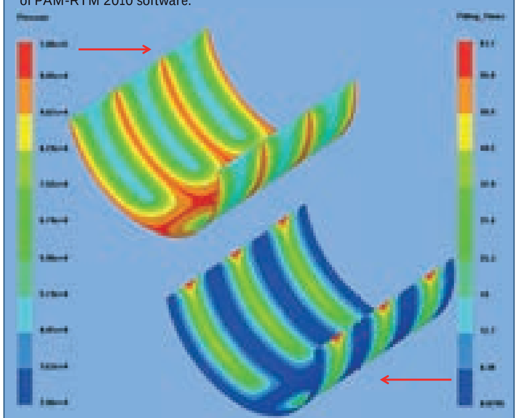


Figure 2: A case study presenting the pressure and filling times in the VARI process

Aims

- Analysis of the VARI process and identifying the process parameters.
- Development of an experimental setup.
- Measurement of the permeability of non-crimp glass fibre preforms in the VARI process.
- Monitoring of the cure experimentally.
- Infusion and cure simulations of the VARI process with PAM-RTM simulation software.
- Studying the processability of novel fire resistant resin systems.

Experimental Setup

- A compaction test rig is necessary to simulate the VARI process (Figure 3)
- Multi-thermocouple system for monitoring flow front and cure (Figure 4)
- Monitoring of thickness change (LVDT)
- In-built pressure sensors
- Monitoring of flow rate
- Camera

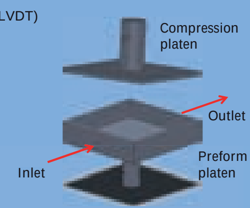


Figure 3: Preform compaction test rig

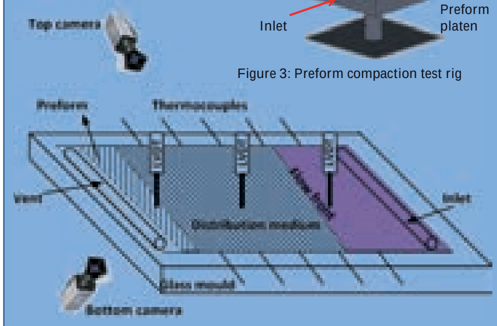


Figure 4: Monitoring methodology of the VARI process

References

[1] http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/H020926/1

Acknowledgement: This project is supported by the EPSRC Grant Number: EP/H020926/1

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Thermal Degradation of Polymeric Foam Cored Sandwich Structures

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Background

- Polymeric foam cored sandwich structures are being widely used in wind turbine (see Figure 1), naval, transportation and civil industries.
- At elevated temperatures, the linearity, stability and failure mode/strength of sandwich structures could be altered due to the degradation of material mechanical properties together with the mismatch of thermal expansion as shown in Figure 2 [1].
- The thermo-mechanical interaction on sandwich structures is not well understood at present, especially in the viewpoint of experimental validation.

Aims

- Develop a methodology to obtain the elastic properties of polymeric foam materials at elevated temperatures using DIC (digital image correlation).
- Construct an experimental system to characterise the thermo-mechanical interaction on polymeric cored sandwich structures; validate the behaviour predicted by the high-order sandwich panel theory [1].

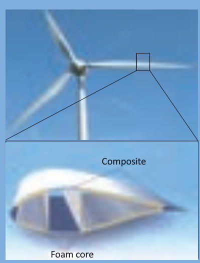

Figure 1: Application of sandwich structures on wind turbine blades

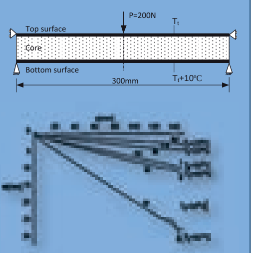

Figure 2: Behaviour of a sandwich beam at elevated temperatures [1]

Experimental apparatus

- The experimental apparatus to study the thermo-mechanical behaviour of sandwich structures is shown in Figure 4.
- Sandwich beam specimens were manufactured with a 25 mm thick Divinycell H100 PVC foam core and 0.9 mm thick aluminium face-sheets/0.8 mm thick E_glass/Epoxy composite face-sheets. The specimen length and width were 450 mm and 50 mm, respectively.
- A three-point bending load was applied to the specimen. The ends of the specimen was constrained in three different manners: only constrain the vertical displacement of the bottom surface (BC1); constrain both vertical and horizontal displacements of the bottom surface (BC2); in addition to BC2, constrain the horizontal displacements of the top face-sheet (BC3). The full-field deformation of specimen was characterised using DIC.
- An infra-red lamp was used to heat the top face-sheet of the sandwich beam specimen. The temperature distribution was monitored by an infra-red camera. A linear temperature gradient was achieved through the specimen thickness.

Figure 4: Experimental apparatus to study the mechanical behaviour of sandwich structures with a thermal gradient through the specimen thickness

Temperature dependence of foam material

- A novel methodology based on DIC was developed to characterise the temperature dependence of the elastic properties (tensile, compressive, shear) of polymeric foam materials [2].
- This methodology was verified with good repeatability and can be applied for most polymeric foam core materials.
- Figure 3 shows the thermal degradation of elastic properties of Divinycell H100 PVC foam. The normal and shear moduli reduce linearly with increasing temperatures from room temperature to 70°C, and then significant non-linear reduction occurs. At 90°C, the stiffness has reduced by over 50%.
- The thermal degradation behaviour was found to depend only on the properties of the base polymer material rather than the cell structure. A master curve to describe the thermal degradation path of foam Divinycell H100 – H200 using a combination of a linear and second order polynomial was proposed:

$$E(T)=\begin{cases} E(T_0)*(-6.2*10^{-3}T+1.1631) & T\le 70^{\circ}C \\ E(T_0)*(-5.46*10^{-4}+7.03*10^{-2}-1.51) & T>70^{\circ}C \end{cases}$$

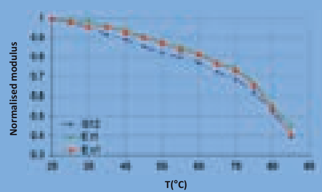

Figure 3: Normalised thermal degradation path of tensile, compressive and shear modulus of Divinycell H100

Results and discussion

- Initially, the influence of temperature on the load-deflection behaviour was studied, as shown in Figure 4. The specimen was constrained in BC1 manner and subjected by a load of 1 kN at the mid-span.
- The experimental result agrees well with the corresponding FE study. It was concluded that the overall bending stiffness reduces greatly with increasing temperature due to the stiffness loss of the core material.
- Future work will focus on validating predictions of the non-linear geometrical deformation triggered by elevated temperatures. The influence of temperature on the failure mode and failure strength will also be investigated.
- This work will form the first experimental characterisation of the thermo-interaction effects on sandwich structures.

Figure 4: Mid-span deflection of a sandwich beam at different temperatures; (top: top face-sheet, bot: bottom face-sheet)

References:

1: Frostig, Y. and O.T. Thomsen, Non-linear thermal response of sandwich panels with a flexible core and temperature dependent mechanical properties. Composites Part B: Engineering, 2008. 39(1): p. 165-184.

2: Zhang, S., Dulieu-Barton, J., Fruehmann, R.K. and Thomsen, O.T., A Methodology for Obtaining Material Properties of Polymeric Foam at Elevated Temperatures. Experimental Mechanics, 2011. Online first: 1-13.

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Hygrothernal Ageing and the Implications on Adopting Sustainable Composite Materials for Structural Marine Applications

Dr J Blake

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Hygrothermal ageing and the implications on adopting sustainable composite materials for structural marine applications

Mari Malmstein – M.Malmstein@soton.ac.uk
Supervisors: **Dr. James Blake** and **Dr. Alan Chambers**

BACKGROUND

Exposing composite materials to the marine environment tends to degrade the material's mechanical properties. Recently, new sustainable materials have been introduced due to environmental concern and societal awareness. However, the high structural performance end of the market seen in the marine industry (Figure 1) has little confidence in the performance of these emerging materials. Manufacturing petroleum based resins has higher environmental impact than fibres. Hence, this research seeks to determine the viability of using glass fibre reinforcements with two candidate plant oil-based resins, linseed oil and castor oil resins (Figure 2), for marine structures.

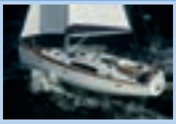

Figure 1: example application for sustainable composites – Beneteau Oceanis

Figure 2: castor oil resin

AIM & OBJECTIVES

The **aim** of the project is to investigate the issues of environmental degradation and durability of composite materials in the marine environment.

This leads to the following **objectives**:

- Investigating the effect of water uptake on the durability of glass reinforced natural resins in comparison to epoxy resin through accelerated conditioning tests (hygrothermal ageing);
- Increasing the understanding of the processes behind the reduction of mainly flexural properties of composite materials;
- Using visual inspection techniques to relate moisture uptake and storage areas to the failure modes of composites.

METHODOLOGY

Ageing →	Accelerated ageing (36 weeks)	Non-accelerated ageing (16 weeks)
Water	Distilled	Distilled & salt
Water temp	40 °C	20 °C
Specimens	Glass/epoxy, castor & linseed oil	Glass/linseed oil

- Flexural tests were carried out with 2 week intervals for the first 10 weeks of ageing to monitor reduction of properties
- Computed tomography and scanning electron microscope were used to investigate the changes in flexural failure modes due to moisture uptake in glass/epoxy and glass/linseed oil

FLEXURAL PROPERTIES

Accelerated ageing

- Water uptake of glass/epoxy reaches moisture equilibrium content after 6 weeks of immersion, glass/castor oil after 25 weeks (Figure 3); up to 6 weeks of immersion the water uptake of glass/epoxy and glass/castor oil is very similar
- The moisture uptake of glass/linseed oil kept increasing even after 36 weeks of immersion (Figure 3) due to blistering

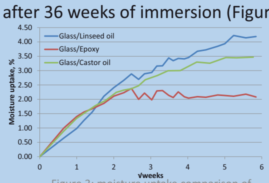

Figure 3: moisture uptake comparison of glass/epoxy, glass/linseed and glass/castor oil

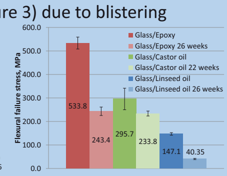

Figure 4: reduction of flexural strength over 20+ week ageing period

- The flexural properties of glass/castor oil compared better to glass/epoxy than glass/linseed oil (Figure 4), especially after ageing
- Degradation of glass/linseed oil was most rapid during the first 2 weeks of ageing

Non-accelerated ageing

- Non-accelerated ageing showed that reduction of flexural strength is related to water content rather than water temperature or chemistry (Figure 5)

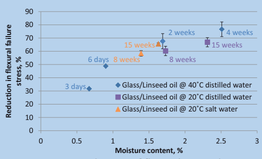

Figure 5: reduction of flexural strength vs. moisture uptake under accelerated and non-accelerated conditions

VISUAL INSPECTION

Computed tomography (CT)

- CT provides 3D overview of the damage occurring inside the materials after flexural failure
- Failure of glass/epoxy changes from a tensile/compressive mode into a tensile failure after 10 weeks of ageing (Figure 6)

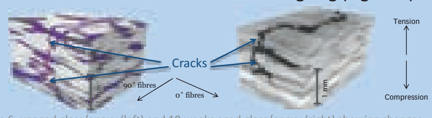

Figure 6: unaged glass/epoxy (left) and 10 weeks aged glass/epoxy (right) showing changes from tensile/compressive into a tensile failure mode

- Failure of glass/linseed oil changes from a tensile/compressive mode into a compressive one after 3 days of ageing (Figure 7)

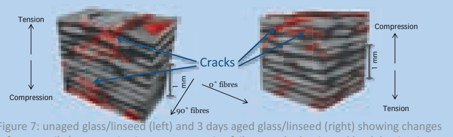

Figure 7: unaged glass/linseed (left) and 3 days aged glass/linseed (right) showing changes from tensile/compressive into a compressive failure mode dominated by delamination

Scanning Electron Microscope (SEM)

- SEM showed that in glass/epoxy specimens the interface has degraded already after 3 weeks of immersion

Figure 8: unaged (left) and 3 weeks aged glass/epoxy (right). Clean fibres in aged material indicate interfacial damage

CONCLUSIONS

Moisture uptake causes rapid loss of strength in all tested materials. Glass/castor oil compares better to glass/epoxy than glass/linseed oil. The reduction of strength can partially be attributed to changes in flexural failure modes due to water ingress. While the failure of glass/epoxy remains mainly tensile/fibre dominated, the failure of glass/linseed oil changes from a tensile/compressive into a compressive failure.

FUTURE WORK

Investigating the possibility of using CT for detecting moisture storage areas and relating them to the failure modes.

Sustainable Composites Ltd and Bioresin are acknowledged for providing the natural resin systems
IMarEST is acknowledged for providing additional funding for the project

FSI Away Day 2012

Modelling Characterisation and Development of New Magnetorheological Materials with Enhanced Vibration Control Performance

Dr Y Xiong

TT23

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Modelling, Characterisation and Development of New Magnetorheological Materials With Enhanced Vibration Control Performance

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Background

Magnetorheological elastomers (MRE) are solid materials composed of magnetisable (usually iron) particles suspended in a low permeability carrier matrix (usually rubber). They are the solid equivalent of magnetorheological fluids that already find applications in vibration isolation systems. In the presence of an external magnetic field the particles are magnetized and form chains while trying to align in the direction of the field. As a consequence the viscoelastic behaviour of the material can be controlled. In vibration control system design, materials with dynamically variable stiffness and damping, like magnetorheological elastomers, could be useful tools. When an external field is applied to the MR elastomer during curing, the filler particles tend to align parallel to the direction of the magnetic field forming anisotropic elastomers. On the other hand, when the elastomer is cured without the presence of the field the particles are randomly dispensed inside the matrix forming an isotropic material.

Aims

- Investigate the mechanical characteristics of the MR elastomers
- Develop a mathematical model capable of predicting the response of the material
- Manufacture a vibration isolator prototype device for marine applications

Material Characterisation

The mechanical properties characterization of silicon MR elastomers were performed under static and dynamic loading conditions for a range of frequencies and amplitudes following the directions of British standard BS ISO 4664-1:2005 for compression loads in rubber.

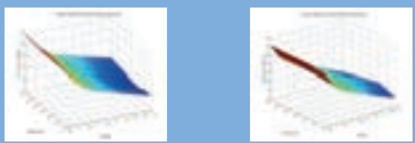


Figure 2: Modulus E of anisotropic MRE at zero field and 0.3T magnetic field

Figure 3: Damping factor tand of anisotropic MRE at zero field and 0.3T magnetic field

Figure 4: Damping factor tand of isotropic MRE at zero field and 0.3T magnetic field

Figure 5: Modulus E of isotropic MRE at zero field and 0.3T magnetic field

Modelling Methodology

MR elastomers, are governed by a nonlinear stress-strain relationship with a complex modulus of elasticity that depends weekly on the frequency and strongly on the applied magnetic field. To model the material the simple Kelvin Voight viscoelastic model is used where both stiffness and damper are amplitude, frequency and magnetic field dependent.

Figure 1: Kelvin Voight viscoelastic model

Storage modulus $E'(e,\omega,B) = K(e,\omega,B)$

Loss modulus $E''(e,\omega,B) = c\omega(e,\omega,B)$

Damping factor tand= $\frac{E''}{E'}$

$$E'(e,\omega,B) = \sum_{i=0}^{N} a_i(\omega,B) exp^{b_i(\omega,B)\, e} \qquad E''(e,\omega,B) = \sum_{i=1}^{N} c_i(\omega,B) exp^{d_i(\omega,B)\, e}$$

e=strain amplitude, ω=2 π f, B= intensity of the magnetic field

Where $a_i(\omega,B) = \sum_{j=0}^{M-i} p_{ij}(B)\left(\frac{\omega}{2\pi}\right)^j$ $\qquad b_i(\omega,B) = \sum_{j=0}^{M-i} q_{ij}(B)\left(\frac{\omega}{2\pi}\right)^j$

and $p_{aij}(B) = \sum_{l=0}^{L} pa_{ijl}B^l$ $\qquad pc_{ij}(B) = \sum_{l=0}^{L} pc_{ijl}B^l$

Transmissibility of a SDOF system

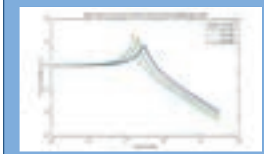
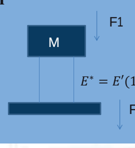


Figure 6: Transmissibility curves for isotropic MRE at different strain amplitudes



$E^* = E'(1 + j\, tand)$

$$T = \left|\frac{F_2{}^*}{F_1}\right| = \sqrt{\frac{1 + tand_\omega{}^2}{\left|1 - \left(\frac{\omega}{\omega_n}\right)^2\left(\frac{E'|_{\omega=\omega_n}}{E'_\omega}\right)\right|^2 + tand_\omega{}^2}}$$

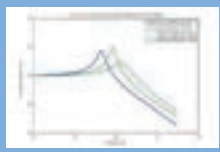


Figure 7: Transmissibility curves for anisotropic and isotropic MRE at zero and 0.3T field

Conclusion

- Isotropic MREs have a higher MR effect than anisotropic MREs
- When the field is applied the natural frequency and damping factor changes
- Transmissibility and damping factor depends heavily on the amplitude of the applied force and thus a nonlinear model is needed

Further Work

- Manufacture natural rubber MRE
- Investigate the dynamic properties of MRE under multi loading conditions
- Derive a constitutive equation model for both types of MRE
- Design and manufacture a semi active vibration isolation device and the appropriate control system

This project is funded by:

Lloyd's Register Educational Trust

UNIVERSITY OF Southampton

FSI Away Day 2012

Crust Formation on Natural Rubber

Professor G Hearn

TT24

FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

University of Southampton

Crust Formation On Natural Rubber

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Motivation

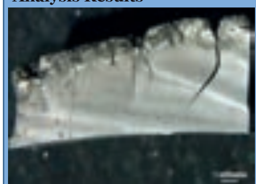
• Accelerated ageing tests suggest no crust would be formed at ambient temperature (Lindley & Teo, 1977). This conflicts with some observations on naturally aged natural rubber (NR).

Objectives

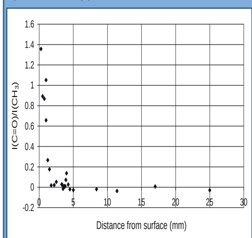
• Characterise the crust that has formed on rubber aged naturally over a period of 80 years.
• Probe the chemical and physical character of the crust and interpret the results to assess the significance of hypothetical mechanisms
•Seek to resolve the conflict with extrapolation from accelerated ageing tests by identifying the primary mechanism and modelling it.

Bramfield tyre: aged ~80 years in woodland

Analysis Results



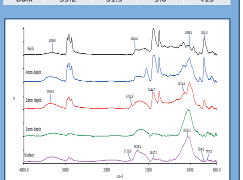
Section showing the hard layer and cracks into the transition layer (~4mm deep)



Normalized C=O intensity, at different distances from the surface (left) to bulk (right)

Table: TGA weight loss and T_{max}

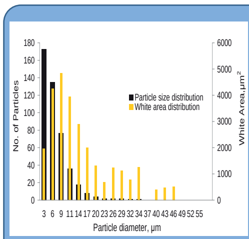
	Rubber (wt%)	Black (wt%)	Ash (wt%)	Tmax
Surface	47.2	47.7	5.0	445
1-3mm	55.0	38.3	5.4	446
5-7mm	59.5	31.5	8.6	418
Bulk	59.2	31.9	9.0	413



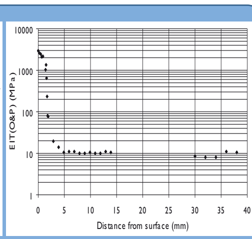
FTIR spectra from different depths (labelled in mm) into rubber

Table : IR Peak ratios /CH_2 backbone (1460-1450cm^{-1})

	3360 cm^{-1} -OH	1708 cm^{-1} C=O ketone	1014 cm^{-1} C-O	831 cm^{-1} C=CH
Surface	1.67	0.67	8.3 with silica	0.33
1mm	1.00	0.33	8.67 with silica	0.67
2mm	0.35	0.29	1.65	0.59
4mm	0.22	0.04	0.89	0.96
Internal bulk	0.07	<0.01	<0.30	0.63



Distribution of particle diameters and total area contribution of each tranche of particles



Reduced modulus from micro-indentation according to the analysis of Oliver & Pharr (1992)

Discussion

UV light catalyses oxidation, but doesn't penetrate deeply:

$$\frac{dI}{dx} = -KI \quad \text{where} \quad K = \frac{\varphi}{L} \cong \frac{0.2}{0.5\mu m}$$

where I is intensity, φ is volume fraction of black and L is effective length scale of black agglomerates

I falls to 1% after only ~12mm.
Ozone is too low in concentration and too reactive to penetrate more than ~0.5μm.
Only oxidation could penetrate as deep as ~1mm to form the crust; with ozone attack, photo-oxidation and loss of scission products by leaching and evaporation contributing to microcracks at the surface.
General model for diffusion-limited oxidation:

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(D(m(t,x))\frac{\partial c}{\partial x}\right) - r(m(t,x))c^n$$

$$m(t,x) = \int_0^t r(m(t,x))c^n dt$$

Needs to be solved numerically, but analytical solutions exist if D and r are at least piecewise constant, that is :

(i) On moving front,

$$n = 0 \text{ and } \begin{array}{ll} r(m(t,x)) = r_o & \text{for } m(t,x) < m_\infty \\ r(m(t,x)) = 0 & \text{for } m(t,x) = m_\infty \end{array}$$

(ii) In steady state,

$n = 0$ and $r = r_0$

(iii) In steady state,

$n = 1$ and $r = r_0$

Conclusions

➢ A crust ~1mm thick has formed on NR aged naturally over 80 years in conflict with the extrapolation of Lindley & Teo (1977).
➢ Ozone attack and photo-oxidation could only degrade a layer a few microns thick.
➢ The primary mechanism determining thickness is oxidation.
➢A model based on diffusion limited oxidation is being developed.

References:
Lindley ,P.B and Teo,S.C., (1977), "High temperature ageing of rubber blocks ", Plastics & Rubber:Materials & Applications, **2**, 82-88
Li G.Y., Keong J.L., (2005), "A review of rubber oxidation", Rubber Chemistry Technology, **78**, 355-389

Acronym:
TGA= Thermogravimetric Analysis, FTIR=Fourier Transform Infrared Spectroscopy (FTIR) , IR = Infrared

Acknowledgement:
This project is supported by funds from the Malaysian Rubber Board

FSI Away Day 2012

An Improved Concurrent Engineering Framework through Incorporation of Management Methodologies

Professor D Macbeth

TT25

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

An Improved Concurrent Engineering Framework through Incorporation of Management Methodologies

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Background

*"**Concurrent Engineering** is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements."*

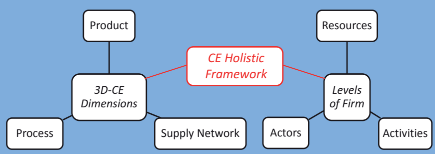
Institute for Defense Analyses (USA, 1988) [1]

In both research and practical application the wide range of action proposed in this definition of Concurrent Engineering (CE) has traditionally been reduced for the sake of practicality: first to an integration between the Design and Production functions of a company, then life cycle considerations were incorporated, and lately 3D-CE has also included Supply Chain Management. Our intent is to bring together Engineering and Management to define the wider scope that is still missing.

Aims & Objectives

The aim is to incorporate Management tools and practice into the theoretical body of Concurrent Engineering. In order to do this a characterisation of the state-of-the-art of CE, and an investigation into parallel research areas in Management are needed.

- Develop a holistic framework representing the scope and mapping the processes involved in CE.
- Define framework cells in detail by correlating the 3D-CE dimensions [2] with the three levels of the firm in *Industrial Network Theory* [3]:



- Compile a first expansion of the general framework in terms of resources by reflecting the state-of-the-art theories and tools available in each area.
- Classify said tools by purpose: Analysis, Synthesis and Evaluation [4].
- Arrive at a second expansion of the general framework that reflects the roles of the different actors, individual employees and departments, in interaction, and the value of the company's portfolio of relationships [5]
- Perform a gap analysis of available Concurrent Engineering and Management tools
- Determine a methodology for integrating management tools into Concurrent Engineering

Activities: CE Holistic Framework

Development of the CE Holistic Framework, seen below, centres around the idea that the 3D-CE dimensions share the same decision making structure , thus highlighting the existing opportunities for new ideas, better communication and collaboration.

The Life Cycle stages originate from CE , which has traditionally focused on Product Design. The stages can also be used to define a post-decision process covering consequences and implications in the Management dimensions. The life cycle phases are:

- ***Inception***: Generation of ideas
- ***Basic Development***: Ideas develop into general principles
- ***Detailed Development***: General principles result in a solution/decision
- ***Production***: The solution/decision is implemented
- ***In-service***: The solution/decision is in place requiring maintenance/active monitoring
- ***End-of-life***: End of application

The general framework expands Supply Chain to Supply Network to incorporate the internal structure of the focal company, which could be at any point along the traditional chain, and to map the customer sub dimension explicitly.

Resources: Tools Expansion

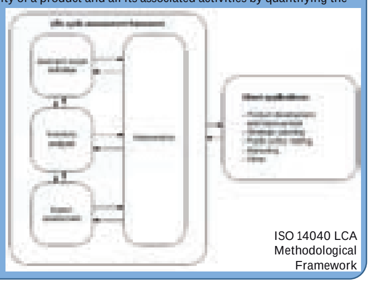
The general framework has been expanded into resources, tools and methodologies, to close the gap between opportunity awareness and fulfilment. This collection of tools is classified by purpose into Analysis, Synthesis and Evaluation in each framework cell.

Life Cycle Tools

An example of a resource which is an integral part of CE are Life Cycle Tools. They evaluate the sustainability of a product and all its associated activities by quantifying the following impacts:

- Economic: ***Life Cycle Cost (LCC)***
- Environmental: ***Life Cycle Assessment (LCA, E-LCA)***
- Social: ***Social Life Cycle Assessment (S-LCA)***

The expanded framework covers their evolution through the above life cycle stages.



ISO 14040 LCA Methodological Framework

CE Holistic Framework

Conclusions and Future Work

The literature review has shown that there is potential for collaboration between Engineering and Management. Theories in both disciplines pursue the same objectives, but because they use different vocabularies and methodology styles their application in conjunction is limited. The framework presented here is intended to bypass this communication difficulty.

Our next steps will be:

- Completion of the framework documents, including finding a categorisation of actor roles equivalent to Analysis, Synthesis and Evaluation for tools.
- Validation of current research through interviews with industrial partners
- Gap analysis to identify opportunities for future research
- Development of a new methodology to incorporate available management tools into Concurrent Engineering

References:

[1] Institute for Defense Analysis (IDA), Report R-338, "The Role of Concurrent Engineering in Weapons System Acquisitions", 1988.

[2] C. H. Fine, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, 1998 Perseus Books Group, New York, USA.

[3] Gadde, Hakansson and Persson, *Supply Network Strategies*, 2nd Edition, 2010, John Wiley & Sons Ltd, Chichester, UK.

[4] P. Farias, J. Aca, A. Molina, H. Maury, C.Riba, "Evolución de los modelos del proceso de diseño", *Ingeniería Concurrente: Una metodología integradora*, 2006, C.Riba and A.Molina, Universitat Politécnica de Catalunya, Spain.

[5] J. Tikkanen and A. Halinen, "Network Approach to Strategic Management – Exploration of the Emerging Perspective", Turky School of Economics and Business Administration, University of Turku, Finland, 2003.

FSI Away Day 2012

Professor RA Shenoi

Communities

UNIVERSITY OF Southampton

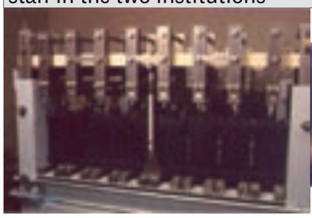
RNLI Advanced Technology Partnership

Maritime Engineering Sciences and Maritime Safety

Context

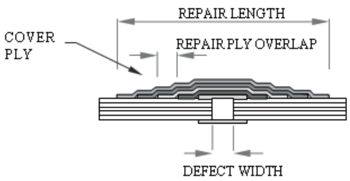
The purpose of this venture is to create an environment and culture for co-operative research and education within the RNLI and the University on maritime engineering subjects of common interest to the two institutions.

The objectives are to: (a) To conduct fundamental research in engineering disciplines pertinent to the design, manufacture and operation of lifeboats and associated engineering systems, where possible and desirable through collaborative endeavours with other organisations utilising leveraged funding from those sources (b) To apply such knowledge to the solution of potential and practical problems in the design and operation of lifeboats and associated engineering Systems; (c) To disseminate such knowledge and good practice to RNLI and UoS audiences and to the wider community outside; and (d) To facilitate technology transfer between RNLI and UoS and continuous professional development of staff in the two institutions

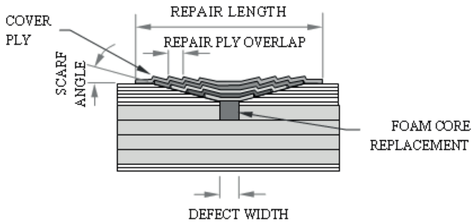


Example Projects

- Fatigue behaviour sandwich structures
- Hygrothermal ageing of sandwich tee joints
- Repair of sandwich plates and beams
- Principles underpinning of RIB design
- Life extension of composite structures and boats
- Behaviour of composite sandwich plates under fire



(a)



(b)

Impact

The impact of this work has been four-fold:

- Fatigue design procedure for lifeboats
- Repair manual for the RNLI fleet
- Design manual for RIBs
- Safety case format for lifeboats under extreme load events

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Professor P Temarel

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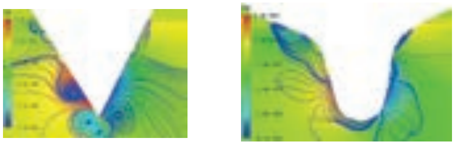
Trade / Communities

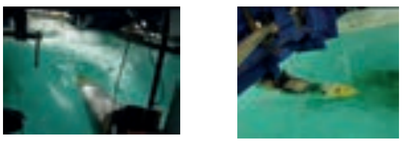
Ship Hydrodynamics: Wave-induced Motions and Loads

Research purpose/impact

Changes in ships in terms of scale and type, as well as operational, economic and environmental requirements, make the use of "first principles approach" in the global structural analysis and design of the ship more prevalent, either on its own or in combination with prescriptive rules of Classification Societies. The arrival of the Goal Based ship construction Standards and the drive for efficient and environmentally friendly operations make the development of numerical tools for the accurate prediction of wave-induced motions and loads extremely important.



Pressure coefficients on rolling shiplike sections obtained using RANS CFD



Model tests showing bow immersion in rogue waves

Research description

A range of research projects aimed at obtaining an accurate prediction of ship motions and loads, using **rigid body hydrodynamics**, **hydroelasticity** and **Computational Fluid Dynamics (CFD)**.

- G-HYdroflex: Evaluation of wave-induced motions and loads on mono- and multi-hulled vessels using two- and three-dimensional hydroelasticity analyses whereby the vessel's structure is idealised using beam or three-dimensional Finite Element idealisation and the fluid actions described using potential flow.
- Parametric roll resonance occurs in (nearly) head or following seas, due to transfer of energy from heave and pitch motions to roll. Two- and three-dimensional methods are developed, including influence of nonlinearities, to predict parametric roll.
- Inclusion of the influence of viscous effects on hydrodynamic actions of heaving, swaying and rolling sections using Reynolds Averaged Navier Stokes equations (RANS CFD). The effects are especially important for roll damping and the prediction of roll motion.
- Rogue or Freak waves are extreme events. The research focuses on their experimental and numerical generation, as well as the evaluation of wave loads for ships encountering rogue waves.

Collaborations

Lloyd's Register
The Lloyd's Register Educational Trust
Prof. P. Temarel
Prof. S.R. Turnock
Dr. D.A. Hudson
Dr. T.M. Ahmed (University of Alexandria)
Dr. S.H. Miao
Dr. S. Denchfield

Damage sustained by a Post-Panamax container ship due to parametric roll resonance

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Dr M Tan

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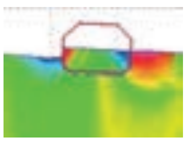
UNIVERSITY OF Southampton

Trade / Communities

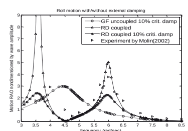
Ship Hydrodynamics: Sloshing

Research purpose/impact

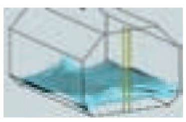
Natural gas has become an increasingly important source of primary energy for developed countries such as the UK and sea borne liquefied natural gas (LNG) is a vital component in the infrastructure for the national energy security. Because of increased demand and economies of scale, larger LNG ships and facilities are designed and built. Violent liquid motion known as sloshing in the LNG tanks due to external excitations can have significant effects on the safe operations of LNG carriers and storage tanks so it is critical to have deep understanding of sloshing and efficient modelling techniques.



Mode shape of a tank-water system (A)



Roll RAO for barge-tank coupled motion (B, E)



Sloshing simulation using URANS CFD (C)

Fluid motion in a chamfered tank (D)

Research description

Development of methodology and techniques for sloshing simulations in partially filled containers and prediction of sloshing impact with fluid structure interaction effect:

•(A) Application of a mixed finite element method for sloshing analysis with fluid-structure interactions: A variety of tank sloshing problems have been studied.

•(B) Coupling between ship motion and sloshing: A method for coupled ship motion with partially filled tanks is formulated based on potential flow theory. Added mass and motion RAOs are calculated.

•(C) A unsteady RANS model for nonlinear sloshing simulation: Modelling techniques are developed and validated utilising experimental data for high fidelity nonlinear sloshing simulations using URANS CFD.

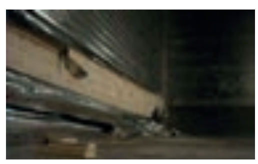
•(D) Solution of low speed two-fluid flows occurring in liquid sloshing in an enclosed container: Free surface waves due to sloshing are captured and tank wall pressure time histories are obtained.

•(E) A rapid sloshing prediction model based on analytical approach: A faster than real time method is developed using nonlinear pendulum model to predict the sloshing occurrence and severity for LNG carriers in seaway under different conditions.

Collaborations

DSME
Lloyds Register

Prof. P. Temarel	Dr M. Tan
Prof. S.R. Turnock	Prof J.T. Xing
Dr Y. P. Xiong	Dr Y. Chen
Dr B. Godderidge	Dr Y.B. Lee



Damages to the containment system on an LNG ship due to sloshing

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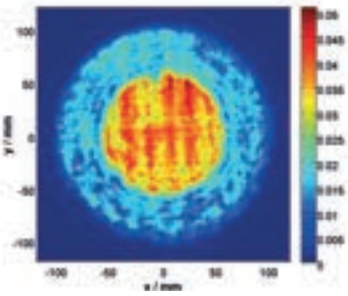
UNIVERSITY OF Southampton

Sonar System Development

Background

With an increased awareness of the potential risks to maritime trade there is a need to develop and characterise improved sonar systems capable of detecting and identifying unwanted objects in the coastal and harbour environments. These developments will also be of potential benefit in a range of other areas including the remote sensing of the marine environment.

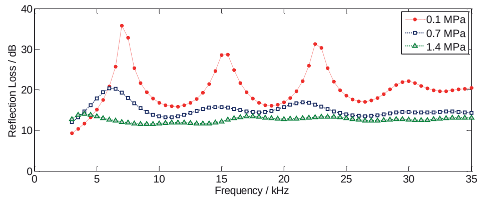


Optical measurement of the surface velocity of a circular 330 kHz transducer made with a scanning Laser Doppler Vibrometer.

Research

Research is undertaken to aid the development, improvement and characterisation of sonar systems in general. This includes studies of transducer design, material development, characterisation of sonar fields, high amplitude acoustic propagation and acoustic scattering from underwater structures and targets. In particular this research looks at:

- The performance of transducers and transducer arrays using a mixture of Finite Element (FE) modelling and analytical approaches;
- The optical measurement of the acoustic fields of high frequency underwater transducers;
- The prediction of far field characteristics of high frequency transducers from near field measurements under both linear and high amplitude (nonlinear) propagation conditions;
- The measurement or transmission and reflection properties of materials for use in sonar systems including the implementation of measurement techniques in the NPL pressure vessel;
- The assessment of composite anisotropic materials for use in sonar domes;
- The measurement and FE modelling of acoustic scattering from man-made structures in order to identify measurement techniques that may be used to improve sonar system performance.

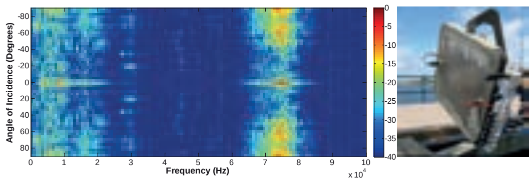


Measured results for the reflection loss of a test panel at three values of hydrostatic pressure obtained in the NPL pressure vessel using a parametric array system.

Impact

The research will aid the provision of improved systems and security measures for the protection of maritime trade and harbour security.

The techniques and understanding can also increase the commercial advantage of UK industry by providing improved knowledge, measurement techniques and systems.



Measured scattering from a target as a function of frequency and angle of incidence obtained on a trial at the NPL Wraysbury Facility. A parametric array was used to measure scattering over ranges 2-25 and 65-85 kHz.

Collaboration

Parts of this programme have been funded by the Osprey Consortium (led by QinetiQ), Dstl, DTIC and Industry.

The work on optical measurement of sonar fields is performed in close collaboration with the National Physical Laboratory.

The development of techniques for measuring the performance of sonar materials under ocean conditions using the NPL pressure vessel is being performed in collaboration with NPL, Dstl and QinetiQ.

Recent work on acoustic scattering has been funded by DTIC and has involved a consortium led by Ultra Electronics.

Victor Humphrey, Fluid Dynamics and Acoustics Group, ISVR. (vh@isvr.soton.ac.uk)

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Professor RA Shenoi

TT30

University of Southampton

Trade

Lightweight and high performance ships and boats

Research

An important factor in the increasingly competitive seaborne trade market is fuel efficient ships. Increasing energy efficiency of ships implies a reduction in the weight of the ships thus allowing them to carry more payload for the same fuel consumption or the same payload as in a heavier ship with reduced fuel consumption.
One way to achieve such weight savings is to use lightweight materials such as fibre reinforced polymer composite materials. The focus of the work in this area in Southampton has been to increase confidence in the design ability and safety of the ship structure under the extreme loads that the ships could be subjected to in hazardous sea conditions.

Impact

The fundamental research has resulted in improving industrial practice through practical guides:
•Repair manual for the RNLI fleet of lifeboat hulls
•Design manual for the use of composite materials for commercial ships
•Defence Standards (DEFSTAN) in the use of composite materials for ship construction
•Safety case for fire in the design of boats

Scientific thrust

The scientific aims of the work in this regard are:
•Better understanding of the strength and stability limits of structural configurations under monotonic, static loading
•Improved modelling ability to predict the long term durability and ageing phenomena in a marine environment
•Achieving enhanced integration of production and operational issues at the ship design stage through concurrent engineering.

Example Projects

• Static, fatigue and impact behaviour of single skin and sandwich tee joints.

•Ultimate strength of composite structures

•Reliability modelling and safety engineering of lightweight structures.

•Concurrent engineering and design-production engineering of boat structures.

•Life cycle analysis of improved structural materials and configurations.

•Thermo-mechanical behaviour of composite structures under combined fire and mechanical load conditions.

Collaborations

Collaborators and partners in this work have included Vosper Thornycroft, BAE Systems, RNLI, Lloyd's Register, QinetiQ, British Marine Federation, Shipbuilders and Shiprepairers Association, Sunseeker, Fairline, Princess Yachts, Sealine, Oyster Yachts.
Public funding for this work has come from EPSRC, DTI/TSB, MoD, EU

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Professor RA Shenoi

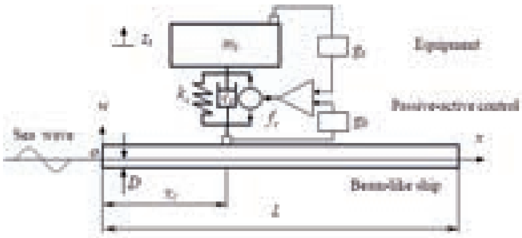
TT31

Trade

UNIVERSITY OF Southampton

Lloyd's Register Educational Trust University Technology Centre

Hydrodynamics, Hydroelasticity & the Mechanics of Composites



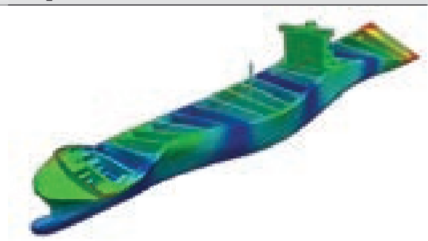
Context

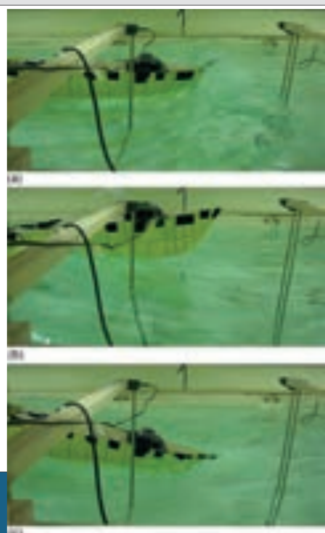
Lloyd's Register (LR) is an independent risk management organisation. The Lloyd's Register Group works to improve its clients' quality, safety, environmental and business performance. Founded in 1760 to examine merchant ships and 'classify' them according to their condition, today the organisation's expertise and activities extend far wider than the shipping field.

The objectives of the University Technology Centre or UTC, sponsored by the LR Educational Trust (LRET) are: (a) Support LR's constitutional objective of fostering research; (b) Encourage a general advance in technology in areas of interest to LR; (c) Promote closer working relationship with high quality academic institutions such as UoS; and (d) Provide opportunities for collaborative working and staff development

Example Projects

- Parametric roll of ships
- Rogue waves and influence on ship loading
- Sloshing in tanks and effect on ship behaviour
- Power flow and structural dynamics
- Reliability of composite structures
- Ultimate strength modelling of FRP plates
- Slamming and water impact loading
- Remote processing and distributed computing
- High speed vessels





Impact

The impact of this work has been four-fold:

- Better methods for the design of ships and floating structures
- Computer programs for ship loadings and responses
- International collaboration with colleagues and industrialists in Singapore and Korea
- Public workshops where results from the research have been disseminated

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Professor RA Shenoi

TT32

Trade

UNIVERSITY OF Southampton

MoD Centre of Excellence in Marine Structures

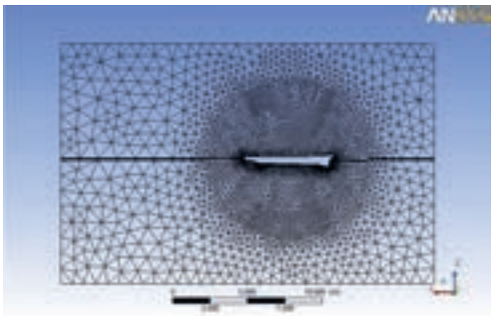
Mechanics and integrity assessment of damaged structures

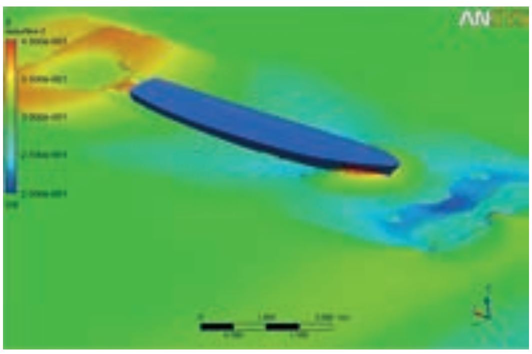
Context

The Centre of Excellence represents a long term, strategic collaboration between MoD and Lloyd's Register on the one hand and the University of Southampton and University College London on the other.
The two main areas of study by researchers and students are analysis of loads on damaged ships and modelling techniques for damaged and aged structure.
The strategic aim of the project is to deliver a set of analysis processes and procedures that may be implemented to provide an Emergency Response Service to Warships .
The project is being in close collaboration with a number of UK based shipyards, design consultants and naval architectural companies.

Example Projects

- Load determination in damaged ships
- Ultimate strength of aged and damaged ship structures
- Collapse strength of orthotropic stiffened structures
- Computation models for coupled fluid structure modelling of damaged ships





Impact

The impact of this work, when completed, would be for safer ships operating with enhanced standards for seafarers . The work will also serve to ensure reduced profiles for potential environmental pollution.

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Environment and Mitigation

UNIVERSITY OF Southampton
School of Engineering Sciences

Nickel-aluminium bronze pitting corrosion in seawater

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[2] Physical Sciences Department (Dstl), Dstl Porton Down, Salisbury, Wiltshire, SP4 0JQ, UK.
[3] *Current address*: School of Engineering and Electronics, University of Edinburgh, Mayfield Road, Edinburgh, EH9 3JL, UK.

Introduction and background

Nickel-aluminium bronze (NAB) is widely used in marine applications because of its high toughness and erosion-corrosion resistance

- NAB is used for **high performance** propellers and seawater handling systems – seawater valves and heat exchangers.
- Pitting and crevice corrosion for copper-based alloys is often attributed to a **metal-ion concentration cell**.
- Areas exposed to high copper-ion concentrations are considered to act as cathodic sites (**with copper deposition** sometimes observed).

NAB may encounter corrosion related problems under in-service conditions:

- NAB can encounter variability in corrosion performance worldwide, *i.e.* different local environments.
- NAB components in naval vessels can be affected by their operational cycles (open / dock type seawater) – long periods in the dock compared with commercial vessels.
- Corrosion problems can lead to expensive repairs to NAB propellers and seawater intakes.
- Propeller replacement costs can be £0.25 million (€0.31 million) and dry dock costs are £20k / day (€25k / day).

NAB is known to be susceptible to localised corrosion, *e.g.*:

- **Crevice corrosion rates as high as 0.7 to 1.0 mm.y^{-1}** have been reported - compared with 0.25 mm.y^{-1} for type 304 stainless steel.
- NAB is prone to selective phase corrosion (SPC).
- SPC may initiate pitting corrosion.

Research impact

The results and conclusions derived from the collaboration has been passed to many MOD Integrated Project Teams (IPTs) where NAB issues constitute a major, and costly, area of concern. Knowledge gained from biofouling interactions are also currently being promulgated and exploited through existing corrosion work groups.

Test material

Casting NAB (Cu**Al9Ni5Fe4Mn – NES 747 Part 2 spec.**) used for naval applications is typically given a heat treatment at 675 °C for 2 to 6 hours.

NAB is susceptible to selective phase corrosion due to its complex microstructure:

- Copper-rich α-phase.
- Plus, β-phase (retained martensite) and a series of κ-phases based on Fe_3Al and NiAl (with one exception - κ_I may be based on Fe_3Al or FeAl).

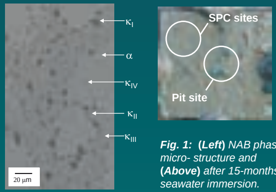

Fig. 1:* (Left)** *NAB phase micro- structure and* ***(Above) *after 15-months seawater immersion.*

Results and discussion

The SEM study in Fig. 2 shows the NAB surface corrosion was initially confined to the eutectoid regions with slight attack of the copper rich α-phase within the $\alpha+\kappa_{III}$ eutectoid. While the eutectoid α-phase was preferentially attacked the α-grains show very little attack, this is a form of selective phase corrosion.

The accumulation of Cu_2O deposits at these locations will limit the diffusion (mass transport of species including: copper-ions, chloride and dissolved oxygen) towards and away from the NAB surface, thus there is the potential for a microenvironment to develop beneath the deposit. If the pH of this microenvironment becomes acidic, *e.g.* below pH 4.0, the κ_{III}-phase becomes anodic to the α-phase and corrodes preferentially.

Fig. 3 illustrates the accumulation of initial corrosion products from SPC acting as a site for 'pitting' type attack.

Cu_2O is **porous** and **electrically conducting** layer with the upper surface acting as a cathode and the lower surface as an anode.

In contrast to stainless steels, there is **no preferred cathodic reactions** on the surface **surrounding the corrosion** activity, thus, resulting in the observed **rapid peripheral growth** of corrosion around the pit.

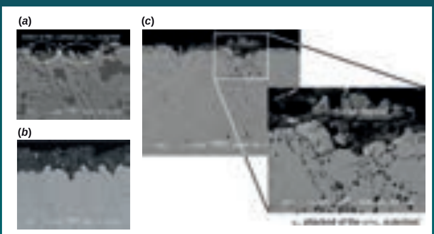

Fig. 2: *Backscattered SEM micrographs of the NAB exposed to estuarial seawater:* ***(a)*** *initial attack at the α-phase within the $\alpha+\kappa_{III}$ eutectoid,* ***(b)*** *development of protective oxide film (uniform corrosion) and* ***(c)*** *selective phase corrosion and the accumulation of corrosion products.*

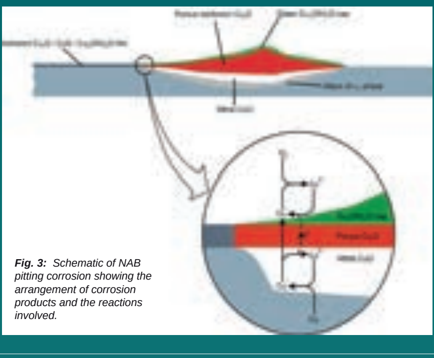

Fig. 3: *Schematic of NAB pitting corrosion showing the arrangement of corrosion products and the reactions involved.*

Conclusions

1. On exposure the copper-rich α-phase was initially (during the first 6 months) susceptible to corrosion leaving the unattacked κ-phases to create an adherent skeletal lattice.
2. At localised sites, SPC occurred and due to the continuous nature of the κ_{III}-phase this resulted in the accumulation of corrosion products / deposits at these locations.
3. The formation of a micro-environment beneath the deposit developed into a 'pitting' type phenomenon after prolonged exposures (within 15 months).
4. Overall, the pitting mechanism is characterised by very wide although relatively shallow corrosion features.

Worked sponsored by dstl

Marine Biofouling and Antifouling Coatings

Professor R Wood

TT34

Environment and Mitigation

UNIVERSITY OF Southampton
School of Engineering Sciences

Marine biofouling and antifouling coatings

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[2] Physical Sciences Department (Dstl), Dstl Porton Down, Salisbury, Wiltshire, SP4 0JQ, UK.

Introduction and background

Marine biofouling is defined as the undesirable accumulation of microorganisms, plants, and animals on artificial surfaces immersed in sea water. In the case of the underwater hull of a ship, the adverse effects caused by this biological settlement include:

- High frictional resistance, due to generated roughness, which leads to an **increase of weight** and subsequent potential **speed reduction and loss of manoeuvrability**. To compensate for this, higher fuel consumption is needed, which causes increased greenhouse gas emissions.
- It may also necessitate heavier and less energy efficient machinery. The increase in fuel consumption can be up to 40%.
- An increase in the frequency of dry-docking operations, *i.e.* time is lost and resources are wasted when remedial measures are applied. Potentially harmful waste is also generated during this process.
- Deterioration of marine polymeric coatings so that corrosion, discolouration, and changes in the electrical conductivity can occur.
- Introduction of marine species into environments where they were not naturally present (invasive or non-native species).

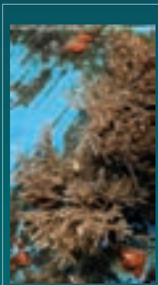
Although the incorporation of tributyl tin (TBT) into coating systems has been widely used for its anti-fouling capacity, recently the use of TBT has been banned due to its toxic affects in the wider marine environment. Furthermore, fresh concerns about the long-term effects of copper pollution in environmentally important estuaries and offshore areas are providing an incentive to study **new antifouling** solutions. Therefore, the need for new, effective and environmentally friendly coating systems has been the focus and challenge for the scientific community. The ideal antifouling coating would prevent marine growth as well as maintain a long performance life while keeping within increasingly **strict environmental regulations**.

Research impact

The fundamental underpinning science derived from the work has led to a very successful and recognised international collaborative programme between the United Kingdom, France and the Netherlands. The project will develop a greater understanding of the influence of biofouling and the impact natural product antifouling coatings for ships.

Project objectives

- Evaluation of emerging technologies to obtain environmentally friendly antifouling coatings with projected long term performance (6-10 years);
- Development of advanced accelerated test methods for assessing new natural products, including biocide free coatings, within a short period (< 1 year) which is representative of long-term *in-service* performance.



Discussion

In the marine environment, a wide variety of species illustrate antifouling abilities by several means, *e.g.* the use of chemical and physical defences, symbiotic relationships between host (*e.g.* algae) and epibionts (*e.g.* bacteria) that prevent fouling. The impediment of biofouling in a natural way, as observed in marine organisms, has triggered the scientific interest and led to the examination of marine natural products as a possible route for a novel antifouling technology.

Nearly 20,000 natural products have so far been described that originate from marine organisms. Since the early 1980s, a great number of marine natural products have been assayed against organisms implied in the biofouling process and several reviews dealing with their potential use as novel antifouling biocides have been realised.

Marine polymeric coatings, like most paint compositions, are made up from a binder and a series of pigments which include additives, colour and extenders. The antifouling additives are included in the top-coat or final coating layer of the multi-coat marine antifouling system. Thus, the binder and solvent selection need to be carefully tailored to the chemical properties of any new potential biocide molecule.

Fig. 1: Hull foulinf by (Top) brown algae and (Above) the green algae 'Ulva enteromorpha'.

This collaborative research programme between the University of Southampton, the Institut des Sciences de l'Ingénieur de Toulon et du Var (France) and TNO (Netherlands) will investigate:

Survey and screen new types of emerging binders for effectiveness as a self-polishing copolymer, *e.g.* block silylated binders, see Fig. 2.

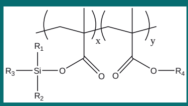


Fig. 2: *Chemical structure of the silylated binder*

Survey and screen new specific (natural product) biocides for antifouling efficacy and toxicological properties. Extracts of algae such as: **(a)** *Chondrus crispus* and **(b)** *Bifurcaria bifurcata.*

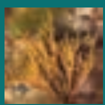


Fig. 3: *Examples of Chrondrus crispus and Bifurcaria bifurcata.*

Characterisation of antifouling paint formulations by erosion, adhesion and mechanical properties.

Worked sponsored by dstl

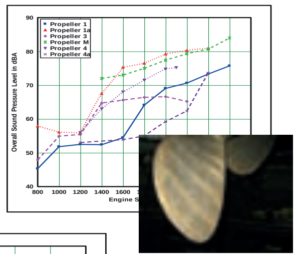
J Dixon

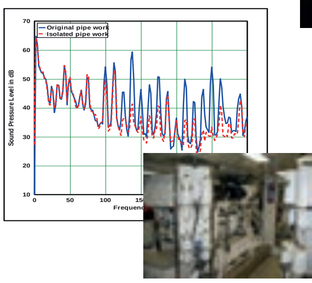
UNIVERSITY OF Southampton

Noise and Vibration Control

Recreational and Commercial Craft

Noise and vibration surveys and solutions
Noise and vibration source identification
New build and refit design reviews
Transmission loss measurement
Exhaust system layout advice
Foot impact measurement
Privacy measurement
Torsional measurement
Propeller selection advice





Contact John Dixon
02380 592273

Health and Environment

Noise and vibration exposure
Passenger and crew comfort
Development of codes of practice
Development of standards
Waterside planning inquiries
Neighbourhood noise control
Harbour noise surveys

"Working towards a Quieter Environment"

ISVR Consulting

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Professor D Macbeth

TT36

UNIVERSITY OF Southampton

Theme: Trade and Transport

Research: Management of Maritime Operations

Topic Areas

- Port Operations
  - Container management
  - Cargo loading
  - Ship Operations
- Naval / offshore support
  - Bulk transportation
  - Logistics modal choice
- Vehicle routing and Scheduling
- Design and through-life costing of maintenance
- Risk
  - Project
  - Hazard
  - Disruption

Methodology

Mathematical programming
Mathematical optimisation
Simulation
Project and risk management
Through life costing
Storytelling to transfer tacit knowledge
Historical research

Impact

Economic waste reduction - Minimise risk impact
Support to Concurrent Engineering - Optimise resource use - 'Control' of processes
Increase 'Green' benefit - Support innovation
Development in intermodal logistics

mca [dstl] DP WORLD Cargill Ocean Transportation Lifeboats

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Southampton Management School
Contact : dkm@soton.ac.uk

Power Flow Active Control of Aeroelastic Flutter for a Nonlinear Airfoil with Flap

Dr Y Xiong

TT37

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Power Flow Active Control of Aeroelastic Flutter for a Nonlinear Airfoil with Flap

N.Zhao[1,2], Supervisors – Dr. Y.P.Xiong[1] and Prof. D.Q.Cao[2]
[1] School of Engineering Sciences, University of Southampton
[2] School of Astronautics, Harbin Institute of Technology

Background

- The flutter phenomenon of aeroelastic system is one of the most important issues in many areas, especially in aircraft structures. It is very dangerous when aircraft flutter happens because its vibration amplitude and dynamic stress will increase dramatically. The flutter may lead to rapid structural damage in flight within a few seconds as shown in Fig. 1,2.
- Nonlinear flutter happens with a phenomenon of limit cycle oscillations (LCOs) when the flight speed reaches the critical speed. The most concerned way to suppress flutter is to change the aerodynamic loads by changing the deflection of control surface. The flap as control surface in aeroelastic control system can be driven by an actuator.
- Various modern control methods have been widely used in the design of a control law for active flutter suppression, such as the LQR, adaptive control, robust control, etc. The information is insufficient to determine the pathway of the vibration transmission by the transfer function measurement method.
- Power flow control method takes into account both force and velocity information. Therefore, it is a better control parameter and the impedance characteristics of the structure is considered. It provides an effective measure to evaluate and improve the control performance of complex nonlinear systems.

Aims

- Active flutter control to suppress airfoil flutter by driving the control surface as the aerodynamic shape altered.
- Power flow analysis of the nonlinear coupling dynamic system and active control to optimize the vibration control performance.

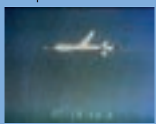


Figure 1: Video frame of DAST just after structural failure of right wing (1984)

Figure 2: The crash of a F117 Stealth Fighter in 1997 was linked to flutter

Modelling Methodology

- A typical supersonic/hypersonic airfoil model with a control surface is shown in Fig. 3. It has two degrees of freedom, i.e., plunging, pitching displacement denoted by h and α, respectively.

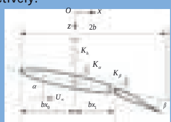


Figure 3: Sketch of a supersonic 2-D (two-dimensional) airfoil-flap system

- Governing Equations of Motion

$$\begin{cases} m\ddot{h} + S_\alpha\ddot{\alpha} + C_h\dot{h} + \left(K_h h + e_1 K_h h^3\right) = -q_h \\ S_\alpha\ddot{h} + I_\alpha\ddot{\alpha} + C_\alpha\dot{\alpha} + \left(K_\alpha\alpha + e_2 K_\alpha\alpha^3\right) = q_\alpha \end{cases}$$

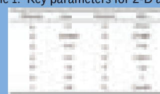
- The bending and torsional stiffness of the airfoil are equivalent to the bending and torsional springs K_h and K_α at the elastic axis E, and the torsional stiffness of the flap is determined by the torsional spring K_β at the hinge H. And cubic nonlinear stiffness is considered in both the bending and torsional springs. b is half chord of the 2-D airfoil and β is the flap displacement. q_h and q_α are the aerodynamic lift and moment in the corresponding degree.
- Thin wings have hard cubic nonlinear characteristic which means stiffness increases gradually as the plunging gets bigger. The torsional stiffness, however, may take soft nonlinear characteristics.
- Active Flutter Control Strategy:

The control objective is to design a control strategy to heighten the critical flutter speed and depress the vibration amplitude of post-flutter oscillation. Toward these goals, a combined control law is proposed to suppress the flutter and it is described as $u = u_1 + u_2$, where the linear control force $u_1 = -K_1 Y$ is designed by using the LQR method for the corresponding linearized model of the system, and the nonlinear feedback control force $u_2 = -K_2\alpha^3$ is designed to suppress the amplitude of the post-flutter oscillation.

Results

- Dynamic Response: Parameters used is shown in the Table 1.

Table 1: Key parameters for 2-D airfoil



- Critical Flutter Speed: $\mu(V) = \max_j[\mathrm{Re}(\lambda_j)]$

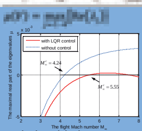


Figure 4: Relationship between μ and $M\infty$

where μ is the maximal real part of all the eigenvalues of system matrix, with respect to flight Mach number, $M\infty$, is shown in the Fig. 4.

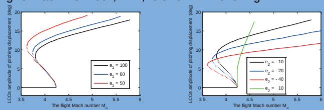


Figure 5: The effect of the nonlinear stiffness coefficients e_1 and e_2 on the amplitude of the limit cycle oscillations.

where e_1 and e_2 are nonlinear coefficients of stiffness in the plunging and pitching, respectively.

- Active Flutter Control Strategy:

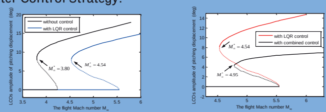


Figure 6: The amplitudes of limit cycle oscillations for the uncontrolled, LQR controlled and combined controlled system.

- Both the structure and aerodynamic nonlinearities have effect on the dynamic behavior of the airfoil. At the linear critical flutter speed, the equilibrium state of the system becomes unstable and a Hopf bifurcation occurs.
- Both subcritical Hopf bifurcation and supercritical Hopf bifurcation were observed in the system. Using the LQR control strategy, not only both the linear and nonlinear critical flutter speeds can be heightened but also the amplitude of LCOs can be suppressed for the airfoil in the supersonic/ hypersonic airflow.

Conclusions and Further Work

- The flutter, post-flutter and active control of a 2-D airfoil with control surface operating in supersonic/hypersonic flight speed regions is investigated first. For the combined controlled system, not only the nonlinear critical flutter speeds can be further increased but also the amplitude of LCOs can be further suppressed in comparison with the LQR controlled system.
- Further study will focus on the development of power flow based optimal active control strategy for the complex nonlinear coupling system and analysis of energy dissipation mechanism.
- Comparative study will be performed to evaluate the cost-effectiveness of the power flow control approach and the combined active control method. Optimal control parameters will be determined to reduce the input and transmitted power to the structure.

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Smart Materials and Structures with Hybrid Nonlinear Vibration Control for Marine Applications

Dr Y Xiong

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FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

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Smart Materials and Structures with Hybrid Nonlinear Vibration Control for Marine Applications

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Motivation

- For passenger ships (Figure 1), vibration and noise pollutions affect the comfort of passengers and crew members.
- Vibration and noise generated by marine engines create pollutions, which harm the marine life and become one of the environmental problems.
- New knowledge and technology need to be developed to address these problems by effectively controlling vibration transmission and acoustic noises.

Figure 1 Passenger ship

Background

When ship is travelling, ship structures experience complex and varying dynamic excitations and become the sources of noise radiations.

Magnetoryeological elastomers (MRE) consist of two parts: polymer matrix and active filler. Their mechanical properties can be controlled rapidly, continuously and reversibly by an external magnetic field (Figure 2).

Passive systems are not adaptive to the changing conditions; active ones consume a lot of energy and need a large activation force. It is showed that hybrid control systems are more effective.

Figure 2 MRE without magnetic field and MRE under magnetic field

Aims

- Develop the MRE materials to obtain greater MR effects, so as to expand their applications to large scale structures.
- Design a vibration control system employing the dynamic properties of MRE material for marine applications.
- Develop nonlinear power flow approach to analyse the energy transmission mechanism and evaluate the vibration control effectiveness.

Methodology

- In order to further investigate dynamical properties of different MREs, it is necessary to perform multiple modes dynamic loading tests.
- The nonlinear vibration theory considering the actual strain–stress relationship will be employed to establish mathematical model and predict the dynamic response of the MRE material and structure.
- A hybrid passive/active vibration control system with adaptive MRE materials (Figure 3) will be investigated.
- Nonlinear power flow approach will be developed to analyze the vibration energy transmission mechanism to evaluate the vibration control effectiveness.

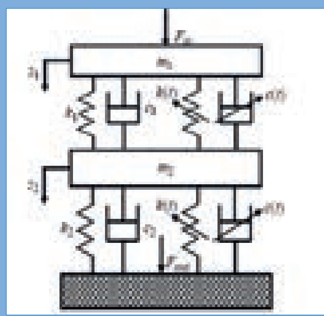

Figure 3 A schematic hybrid control system

Programme

Experimental characterisation of the dynamical properties → Mathematical modelling of MRE materials and structures → Analyze vibration energy transmission and control mechanism → Practical design of hybrid vibration control system for applications

Figure 4 Work programme

Challenges

- Nonlinear mathematical model of MRE materials and structures under multiple loading modes.
- Develop the nonlinear power flow approach to analyse the energy transmission mechanism of the smart nonlinear dynamical systems.
- Develop hybrid active/passive control system to effectively control vibration energy transmissions.

Acknowledgement: Southampton; Lloyd's Register Educational Trust

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Investigation of Numerical Methods for Achieving Energy Efficient Ships

Professor S Turnock

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FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton

Investigation of Numerical Methods for Achieving Energy Efficient Ships

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Motivation

- The increasing cost of fuel is having a significant impact on the maritime industry. Mid and long term fuel prices are expected to increase including surcharges for carbon-dioxide emissions. This increases the need for a paradigm shift in design and powering so as to construct vessels which are more fuel efficient
- The use of flow control mechanisms in restoring the wake flow distribution of the propeller have been identified to improve performance. This requires detailed numerical and experimental tools in resolving such complex flow field with the adequate accuracy.
- The use of Reynolds Averaged Navier Stokes (RANS) simulations have been considered to be a powerful tool for such maritime flow problem.

Figure 1: Hull line optimisation for a specific boat

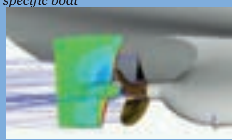


Figure 2: costa bulb investigation

Aims and Objectives

The aim of the research is to achieve a 15% reduction in fuel efficiency for a proposed LNG carrier.

The project will work towards the following objectives

1.Developing rigorous CFD approaches to ships stern flow
-conduct validation test on 2D & 3D aerofoils section
-propeller-rudder study
-validation of twin skeg LNG carrier hull shapes

2.Investigation of energy saving strategies
-methodical tests to establish the effect of varying key dimensions and ratios at the aft body on propeller wake field, propulsive efficiency and propeller vibrations
-investigation of possible improvements to overall propulsive efficiency.

Initial study:
Open FOAM Investigation of flow around an airfoil

- The purpose of this study is to evaluate the Open Source CFD tool [Open Foam] for simulating incompressible flow over a 2D NACA0012 aerofoil operating at Reynolds number =3x10^6 over a range of incidence angles. OpenFOAM (Open Field Operation and Manipulation, www.openfoam.org) allows the user to gain full control over implementation of different features in research activities.
- The physical model is based on the mass $[\nabla \cdot U = 0]$ and momentum $[(U \cdot \nabla)\, U + (\nabla P/\rho) = \nu\, \nabla 2U + g]$ conservation equations and the spalart allmaras one equation model for the turbulent viscosity.

Boundary conditions

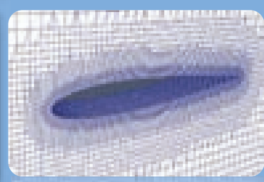
Designation	description	Type of boundary condition
1	Inlet	Freestream
2	Outlet	Freestream
3	Wall	No slip (Fixed wall)
4	Top	Freestream
5	Bottom	Freestream
6	Front	Empty
7	back	Empty

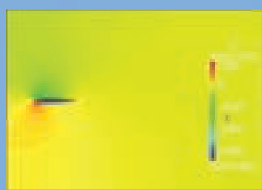
Preliminary Results

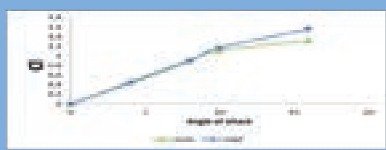
- Simulations on an initial coarse mesh (fig 2) generated using snappyHexMesh show good agreement with experimental data up to ten degrees incidence. The coarseness of the initial mesh lead to poorer prediction of stall.

Future work

- Refining of the meshing in order to capture the wake field
- Boundary layer profile







From top :
Fig 1.naca0012 aerofoil geometry,
Fig 2.Zoom of the generated mesh using snappyHexMesh , Fig 3.velocity Fig 4 .Pressure contours, Fig 5.Lift plot vs. incidence

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Professor S Turnock

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FLUID STRUCTURE INTERACTIONS
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Low Carbon and Hazardous Emissions Shipping

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Lloyd's Register - Foundation Propondis
Supervisors – **Prof. Stephen R. Turnock** and **Dr Dominic A. Hudson**

Motivation and Aim

"The whole is more than the sum of the parts" – Aristotle.

This study is based on the systemic approach of propulsion system (Systems engineering) instead of the traditional optimisation of single components.

Ultimate objective: Provide an alternative reliable, economically feasible, marine propulsion system to reduce CO_2, SO_x, NO_x and particle emissions from ships.

The project investigates the potential of large scale application of Nuclear propulsion using small portable reactors and the installation of energy storage devices for modular operation and controlled energy flow.

Currently, a lot of work has been done in large 2 Stroke engines to reduce SO_x, NO_x using external means, like Selective Catalytic Reaction, Scrubbing but also by optimizing the combustion and the operation of the engines such as valve timing, variable turbine blade area etc.

However, domestic shipping and fishing activity bring emission totals to 1050 million tonnes of CO_2, or 3.3% of global anthropogenic CO_2 emissions. Despite the undoubted CO_2 efficiency of shipping in terms of grammes of CO_2 emitted per tonne-km it is recognised within the maritime sector that reductions in these totals must be made.

Shipping is responsible for a large percentage share of NO_x (~37%) and SO_x (~28%) emissions

Due to the increasing growth of marine the transportation, immediate action is required to stop the climate change

The current state of play is ready for the adoption of new technologies including the nuclear propulsion, combined energy cycles and advanced heat recovery systems.

The combination of such technologies has not been assessed and optimised yet.

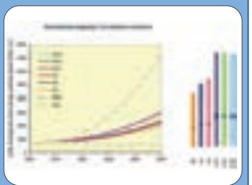

Figure 1: Predicted emissions of the shipping sector according to I.M.O. 2nd Greenhouse emission study.

Ship Simulation (Modular Block Implementation)

A scalable and modular approach in MATLAB/Simulink environment was developed.

Figure 2: Simulator Major Block Description (top) and Engine-Hull simulation schematic (down).

Each block represents machinery comp, weather, engine, ship model

- Hull Resistance (Holtrop – Mennen method, Lap – Keller methods)
- Added Resistance (Aertssen, Kwon methods)
- Wind Resistance (Isherwood, Blendermann methods)
- Wageningen Series open water performance method
- Open thermodynamic system properties (Control Volume Theory)
- Battery models, using Kinetic Energy approach (Manwell, McGowan)
- Heat Transfer (for usage in High Temperature battery applications)

Nuclear Vessel Concepts

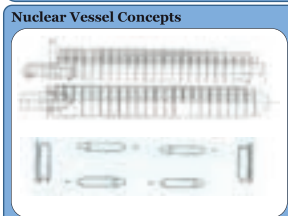

Figure 3: Nuclear Pusher- barge system (top) and schematic of potential commercial chain using pushers and barges (down).

A pusher/ barge concept offers:

- Reactor away from ports (>40nm)
- Well guarded propulsor
- Easy dry-docking for barge/pusher
- Can be leased by ship-owners
- No need for state/ Country regulations
- Hybrid Electric propulsion offers to the Barge self-propulsion capability using energy storage when in national waters and while in open sea, the electricity is supplied by the pusher's Nuclear reactor

Conclusions to date

Fuel savings depending on storage system, vessel condition and vessel type, can reach up to:

- 111,538 tonnes in NO_x
- 74,460 tonnes in SO_x
- 4,162,7 tonnes in CO_2

The above represent a maximum 22.5% reduction in the dry bulk sector and 2.8% of the world's fleet emissions.

The economic feasibility is dependent on the capacity and power of storage medium.

- Sodium Nickel Chloride Battery is more economical feasible option
- Vanadium redox Flow batteries have high potential and it is promising technology
- Depending on vessel type fuel savings can exceed 1m $ per year
- Cost of construction drops
- Initial investment cost remains high
- Internal Rate of Return varies from 4.3% - 44.7%

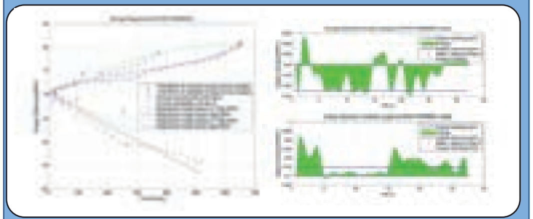

Figure 4: Energy Storage Requirements (left) and Energy fluctuations during Laden and Ballast voyages (right).

- Energy Requirements in Bulk carriers have no flat profile (as it was believed)
- Simulator model accuracy is based on the selected time-step or the amount of given data
- 2-stoke Mechanical Diesel part load optimised and Hybrid propulsion gives notable gains
- Electric propulsion is not suitable for bulks as conversion losses are higher than the fluctuations in Main Engine's fuel efficiency
- Hybrid Propulsion is technically feasible without affecting the basic ship dimensions
- Nuclear Pusher/ Barge system can be achieved using the same principles with the shore power connection ("Cold Ironing")
- Hybrid Propulsion is not necessary when sailing in open sea as Nuclear reactor has rapid load change (5%/ sec. for change up to 15%) without affecting the efficiency

Figure 5: Schematic of two out of total four proposed hybrid propulsion solutions showing conversion efficiencies.

Future planned work

- Code implementation for creation of random weather conditions in order to assess the machinery layout feasibility and verify potential savings in fuel consumption
- Systems engineering by:
  - Concepts of different propulsion systems such as steam, electrical, conventional Diesel
  - Risk and safety assessment for each module of the propulsion system
- Contribute to the Gold based Rules for merchant marine nuclear propulsion

Acknowledgments

The authors wish to thank Lloyd's Register and Foundation Propondis for the financial support of the PhD, the two Greek Maritime companies which prefer to stay anonymous and Carnival Cruises and Plc UK for giving access to the operational data and technical specifications of their fleet.

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FOUNDATION PROPONDIS

Numerical Modelling of Scour around Complex 3D Structures

Professor S Turnock

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GEOLOGY AND GEOPHYSICS RESEARCH GROUP

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Numerical modelling of scour around complex 3D structures

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Motivation

- Scour is understood as the removal of sediment in response to forcing by waves and currents.
- Scour is a function of the local hydrodynamics and geotechnical properties of the seabed. It is often associated with marine structures due to locally amplified flow, turbulence and bed shear stresses.
- The ability to predict scour around seabed structures is vital since non-treatment of scour can result in expensive structural failures.
- In engineering practice often predictive empirical formulae are used for the prediction of scour around simple structure shapes
- The development of a CFD-based approach has the advantage of offering a temporally and spatially resolved method for the assessment of scour around structures with complex shapes.

Figure 1: Scour around caisson

Objectives

1. Critically appraise possible CFD-based methods for the simulation of scour
2. Develop a method within the CFD toolbox openFOAM capable of predicting the hydrodynamically-induced change in morphology of a non-cohesive sediment seabed
3. Validate the performance of the scour model in light of published physical model data and recently acquired field
4. Apply the developed method to:
   - Tidal, bi-directional flow
   - Real-life consultancy problem
5. Evaluate maximum lateral and vertical scour extent and time-development of scour in the model

Granular two-phase model

- The chosen two-phase method solves conservation equations for both the fluid and solid phase in the Eulerian framework. Phases are treated as separate but interpenetrating continua. Momentum-exchange between the two phases is considere by additional inter-phase exchange terms $\overline{M}_\varphi$ consisting of contributions from drag, lift and virtual mass forces
- The conservation equations are derived from single-phase flow equations by conditional ensemble averaging:

$$\frac{\partial \alpha_\varphi \overline{\rho}_\varphi}{\partial t} + \nabla \cdot \left(\tilde{U}_\varphi \alpha_\varphi \overline{\rho}_\varphi \right) = 0$$

$$\frac{\partial \alpha_\varphi \overline{\rho}_\varphi \tilde{U}_\varphi}{\partial t} + \nabla \cdot \left(\alpha_\varphi \overline{\rho}_\varphi \tilde{U}_\varphi \tilde{U}_\varphi \right) + \nabla \cdot \alpha_\varphi \overline{\tau}_\varphi + \nabla \cdot \left(\alpha_\varphi \overline{\rho}_\varphi \tilde{R}_\varphi \right) = -\alpha_\varphi \nabla \overline{p} + \alpha_\varphi \overline{\rho}_\varphi g + \overline{M}_\varphi$$

$$\overline{\tau}_c = -\mu_c \left[\nabla \tilde{U}_c + \left(\nabla \tilde{U}_c \right)^T - \frac{2}{3} \left(\nabla \cdot \tilde{U}_d \right) I \right]$$

Continuous phase stress tensor.

$$\overline{\tau}_d = -\mu_d \left[\nabla \tilde{U}_d + \left(\nabla \tilde{U}_d \right)^T \right] + \left(\lambda_d - \frac{2}{3} \mu_d \right) \left(\nabla \cdot \tilde{U}_d \right) I$$

Dispersed phase stress tensor. Closure models from kinetic theory of granular flow

- The solid-phase stresses are derived from particle-particle collisions. The intensity of the particle velocity fluctuations determines the stresses, viscosity, and pressure of the solid phase. Closure of the solids stress tensor is achieved by empirical models derived from the kinetic theory of granular flow.
- Turbulence closure is achieved using a mixture k-ε model, a slight extension of the standard single-phase implementation. One short-coming of this simple model is that it does not consider turbulence modulation owed to the presence of the particulate fraction:

$$\frac{\partial k}{\partial t} + \nabla \cdot \left(\overline{U} k \right) - \nabla \cdot \left(\frac{\nu^t}{\sigma_k} \nabla k \right) = P - \varepsilon$$

$$\frac{\partial \varepsilon}{\partial t} + \nabla \cdot \left(\overline{U} \varepsilon \right) - \nabla \cdot \left(\frac{\nu^t}{\sigma_\varepsilon} \nabla \varepsilon \right) = \frac{\varepsilon}{k} \left(C_1 P - C_2 \varepsilon \right)$$

$$P = \nu^t \left(\nabla \overline{U} + \left(\nabla \overline{U} \right)^T \right) : \nabla \overline{U}$$

$$\overline{U} = \alpha_c \overline{U}_c + \alpha_d \overline{U}_d$$

2D Test case and initial results

- A test case was set up to evaluate initial performance of the model for scour around a pipeline.
- Figure 2 illustrates the process of scour onset for a pipe in contact with a non-cohesive bed.
- Following the undertunneling of the pipe the jet scour phase begins as illustrated in Figure 3.

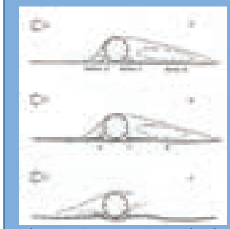

Figure 2: Scour onset at a pipe (Mao, 1986)

Figure 3: Jet scour phase (Mao, 1986)

- Figure 4 shows that the vortices which drive the scouring process are captured.

Figure 4: Simulated vortices around the pipe at onset of scour

- Figure 5: The erosive forces of the vortices have begun to remove sediment from under the pipe. A large pressure difference inside the soil leads to piping in the upper bed aiding in the eventual breakthrough of a tunnel beneath the pipe.
- Figure 6: Once a path between pipe and bed has been created, rapid high-energy jet scour prevails, with high flow velocities in the tunnel and rapid removal of sediment.

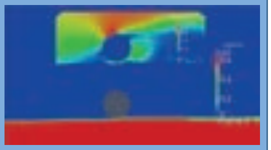

Figure 5: Initiation of jet scour phase

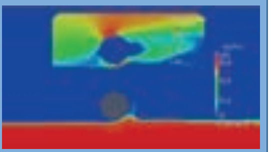

Figure 6: Jet scour develops

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Acknowledgement: This project is supported by funds from the **Natural Environment Research Council** and **HR Wallingford Ltd**

FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

UNIVERSITY OF Southampton

Wave making drag prediction for improved design of marine crafts

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Supervisors –**Dr. Mingyi Tan** and **Dr. Zhimin Chen**

Background

•With globalization and associated rising demand on transportation, the volume and size of the merchant fleet will also increase since the majority of goods are transported by sea.

•In shipping, a significant cost both to the ship owners and the environment is the fossil fuels used for propulsion. With the rising price of oil and the growing environmental concern, the motivation to reduce oil consumption has never been higher.

Motivation

•About 50% of the resistance of a fast container ship is due to wave resistance. This means that even a small reduction in the wave resistance can bring considerable reductions both in operating costs and emissions.

•When designing a ship it is important to be able to make fast and accurate prediction of its resistance so that more efficient hull forms can be selected early in the design process. A RANS solver based CFD software is still too time-consuming to be adopted in the initial design process

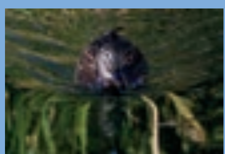

Figure 1: Wave patterns behind a mallard[1]

Aim

- To develop an efficient numerical method for wavedrag based on a dissipative potential theory

Objectives

- To derive a 3-D dissipative Green's function for free-surface flow with forward speed.
- To formulate a numerical scheme of study within the frame work of a panel approach.
- To validate and tune the method for wave drag predictions with available data.

Method

- Rayleigh damping μ_R is introduced in the Navier–Stokes equation, this gives the non-dimensional Bernoulli equation
- $\frac{\partial\phi}{\partial t} + \frac{1}{2}\nabla\phi^2 = -\nabla p - \frac{1}{F_n^2}\begin{pmatrix}0\\0\\1\end{pmatrix} - \mu_R(\phi - 1)$
- The source influences are given by a Green's function, the main benefit of a Green function approach is that the source distribution satisfies the free surface condition so that the sources can be located on the body only. The dissipative Green function is
- $4\pi G = -\frac{1}{r} + \frac{1}{r_1} + \frac{2}{\pi} Re \int_{-\pi/2}^{\pi/2} \int_0^\infty \frac{k e^{\ldots}}{\ldots} \, dk \, d\theta$

Evaluation

•The double integral in the Greens function can evaluated straight away since it has no singularities thanks to the Rayleigh viscosity.

•According to thin ship theory the sources can be placed along the centre line of the vessel at half the depth. The wave pattern from a Wigley hull are seen in Figure 2 and 4 . The wave pattern behind a wedge shaped hull with constant draft is shown in Figure 3

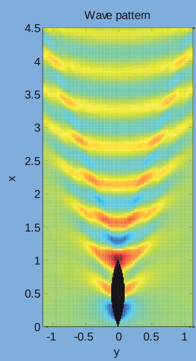

Figure 2: Wigley hull

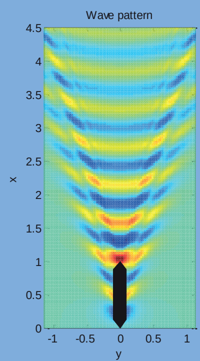

Figure 3: Wedge shaped hull

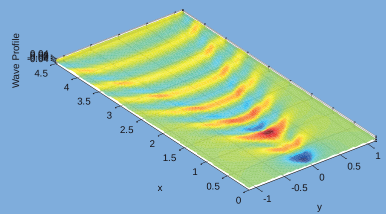

Figure 4: Wave patterns behind a Wigley hull

Next step

•Develop a panel method for 3D hulls.

•Improve the speed of the algorithms.

Outcome

•A fast and reasonably accurate method for ship wave drag prediction.

•A tool for early hull design or optimisation, capable of taking some finer features into consideration.

References

1.http://www.flickr.com/photos/26645490@N07/galleries/72157622444092583/

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Influence of Ultimate Strength on Aged and Corroded Ships

Professor RA Shenoi

TT43

FSI & nCATS

UNIVERSITY OF Southampton

Influence of Ultimate Strength on Aged and Corroded ships

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Background

Over the past few decades, around 90% of aged ship losses have been attributed to structural degradation due to corrosion (Emi et al., 1991). A typical corrosion situation in ballast tank is shown in Fig 1 (Anderson, 2003). A Finite Element Analysis conducted by Sensharma et al. (2006) shows that the critical bulking load can be reduced by about 300 kN if corroded features are applied to a stiffened panel. Thus, to inform maintenance decisions, and to make structure life extension decisions economically, an investigation into the corrosion effects on the ultimate strength of such aged and corroded ship structures is therefore required.

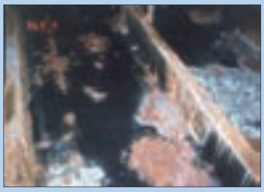

Figure 1: Typical corrosion in ballast tank (Anderson, 2003)

Aims

This study will:

•Investigate the ultimate strength of ships in aged and corroded conditions by constructing a strength model.

•The strength modelling will be based on limit state, non-linear finite element method; geometric and material non-linearities will be considered.

•Also, numerical and experimental studies of the corrosion properties of shipbuilding steels will be included.

Corrosion mechanisms

•The corrosion process is time-variant and a corrosion rate with a unit of mm/year was introduced to define the amount of corrosion damage.

•Corrosion can be categorised into 3 types: General corrosion, Localised corrosion and Fatigue cracks due to localised corrosion.

•The main corrosion protection systems (CPSs) for ships are polymers coatings and cathodic protection (Paik and Thayamballi, 2002).

•The corrosion process is extremely comprehensive because it is affected by numerous factors, most of which cannot be controlled.

•Extensive work has been done to study the corrosion behaviour of shipping steels and develop models that simulate the corrosion rate more realistically.

•Apart from estimating the mean corrosion rate and its COV for different structural members and types of vessels (Loseth et al., 1994; Gardiner & Melchers, 2001; etc.), either Weibull function (Qin & Cui, 2002; Paik et al., 1998) or linear model (Gardiner & Melchers, 1999) is used as a corrosion model to fit the corrosion rate data obtained from real ships. Fig 2 and 3 are two examples of corrosion rate affected by moisture and locations (Gardiner & Melchers, 2001).

•Corrosion is often divided into 3 key stages:

1.The durability of coating; **2.**The transition; **3.**The progress of corrosion

•Almost all studies assumed the time of transition is zero. During stage 3, Qin & Cui (2002) believed that the corrosion rate is at its highest at the beginning, while Paik and Thayamballi (2002) suggested that the rate either accelerates or decelerates under different conditions.

•Fatigue cracks due to corrosion have not yet been considered.

•It is unclear what effect the orientation of each plate has on the corrosion rate.

•Overall, little or no maintenance has been assumed in the corrosion models.

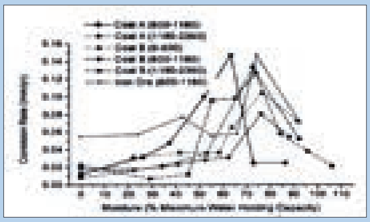

Figure 2: Moisture effects on corrosion rate (Gardiner & Melchers, 2001)

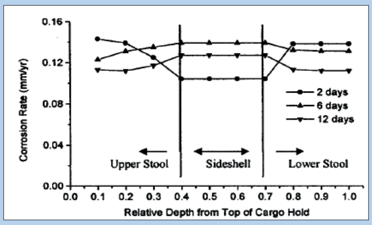

Figure 3: Relative depths effects on corrosion rate (Gardiner & Melchers, 2001)

Ultimate strength

The ultimate strength of structural members of ships has been investigated since 1953 (Timoshenko, 1953). A nonlinear finite element strength model will be constructed by considering material, geometric nonlinearities and initial imperfections. This model will be applied to simulate the progressive collapse behaviour of structural members of aged and corroded ships. Fig 4 gives an example of FEA modelling of pitting corrosion (Huang et al., 2010). Still water and wave induced loading will be applied. For simplicity, it can be assumed that the bending moments are independent of time (Akpan et al. 2003). Reference can be made to the midship section and the ship hull is considered to behave globally as a beam for both short-term and long-term conditions. By applying the corrosion process from the corrosion model to the strength model, the influence of ultimate strength can be obtained, and hence the structural performance.

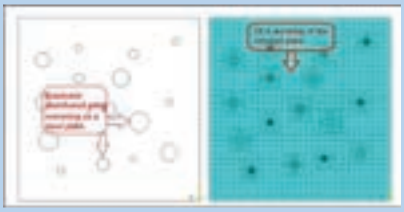

Figure 4: A typical example of FEA model for pitting corrosion (Huang et al., 2010)

Conclusions and Further Work

- The quality of the corrosion modelling is largely dependent upon the quality of the actual corrosion data.
- A method still needs to be found for applying the time dependent corrosion model to the ultimate strength FEA model.
- Corrosion experiments and measurements will be performed to gain greater insight for the corrosion modelling.

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The Influence of Surface Waves on the Added Resistance of Merchant Ships

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RESEARCH GROUP

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The influence of surface waves on the added resistance of merchant ships

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Causes of added resistance in waves

•Unfavourable shifts in buoyancy forces causing heaving and pitching. This absorbs energy both from the waves themselves but also from the ships momentum causing speed loss.

•Reflection of incident waves at the bow

•Disturbances of the flow around the hull causing boundary layer distortion and poor propeller performance

Background

•Predicting the power needed to achieve the designed service speed in the actual conditions experienced on the intended route has always been an issue for ship designers.

•The subject is complex and there has been no conclusive study able to give a solution to the above issue

•Designers therefore tend to use prescriptive percentage additions to the calculated still water resistance based on experience, e.g. +25% for North Atlantic trades, +15% for coastal operations.

•Older studies by Maruo [1], Gerritsma & Beukelmann [2] and Faltinsen[3] have successfully described the global phenomena giving rise to added resistance and is able to predict it well for certain sea states. No method however is able to predict it over a wide range of sea states.

•Because the limit of what can be done analytically to model the whole phenomenon of added resistance seem to have been reached, later studies have focused more on more detailed apects.

•However, there is a strong indication that coupling between different phenomena plays a major role in understanding why some methods work and others don't in certain conditions.

•With developments in computing power and open source RANS-based CFD software it is possible to use large scale CFD simulations to study the behaviour of ships in waves with a high level of detail.

Aims

•To validate the open source CFD-package OpenFOAM© for predictions of added resistance in waves.

•To conduct new towing tank experiments focusing on areas not previously addressed to support this validation.

•To use results from OpenFOAM© and the experiments to highlight important phenomena giving rise to added resistance.

•To use this information to test how new bow designs could reduce added resistance in waves.

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2.Gerritsma J & Beukelman W, Analysis of the resistance increase in waves of a fast cargo ship, International shipbuilding progress, vol 19, No 217, 1972

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Experimental study

•Has shown that there might be an effect of viscous phenomena on added resistance something that has not yet been confirmed in the literature. Figure 1 (a) shows the added resistance at three different periods of encounter and at different forward speeds.

•In Figure 1 (a) When T_e=0.7 the resistance grows with speed due to resonance. The decrease in added resistance for higher speeds at other T_e could be explained by increased viscous damping. This is supported by a measured increase of the decay rate in heave with speed for the same hull (b).

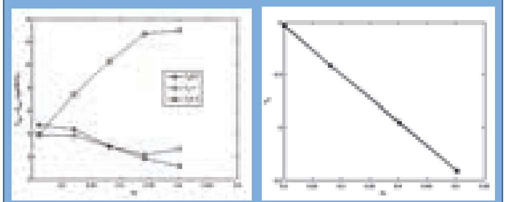


Figure 1 a b

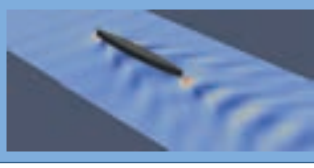
•A large amount of data in regular and irregular waves has been gathered for CFD validation.

CFD study

•Has started with a validation study against a fixed Wigley hull in waves to evaluate how the phase and amplitude of the added forces are predicted. This has proven to be problematic in previous studies.

•Has investigated how best to design the mesh to capture wave propagation and ship-wave interaction without using excessive numbers of cells.

•Has created modified multiphase solvers to deal with wave damping at domain outlet.



Future focus

•To continue to add complexity to the CFD model and monitor the errors arising from each step to get a better understanding of how best to model ships in waves.

•Improve the experiments with more uncertainty analysis and repeated tests to be able to give a confident new contribution to the knowledgebase regarding added resistance.

•Use acquired knowledge and models to test how the bow shape influences the highlighted aspects of added resistance.

Lloyd's Register Educational Trust

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Vibrational Power Flow Analysis of Nonlinear Dynamic Systems and Applications

Dr Y Xiong

TT45

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Vibrational power flow analysis of nonlinear dynamic systems and applications

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Background

- Predicting the dynamic responses of complex systems, such as aircrafts, ships and cars, to high frequency vibrations is a difficult task. Addressing such problems using Finite Element Analysis (FEA) leads to a significant numerical difficulty.
- Power flow analysis (PFA) approach provides a powerful technique to characterise the dynamic behaviour of various structures and coupled systems, based on the universal principle of energy balance and conservation.
- PFA is extensively studied for linear systems, but much less for nonlinear systems, while many systems in engineering are inherently nonlinear or designed deliberately to be nonlinear for a better dynamic performance.

Aims

- Reveal energy generation, transmission and dissipation mechanisms in nonlinear dynamic systems.
- Develop effective PFA techniques for nonlinear vibrating systems .
- Apply PFA to vibration analysis and control of marine appliances, such as comfortable seat and energy harvesting device design.

Fig. 1 Nonlinear seat suspension system

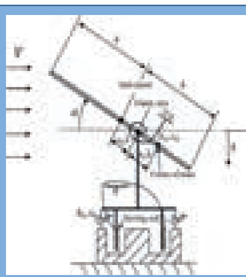

Fig. 2 Nonlinear energy harvesting using a flapping foil[1]

Fundamental PFA Theory

Dynamic equation for a single degree-of-freedom system

$$m\ddot{x} + c(x,\dot{x})\dot{x} + k(x)x = f\cos\omega t. \qquad (1)$$

Equation of energy flow balance can be obtained by multiply both sides of Eq.(1) with velocity

$$m\ddot{x}\dot{x} + c(x,\dot{x})\dot{x}^2 + k(x)x\dot{x} = f\dot{x}\cos\omega t. \qquad (2)$$

$$\dot{T} \quad + \quad p_d \quad + \quad \dot{U} \quad = \quad p_{in}$$

Kinetic energy change rate	Dissipated Power	Potential energy change rate	Instantaneous input power

Typical nonlinear dynamic systems

Van der Pol's (VDP) oscillator -Nonlinear damping

$$\ddot{x} + \alpha(x^2 - 1)\dot{x} + x = f\cos\omega t. \qquad (3)$$

Duffing's oscillator -Nonlinear stiffness

$$\ddot{x} + 2\xi\dot{x} + \alpha x + \beta x^3 = f\cos\omega t\,. \qquad (4)$$

These nonlinear systems behave differently compared with their linear counterparts as the former may exhibit inherently nonlinear phenomenon such as limit cycle oscillation, sub- or super- harmonic resonances , quasi-periodic or even chaotic motion. Their responses may also be sensitive to initial conditions when multiple solutions exist. Although their nonlinear dynamics have been extensively investigated. The corresponding nonlinear power flow behaviours remains largely unexplored.

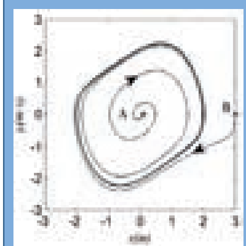

Fig. 3 Limit cycle oscillation of VDP oscillator($\alpha = 0.5, f = 0$)

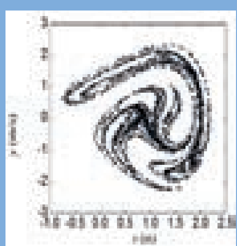

Fig. 4 Chaotic motion of Duffing's oscillator. $\xi = 0.02, \alpha = -1, \beta = 1, f = 1, \omega = 0.6$.

Instantaneous power flow

Fig.5 shows the instantaneous input power flow of Duffing's oscillator when it exhibits chaotic motion. The irregularity in input power pattern shown in Fig.5(a) results from the incorporated infinite frequency components which is demonstrated by Fig.5(b).

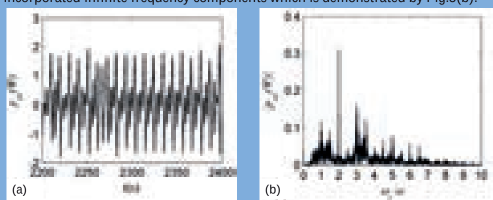

Fig.5 (a) Instantaneous input power and (b) frequency components in the input power of Duffing's oscillator($\xi = 0.02, \alpha = -1, \beta = 1, f = 1, \omega = 0.6$).

Time-averaged power flow

Time averaged input power of the system can be employed to incorporate the effects of multiple frequency components in the response, which can expressed as

$$\overline{p_{in}} = \frac{1}{T}\int_0^T p_{in}\,\mathrm{d}t\,.$$

Fig.6(a) shows the forced response of VDP oscillator may be either periodic or non-periodic for different excitation frequencies. In this situation, the time averaged input power provides a good performance indicator of input power level by using a long time span for averaging. It can be seen that the averaged input power value of VDP oscillator can be negative, which is different from that of linear systems.

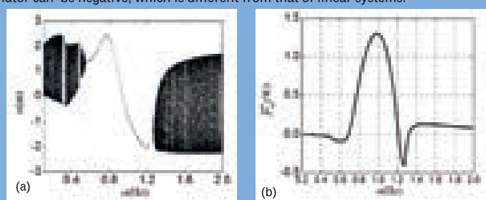

Fig.6 (a) Bifurcation diagram and (b) time averaged input power of VDP oscillator ($\alpha = 0.5, f = 1.0$).

Future work

1. To study power flow behaviours of systems exhibiting inherent nonlinear phenomenon;
2. To develop effective power flow techniques for nonlinear systems;
3. Apply nonlinear power flow theory to vibration control as well as energy harvester design.

Reference

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