Body Non Linear 3D Hydroelasticity

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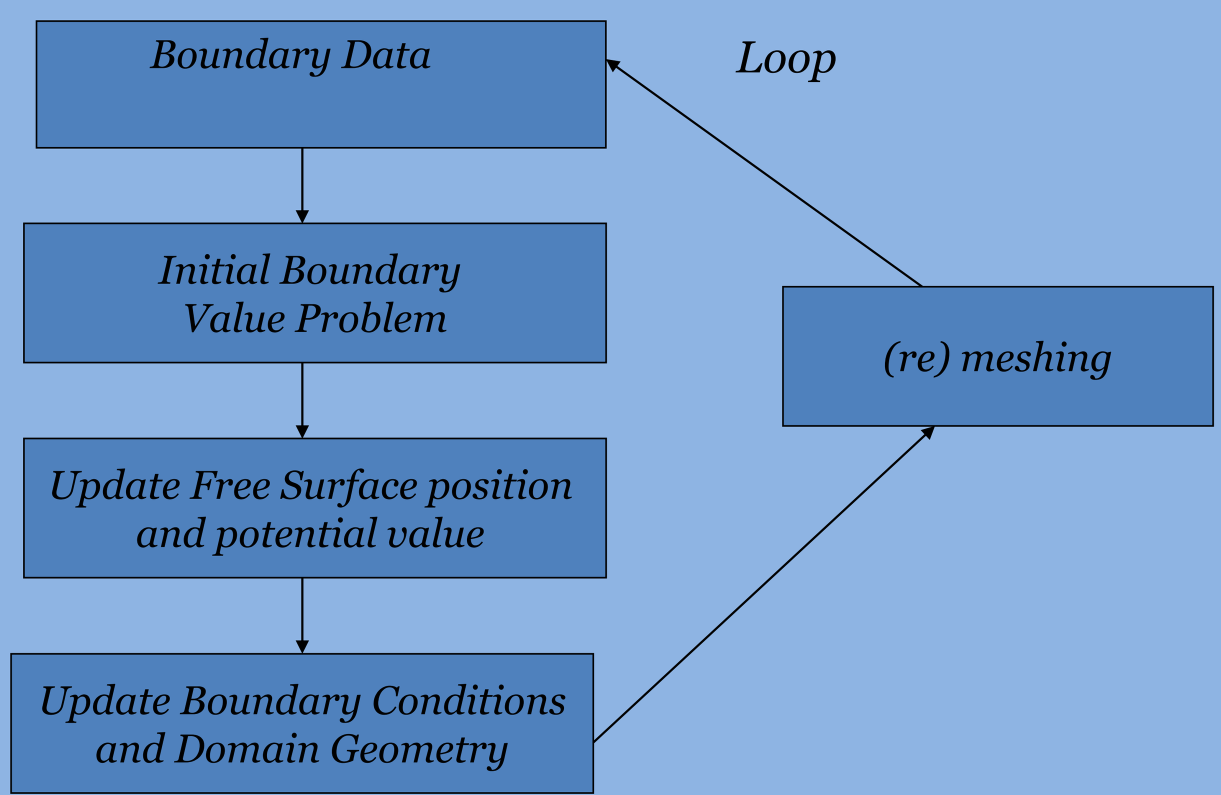
Description and Goal

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 Initial Boundary Value Problem (IBVP) using the rankine source as Green's function.

$$\int\int_{Body}\phi(\vec{y})G_n(\vec{x},\vec{y})ds(y)-\int\int_{FS}\phi_n(\vec{y})G(\vec{x},\vec{y})ds(y)= -\alpha(x)\phi(x)-\int\int_{FS}\phi(\vec{y})G_n(\vec{x},\vec{y})ds(y)+\int\int_{Body}\phi_n(\vec{y})G(\vec{x},\vec{y})ds(y)$$

2-Free surface potential and position are then updated using the IBVP solution, in a Lagrangian fashion this is written as:

$$\frac{D(\mathbf{x(t)})}{Dt}=\nabla\phi \qquad \frac{D(\phi)}{Dt}=\frac{1}{2}\nabla\phi\cdot\nabla\phi-gz$$

3-Current work is focusing on evolving the free surface implicitly by convecting the distance function (d) that represents the domain, namely:

$$\frac{\partial d}{\partial t}+Vn\cdot\nabla d=0$$

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*

Importance of Non Linear Effects on wave-induced motions and loads

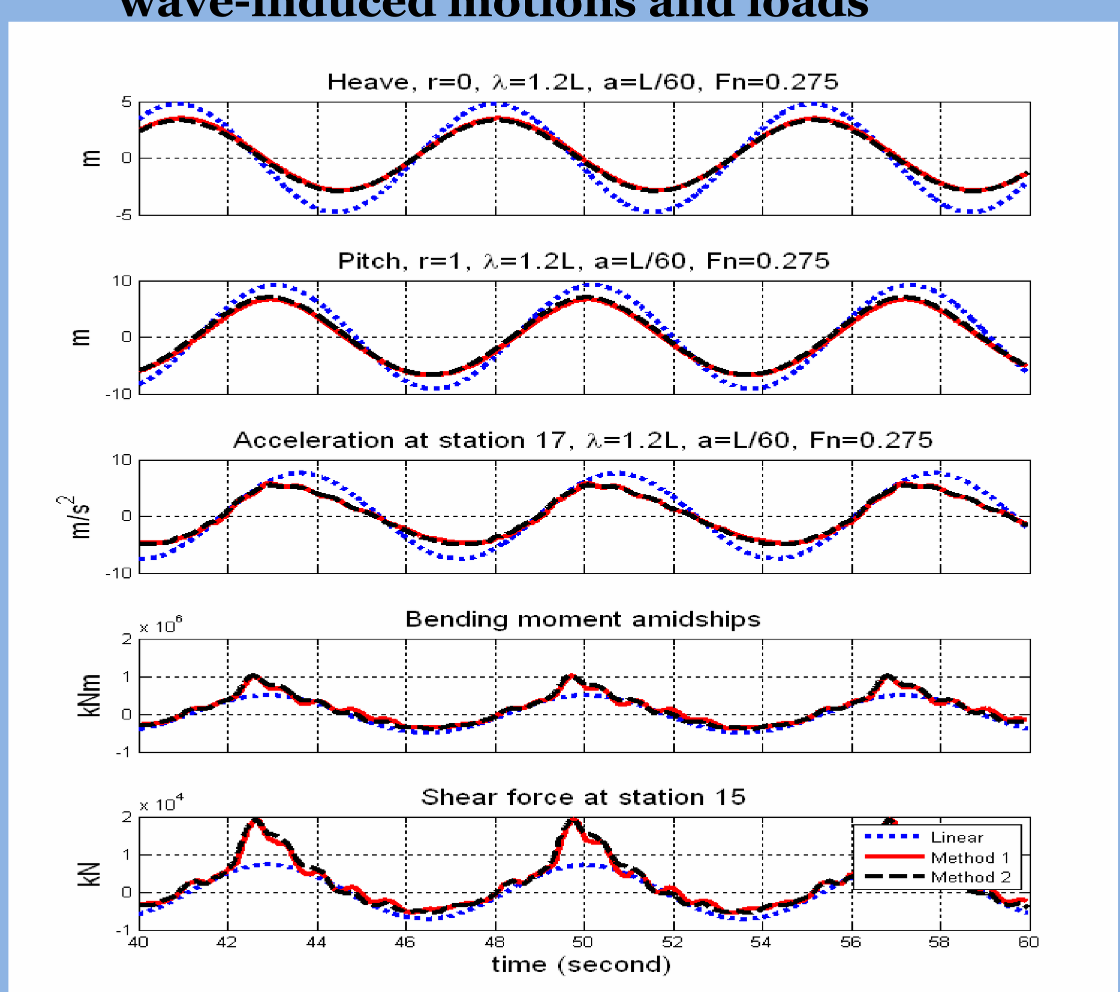


Figure 1: Comparison between linear and non linear 2D hydroelasticity analyses of the heave and pitch motions, bow acceleration at 0.85L, midship bending moment and shear forces at 0.75L for the S175 container ship travelling in regular head waves presented by Park & Temarel (PRADS 2007).

Partial Results

Initial Boundary Value Problem

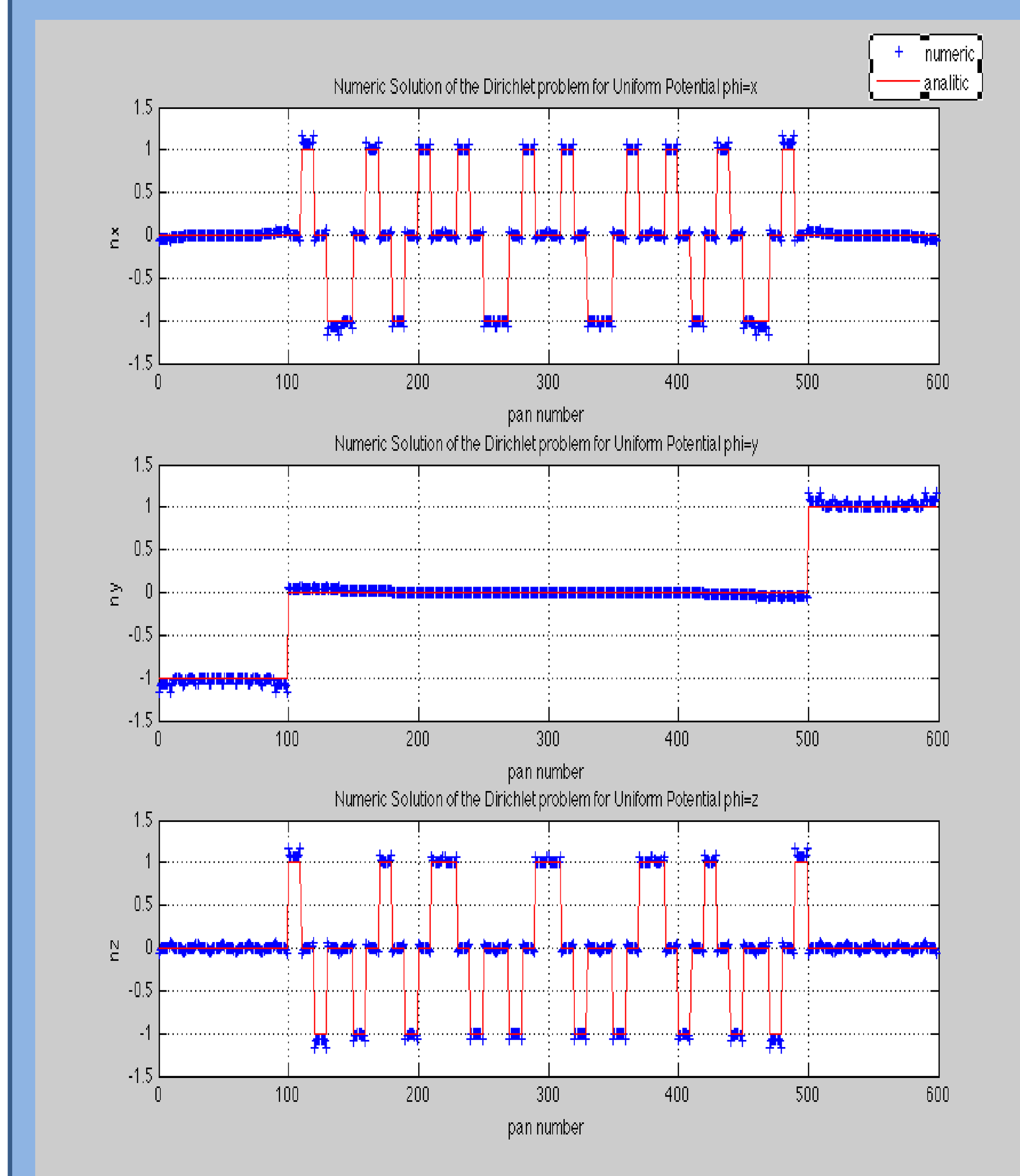


Figure 2 : Solution of the Initial Boundary Value Problem for the simplified case where the potentials are uniform in the x, y and z direction. Values above represent the normal direction in x, y and z respectively.

Mesh Generation and Free Surface evolution

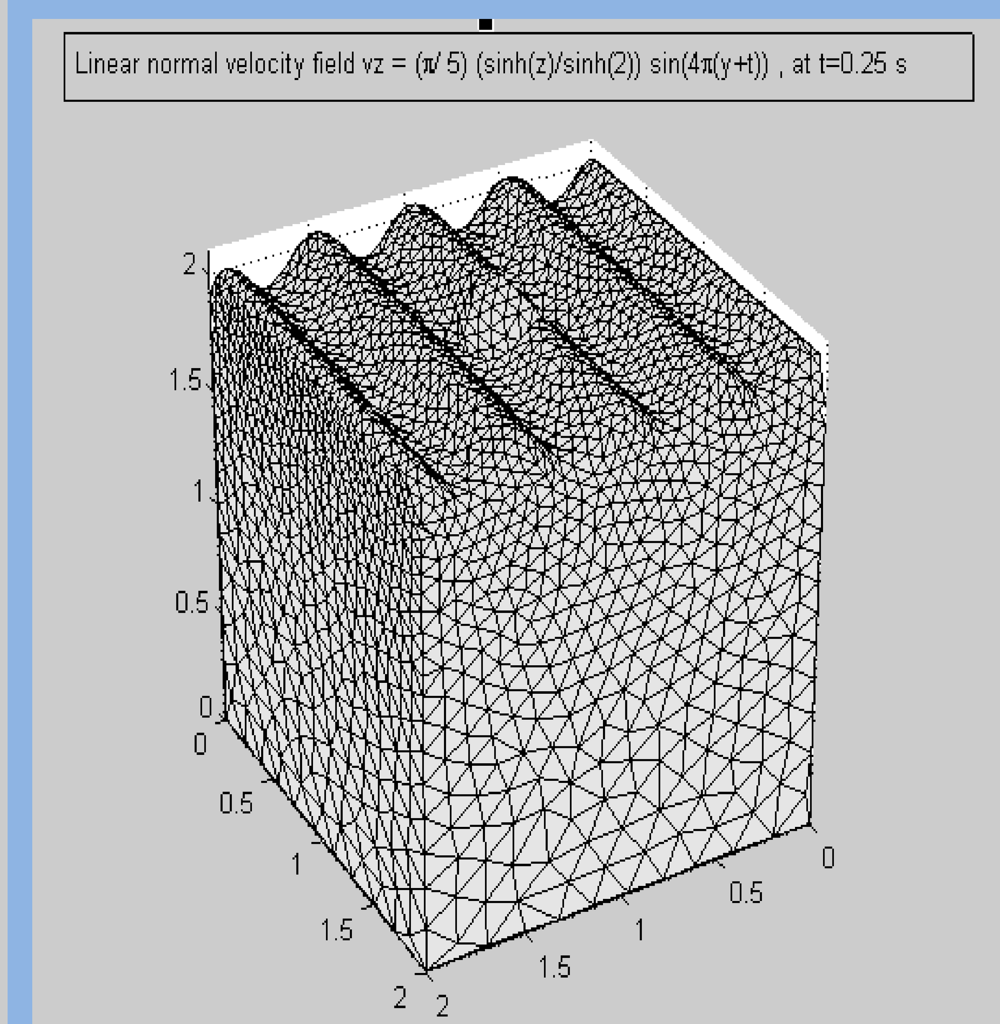


Figure 3 : Mesh generation of the free surface propagating on a prescribed velocity field with a half immersed sphere (r=0.25) using a distance function evolved by single phase level set theory. Mesh size 5218 triangles, edge size density e=ho+ho(2-z), with ho=0.05. A background Cartesian grid was used to represent the distance function.

Future Work

- Combine the free surface evolution with the developed boundary element solver to tackle forced heave and pitch motions, validated against predictions from linear and non linear free surface boundary conditions.
- Extend the methodology to hydroelasticity and to free floating bodies in the presence of incident waves

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FSI Away Day 2011