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Fluid-Structure Interactions for Yacht Sails

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Motivations & Aims

- Ultimate objective: estabilish and assess an effective FSI procedure able to describe the physics of yacht sails.
- Current sail design is more and more technologically based, and great interest is posed in tools able to help the sailmaker in the optimization process.
- Studies have been carried out, but major simplifications have in general been assumed.
- This research intends to make use of OpenSource packages, as an effective way to understand and control the calculations routines.

Figure 1: Upwind and Downwind sails

Sail description:

- UPWIND SAILS:
  - Thin wing profiles acting like lift-generating devices
  - Separation is induced by the sharpness of leading and trailing edges.
  - The flow complexity is increased by the presence of the rigging.
  - Ideally simply supported on one side and one point, relatively small displacements allowed.
  - Build like thin sandwich made of fibres and film-like layers.
- DOWNWIND SAILS:
  - Much more cambered profiles, working at slightly higher angles of attack.
  - They work like drag devices, but a certain amount of lift generation is also involved.
  - Simply supported on three points, large displacements are allowed.
  - Build as an assembly of flat nylon type flat panels.
- IN BOTH CASES:
  - Large flow separation transition and recirculation are involved. Therefore the flow is very complex

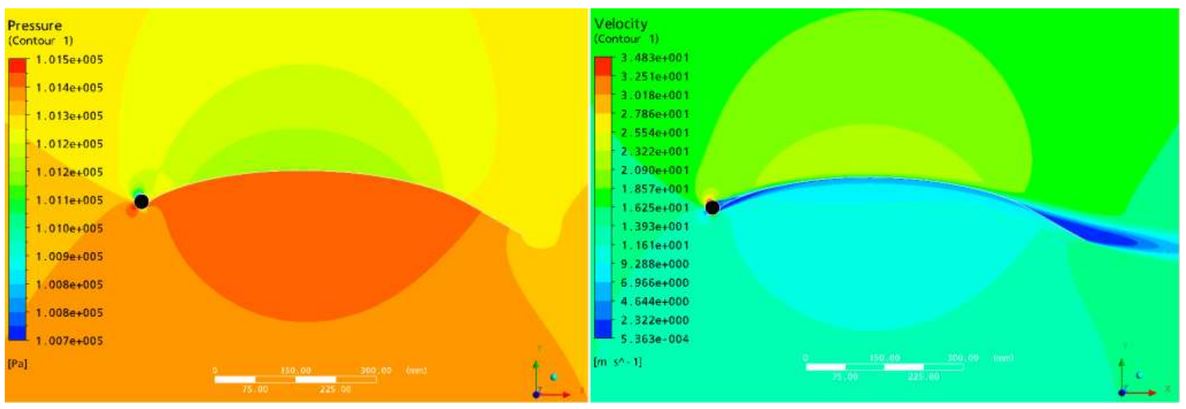

Figure 2: Pressure and velocity distribution for a typical mainsail section

Strategy:

- Produce analysis on simplified geometries like square or hemispheric-like fabrics.
- Test and assess results with a wind tunnel campaign. Measures will regard displacements of the sail and acting forces.
- Carry on analysis on more complex geometries.

Publications:

- *A FEM-Matlab code for Fluid-Structure interaction coupling with application to sail aerodynamics of yachts*. In IMAM Conference, Istanbul, Turkey, 12-15 Oct 2009. Pp. 907-916.
- *Fluid-structure interactions of anisotropic thin composite materials for application to sail aerodynamics of a yacht in waves. I*n 12th Numerical Towing Tank Symposium, Cortona, Italy, 04-06 Oct 2009. Pp.173-178.
- To be submitted: Article for Innov'Sail 2010, Lorient, France, 30 June-01 July 2010.

Fluid:

- A RANSE Finite Volume approach is needed for sail-type flows.
- SST looks like the most suitable turbulence model for such flows.
- Preliminary calculations have been carried out in ANSYS CFX. Results have been assessed against experimental data, available in the literature.
- Investigations are going on for using the opensource package OpenFOAM.

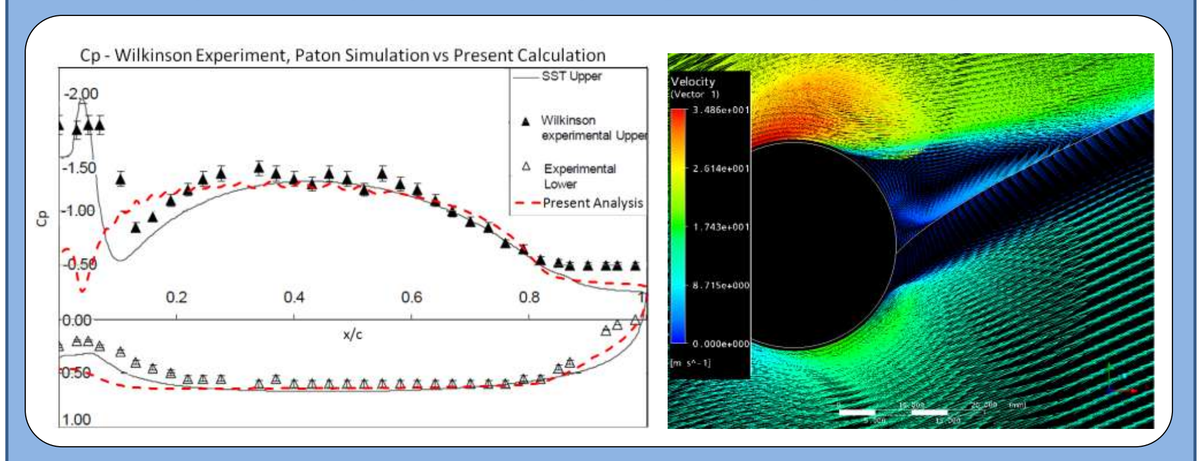

Figure 3: comparison of Cp on the mainsail section vs experimental measurements , and an impression of the separation behind the mast

Structure:

- Investigations have been carried out with an in-house build software, dealing with membranes.
- Such structures are not able to deal with buckling related phenomena such Wrinkling, since the lack of flexural stiffness.
- The analysis is currently carried out with the MITCNL shell elements, which are expected to reproduce the details of the sail's structural behaviour.

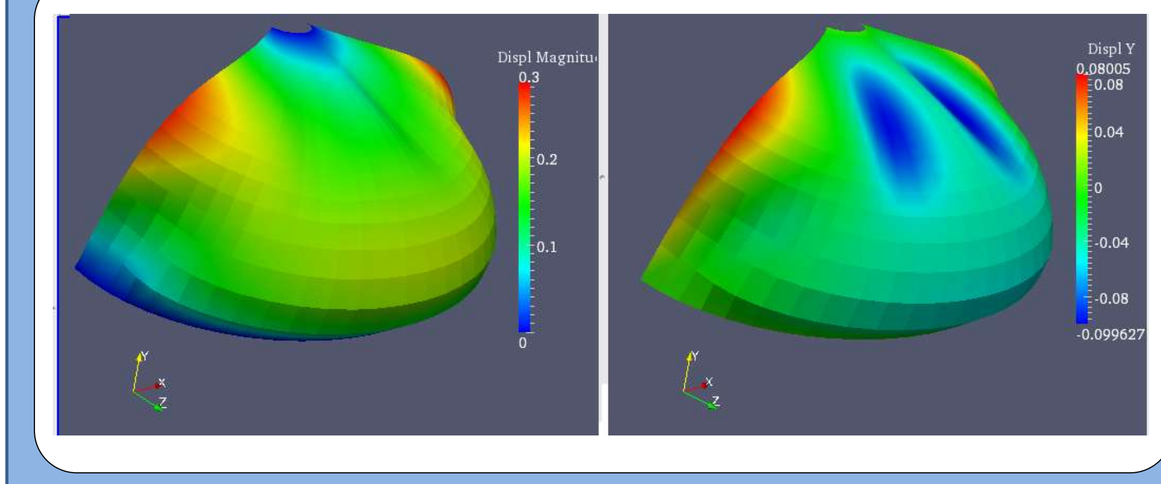

Figure 4:instability for an hemispherifc geometry, representative of a spinnaker head

Coupling:

- Fluid-stucture interactions coupling is a matter of associating a scalar pressure map on a geometric entity. In this case, the sail surface.
- The fluid grid is EULERIAN, whereas the structural grid is LAGRANGIAN. The domain deformation should therefore follow the structural deformation in a lagrangian way on the structure's interface.
- Mesh deformation velocity should be considered in the formulation of Navier-Stokes equations
- The interaction between the fluid and the structure produces added mass effects

Conclusions

- A new type approach for the investigation of Fluid structure interaction for thin fabric is proposed. This is intended to be relevant in sail analysis.
- The flow is modelled with state of the art solvers, turbulent effect are considered.
- The structure is modelled with thin shells, able to reproduce the details of the sailcloth behaviour.
- Effective ALE coupling is needed for interfacing different calculations.
- The calculation will entirely involve open source packages.

FSI Away Day 2010