6DOF coupled dynamic simulation of ship collisions using LS-DYNA and USFOS

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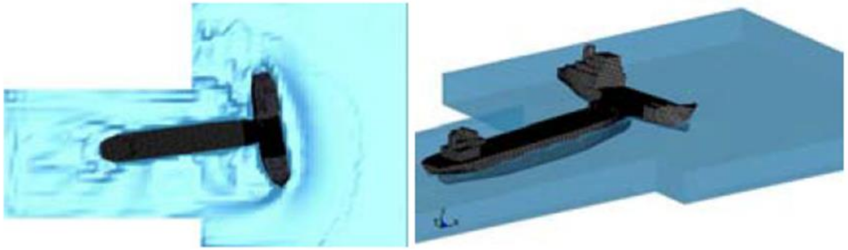

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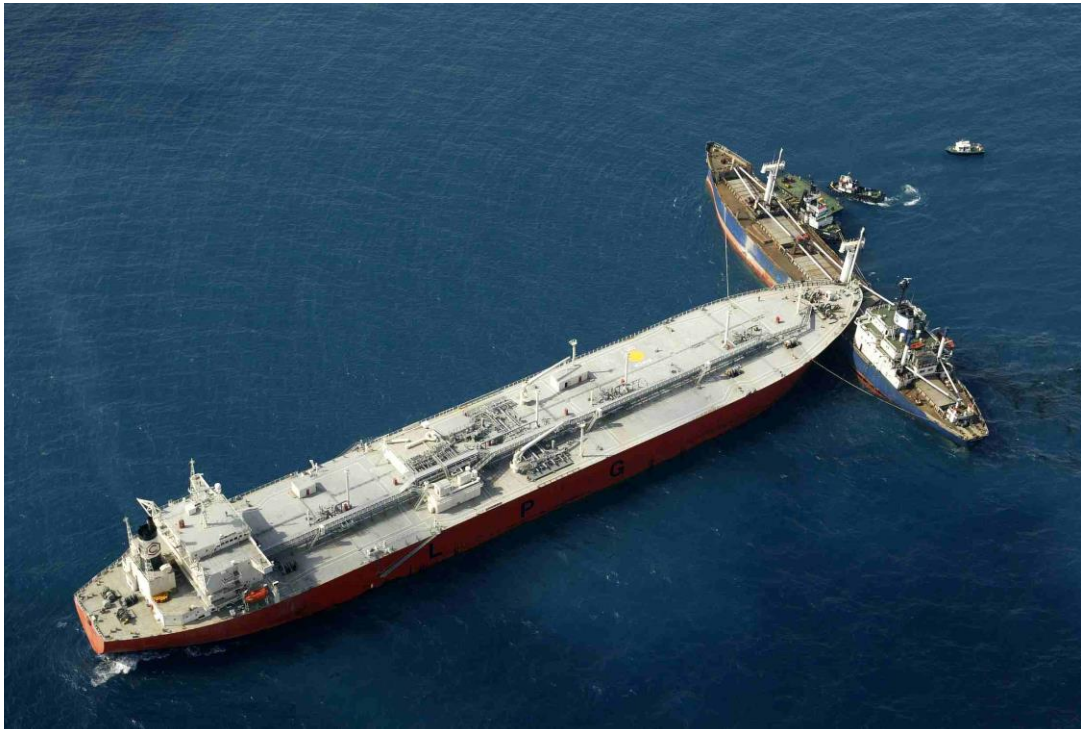

Ship collision and grounding loads represent critical loading to the safety of ships and offshore platforms, which should be designed against.

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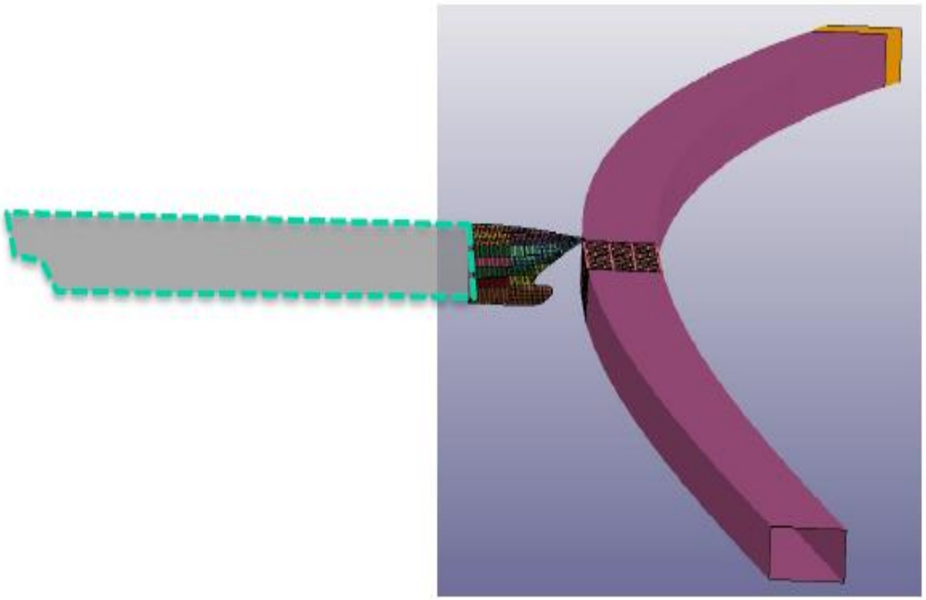

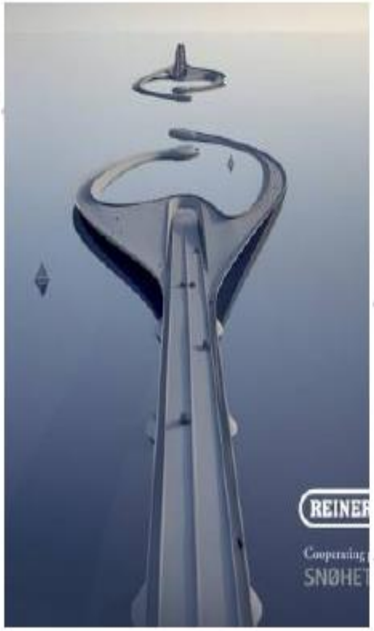

- *Floating bridge projects across fjords by The Norwegian Public Roads Administration (NPRA)*
- *Need to be designed to resist extreme environmental loads and accidental actions*

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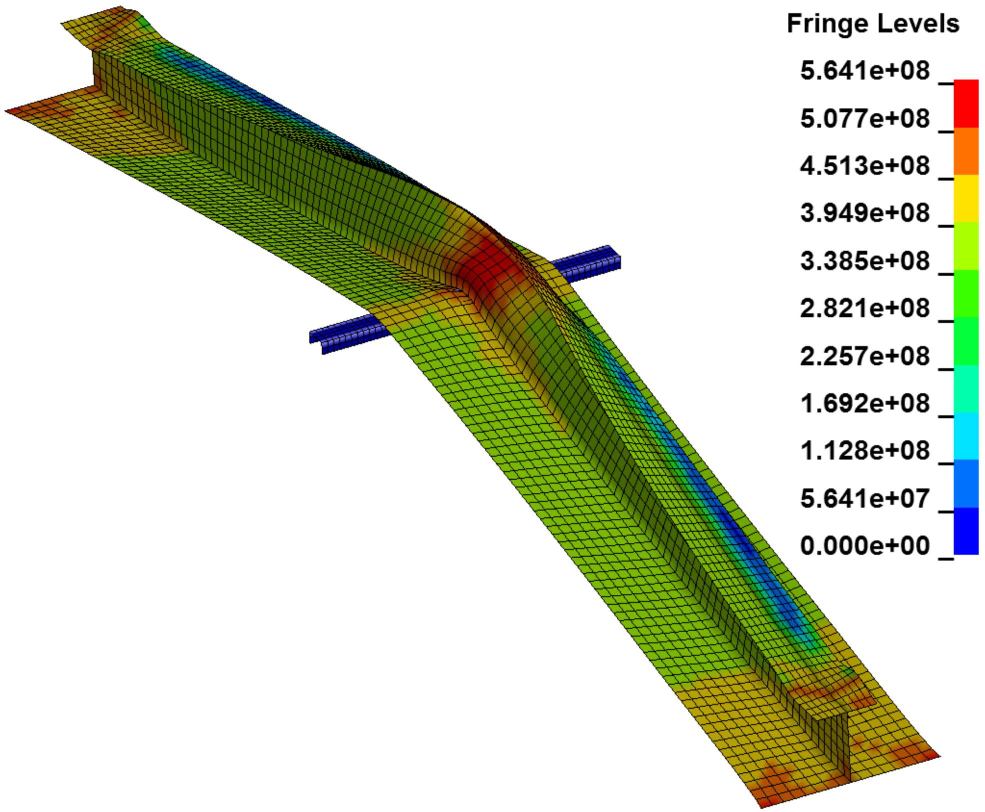
Analysis tools: LS-DYNA and Abaqus

- Traditional nonlinear finite element software



- Detailed finite element modelling
- Penalty based contact algorithm
- Polynomial interpolation functions

Problems for large structures: efficiency

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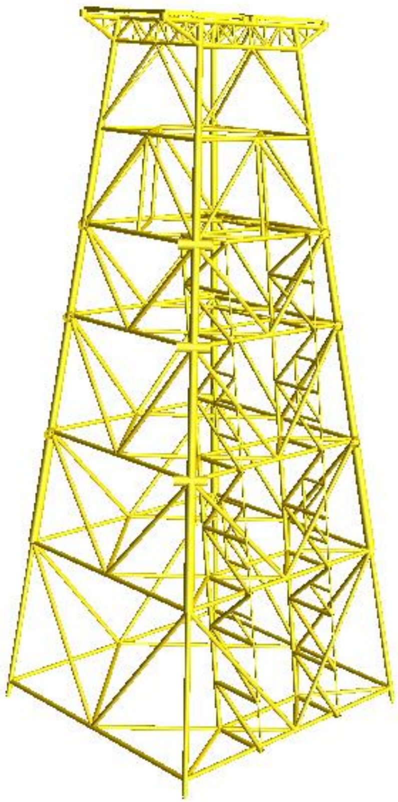
Analysis tool: USFOS

A Computer Program for Progressive Collapse Analysis of Offshore Structures

- Developed by Marintek and NTNU, marketing by DNV-GL software



- The basic idea of the program is to use only one finite element for a basic member of structures.
- Powerful beam elements
- Allow to use a limited number of shell elements

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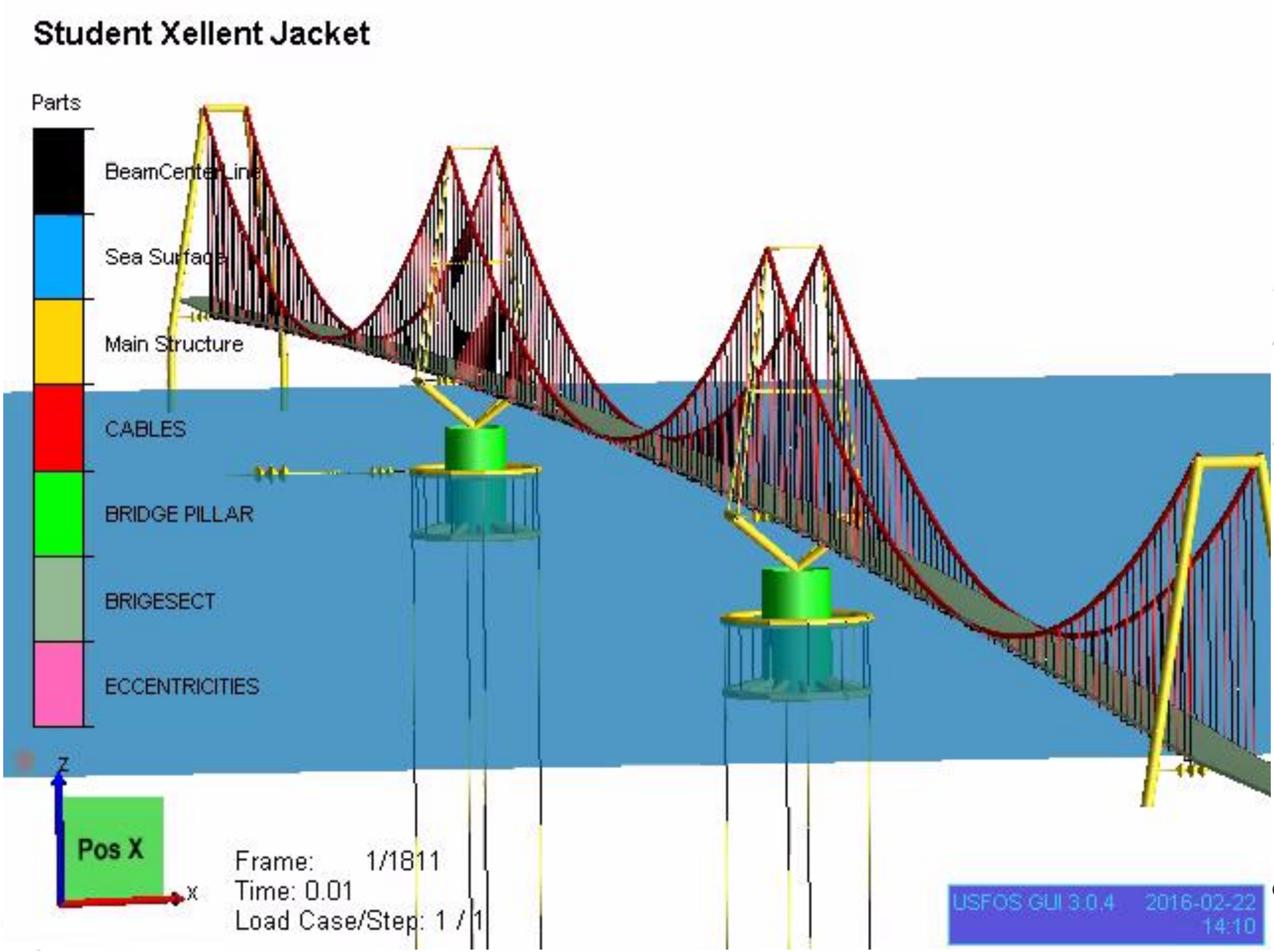
An example of USFOS analysis



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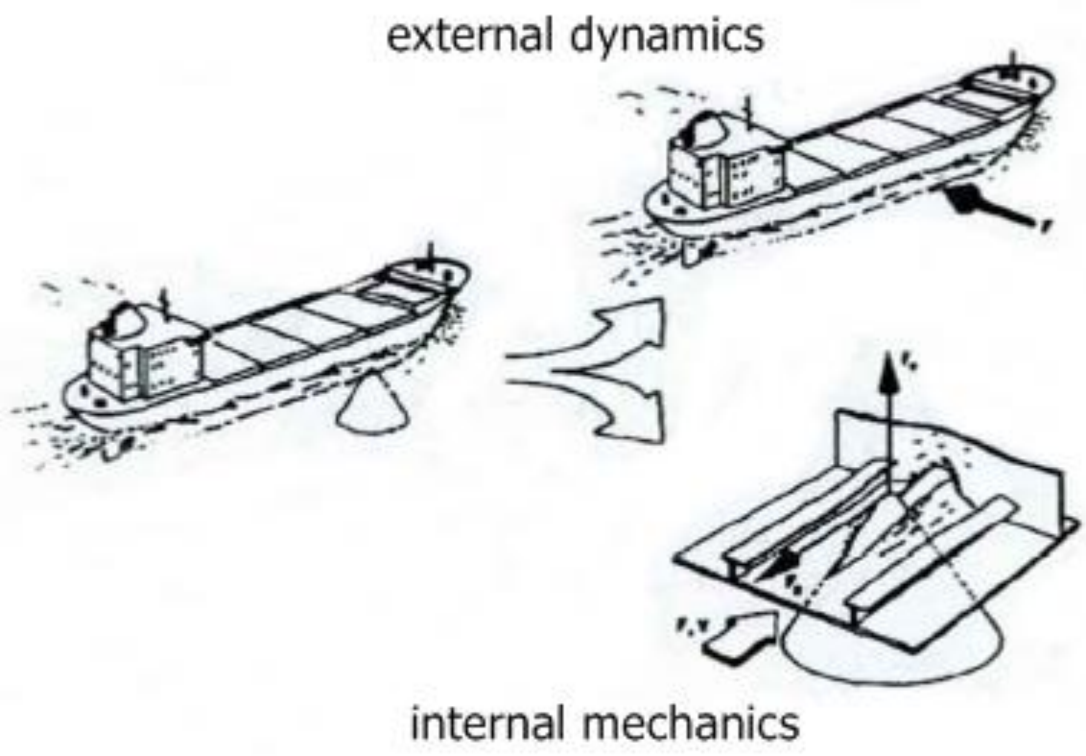
Traditional collision analysis: decoupled method



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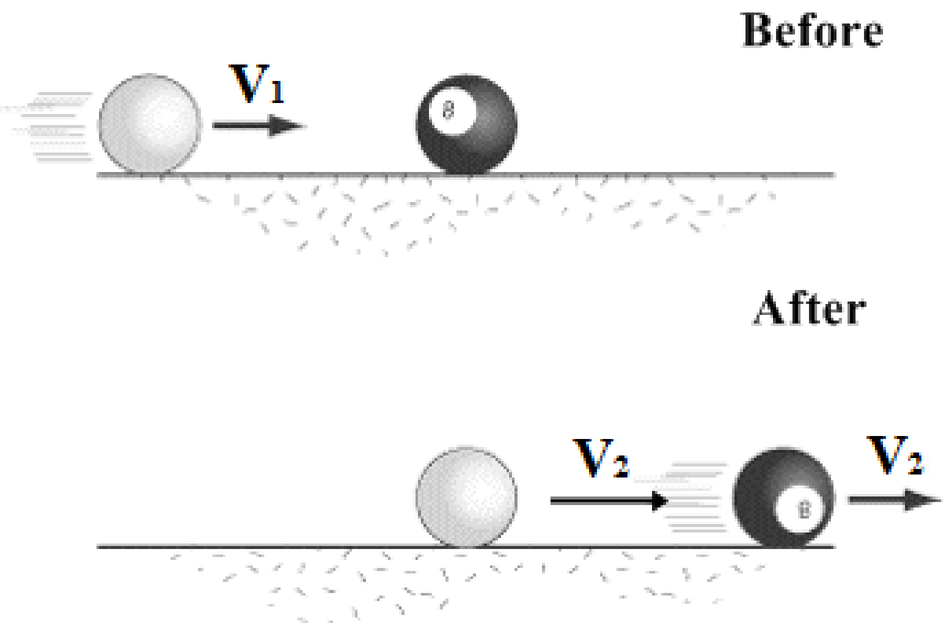
External dynamics



Suppose they move together after collision

$$M_1 V_1 = (M_1 + M_2) V_2$$

$$E_{loss} = 1/2 M_1 V_1^2 - 1/2 (M_1 + M_2) V_2^2$$

The lost energy should be dissipated by:

Local plastic deformation
Global elastic vibration
Fracture
..

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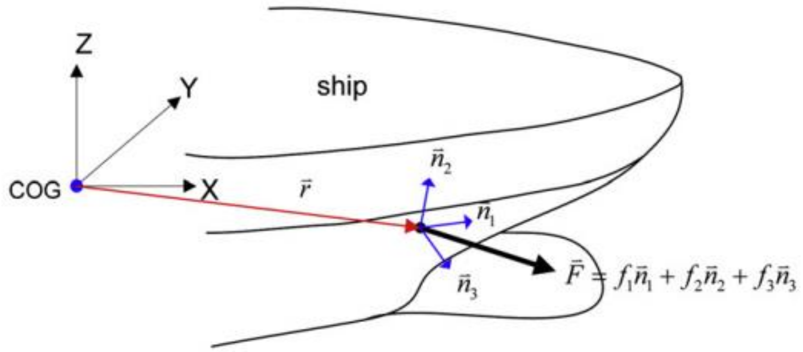
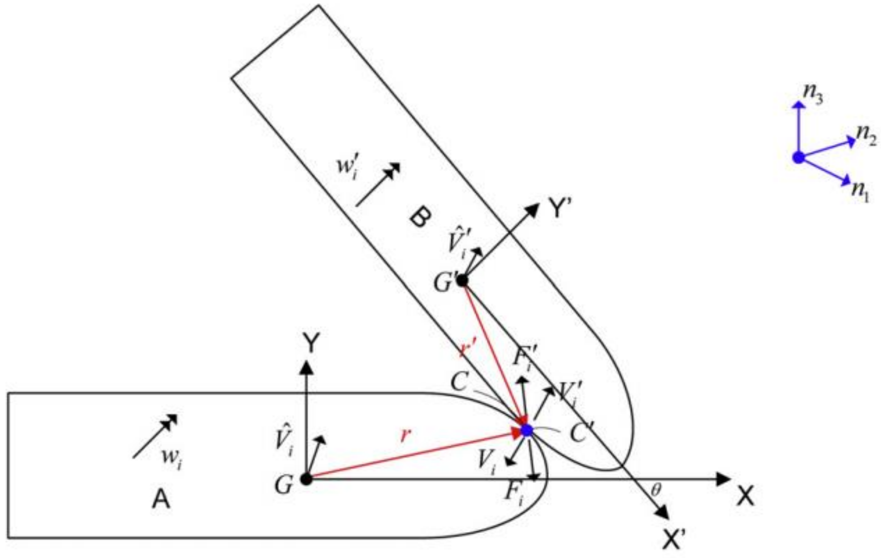
External dynamics





Hydrodynamic forces are simplified as only contant added masses

E_{loss}

The lost energy should be dissipated by:

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Global elastic vibration
Fracture
..

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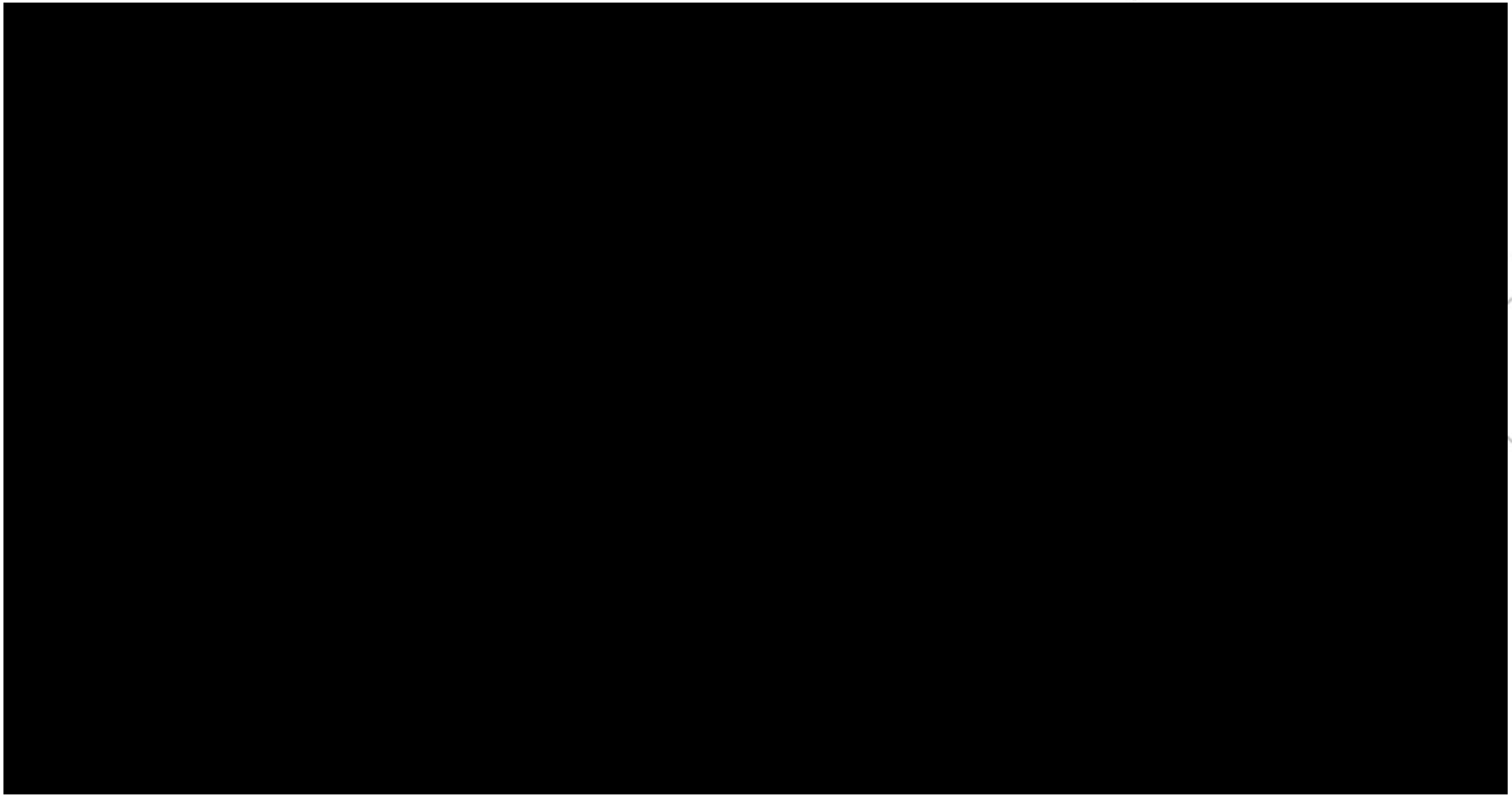
Internal mechanics



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The decoupled method

- Advantages

1. easy to calculate
2. acceptable accuracy for energy dissipation in most cases

- Drawbacks

1. Ship motions can not be considered
2. The effect of fluid is too much simplified
3. Not good accuracy for oblique collisions

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6DOF coupled collision analysis in LS-DYNA

1. Hydrodynamic part: linear potential flow theory, considering possible forward speed effect

2. Structural mechanics part: calculated in LS-DYNA

The forward speed effects:

1. The encounter frequency: $\omega_e = \omega_0 + \omega_0^2 U / g$

2. Bernoulli equation: $p = -\rho\left(\frac{\partial \phi}{\partial t} - U\frac{\partial \phi}{\partial x}\right)$

3. Changes of the free surface and body boundary conditions

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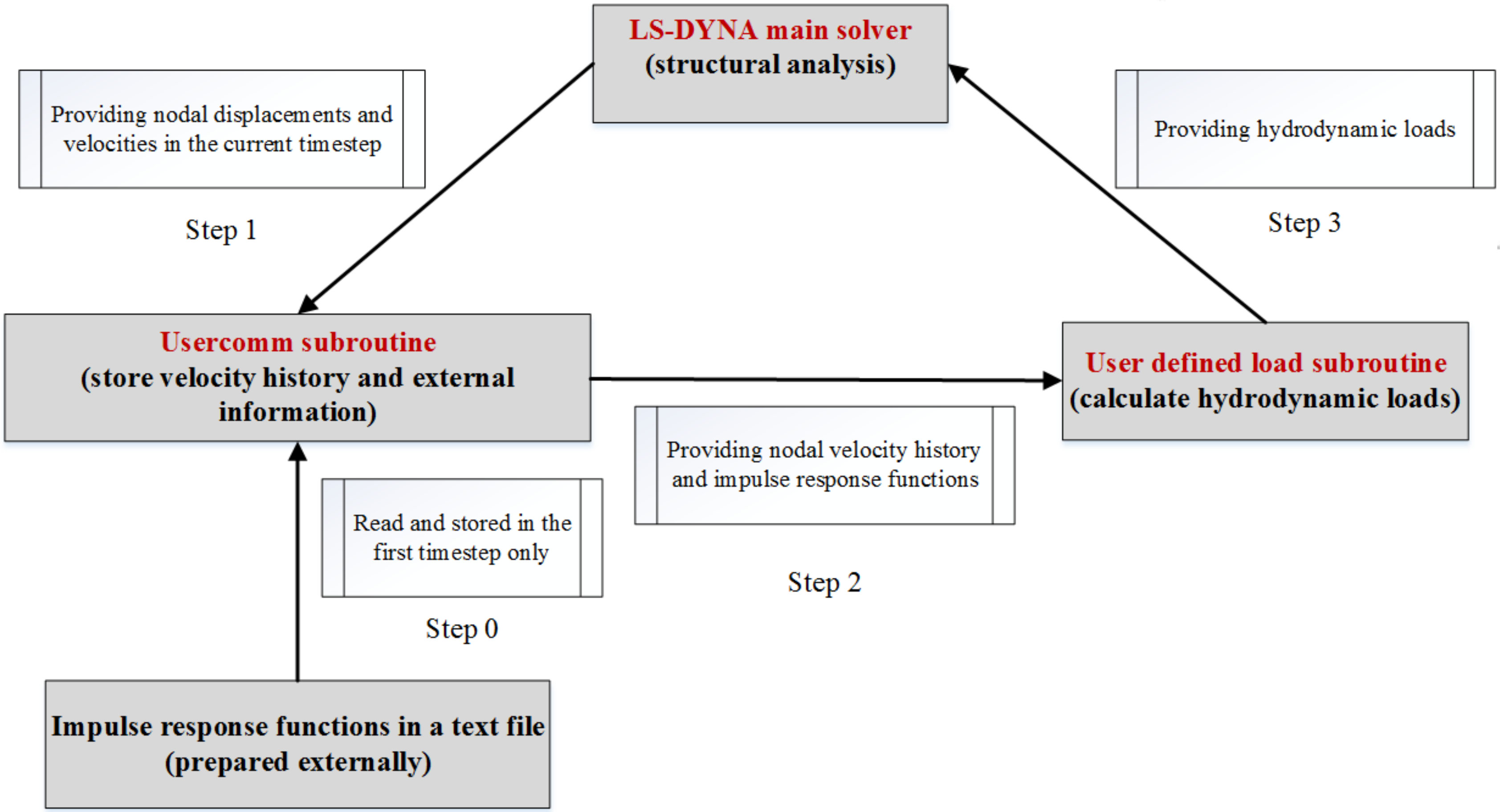
Implemetation procedure



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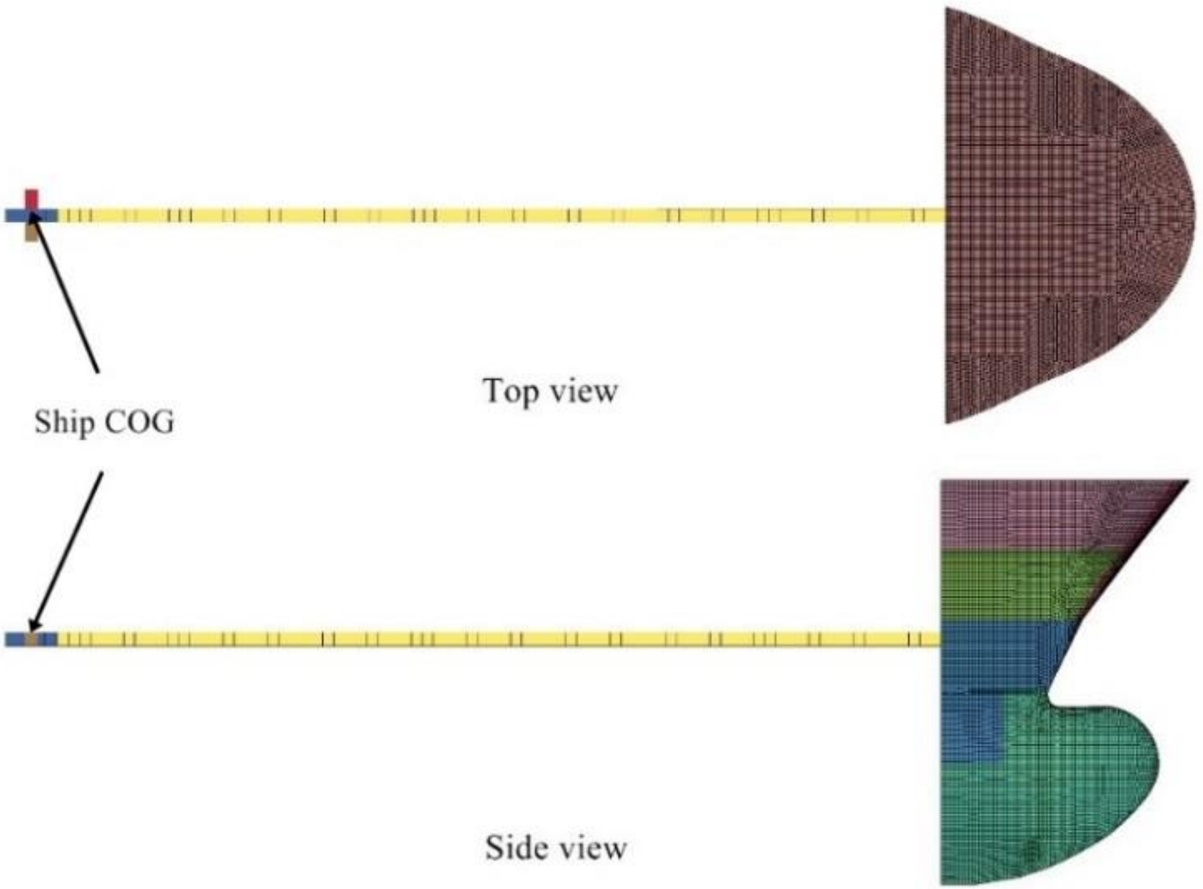
An example case



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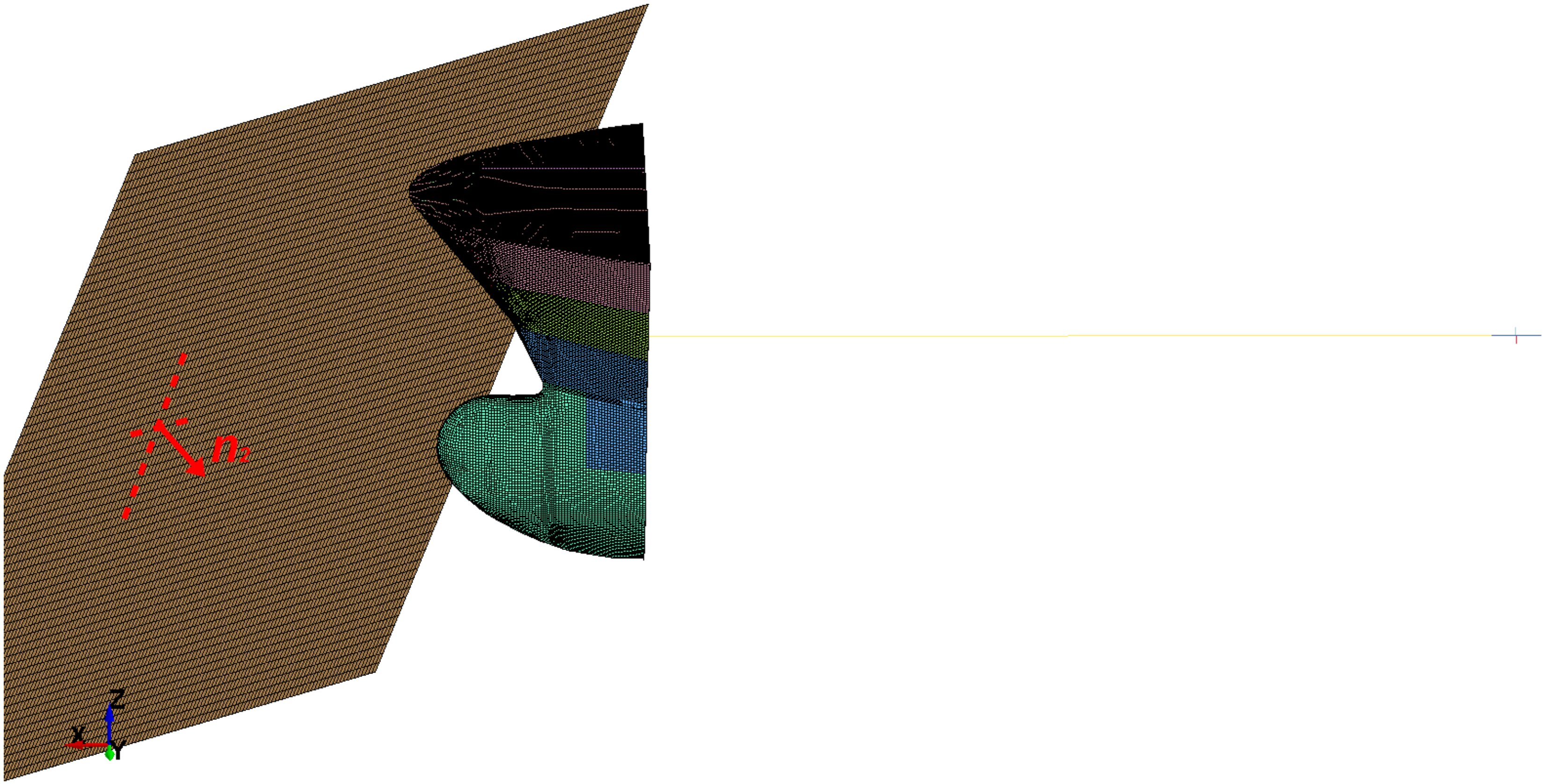
An example case



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Side view

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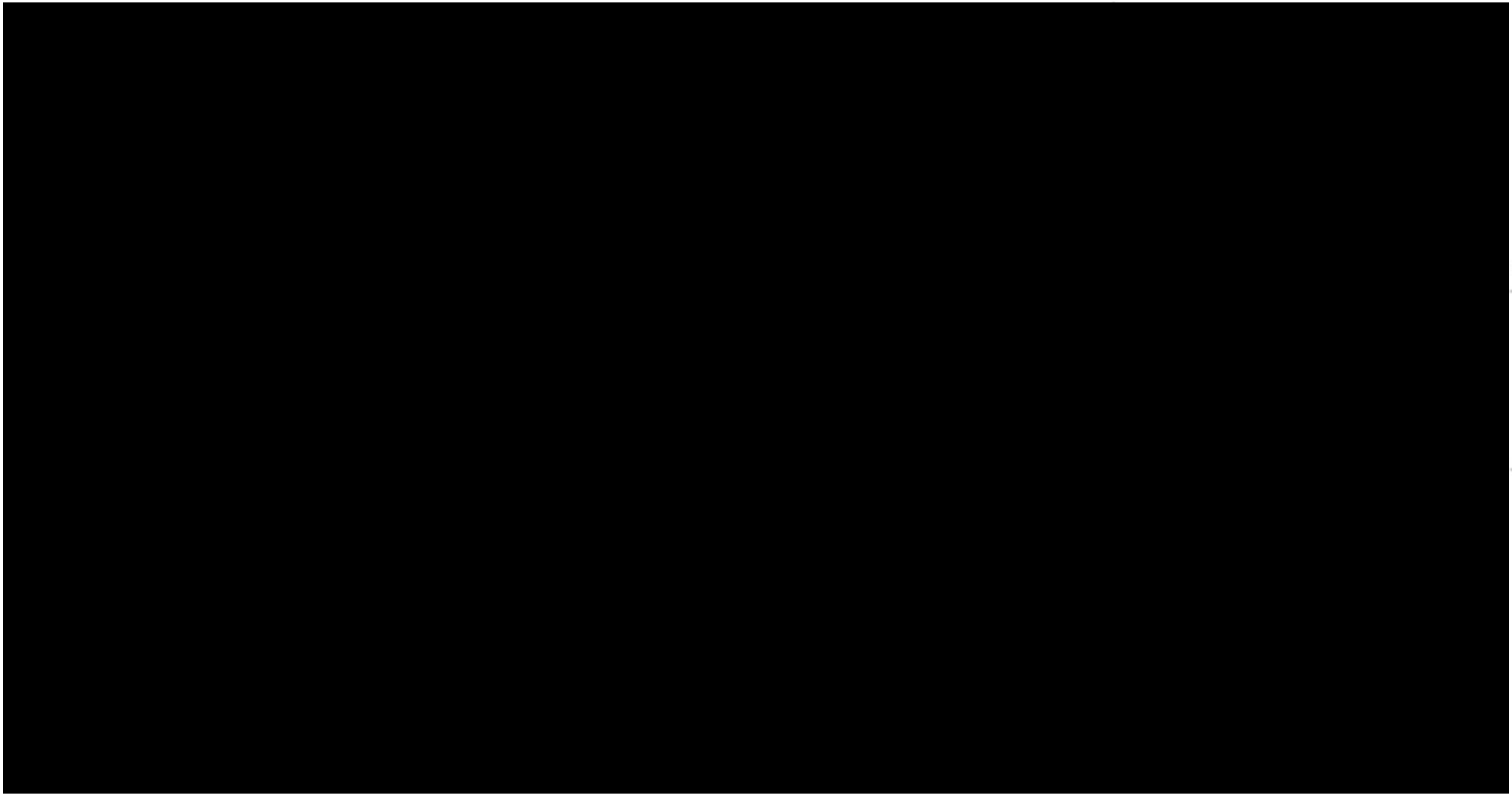
Front view



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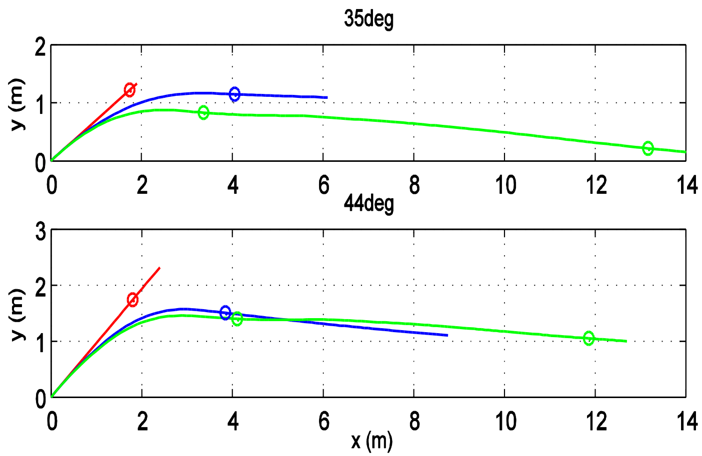
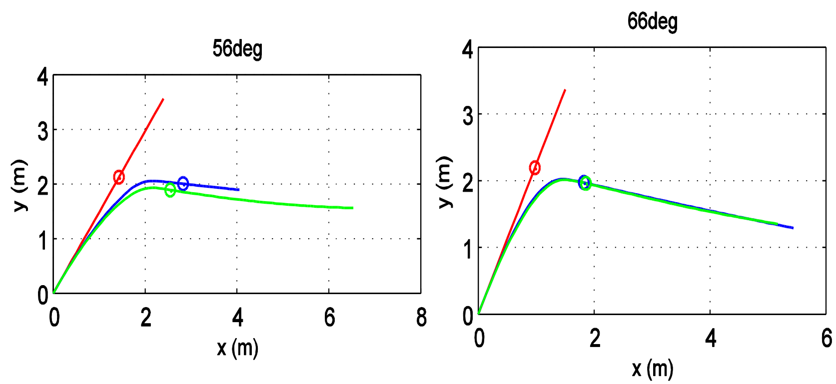
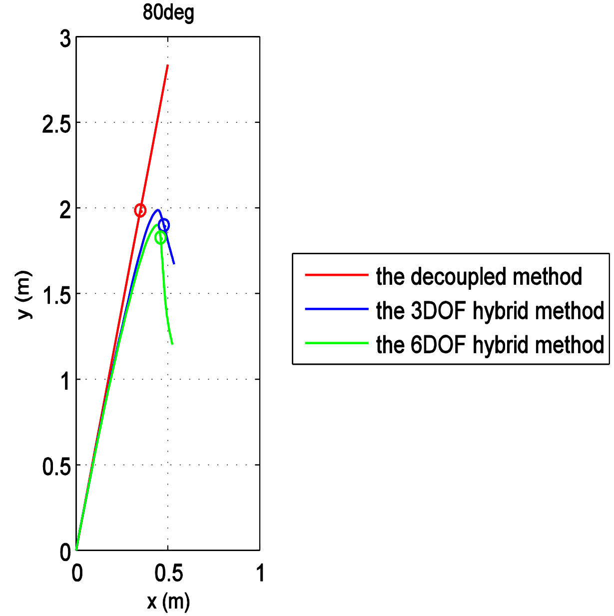
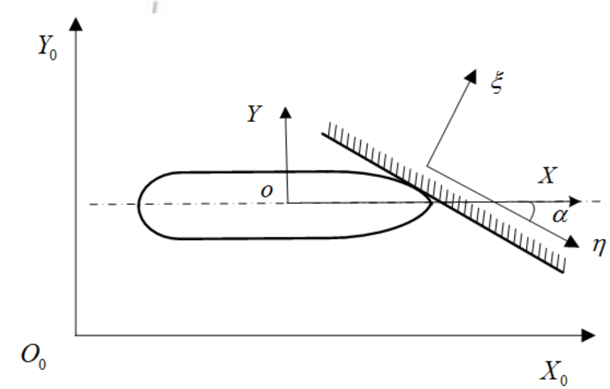
Ship motion trajectories









In the local η-ξ coordinate

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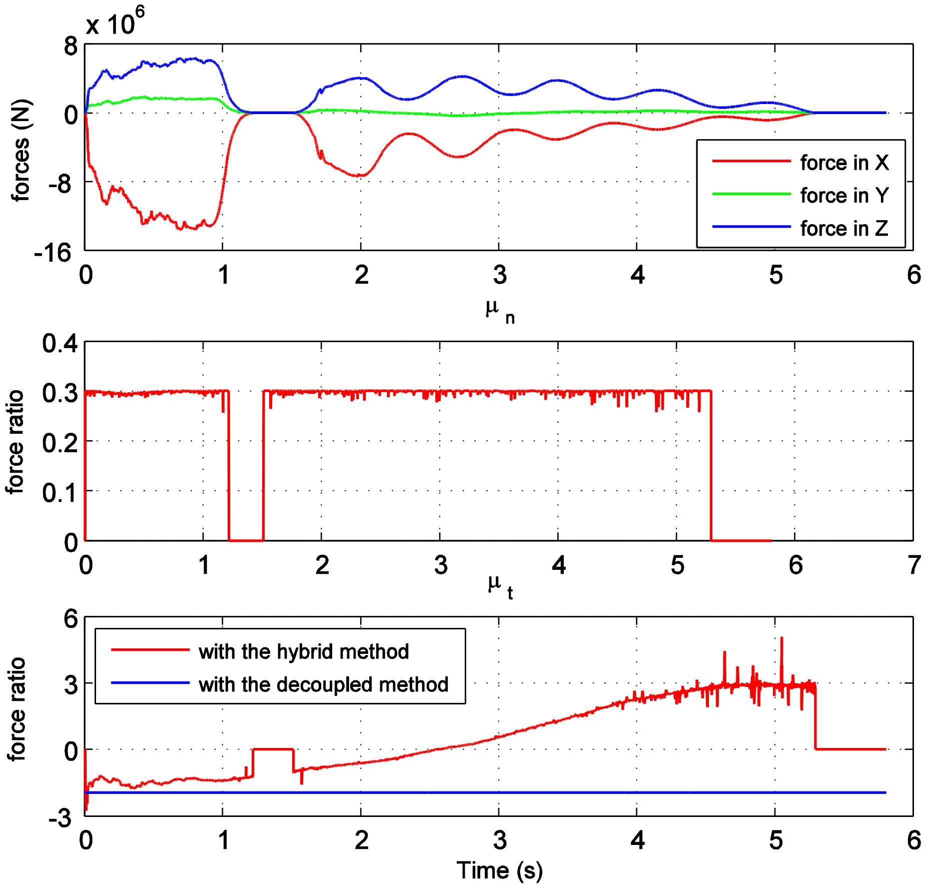
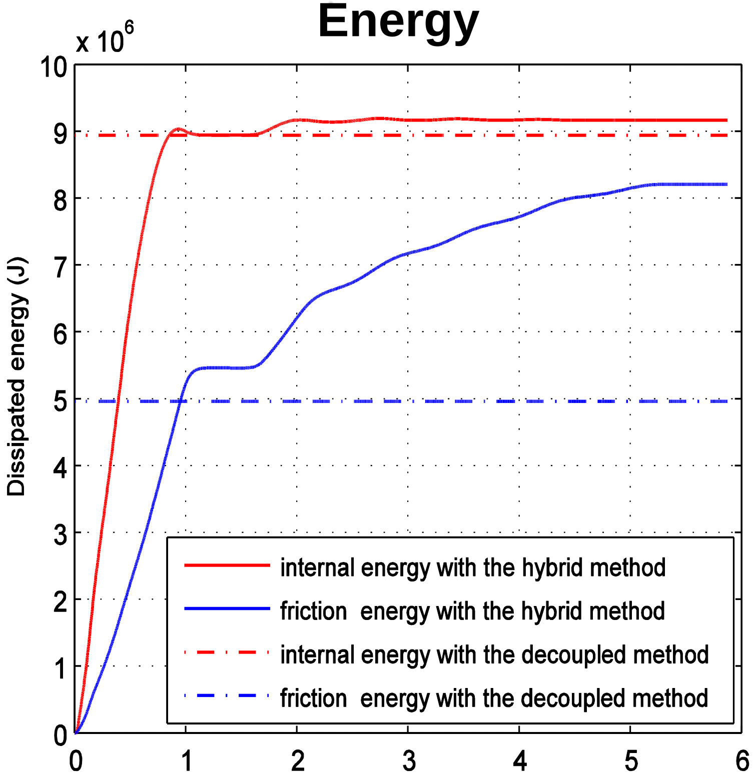
Secondary impacts

Force



Energy



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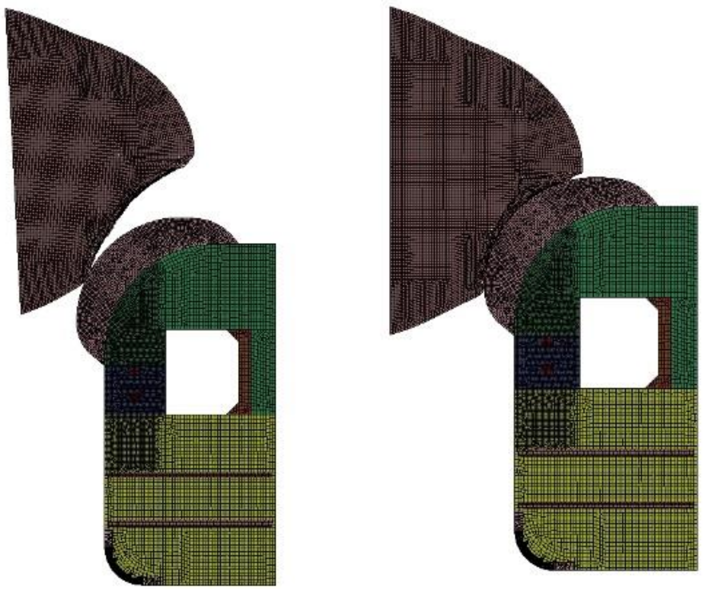
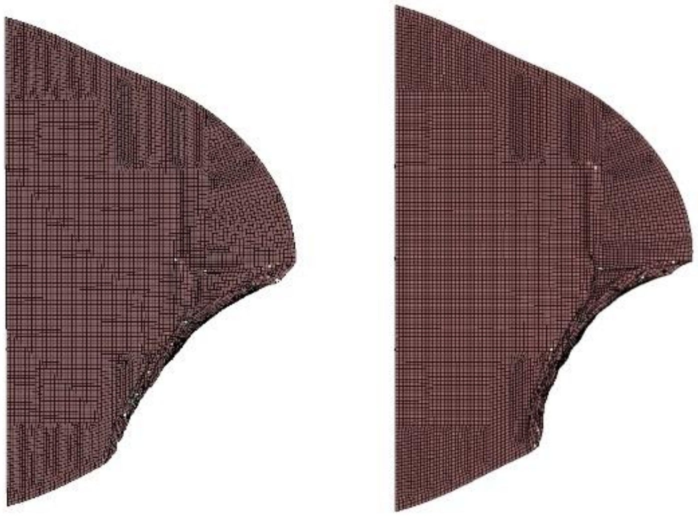
Structural damage



coupled model decoupled model



coupled model decoupled model

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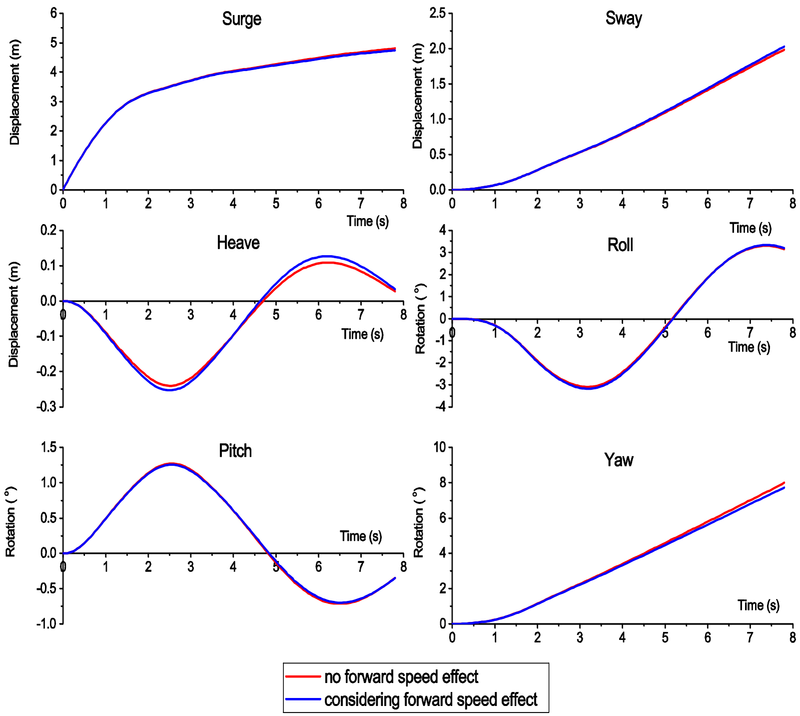
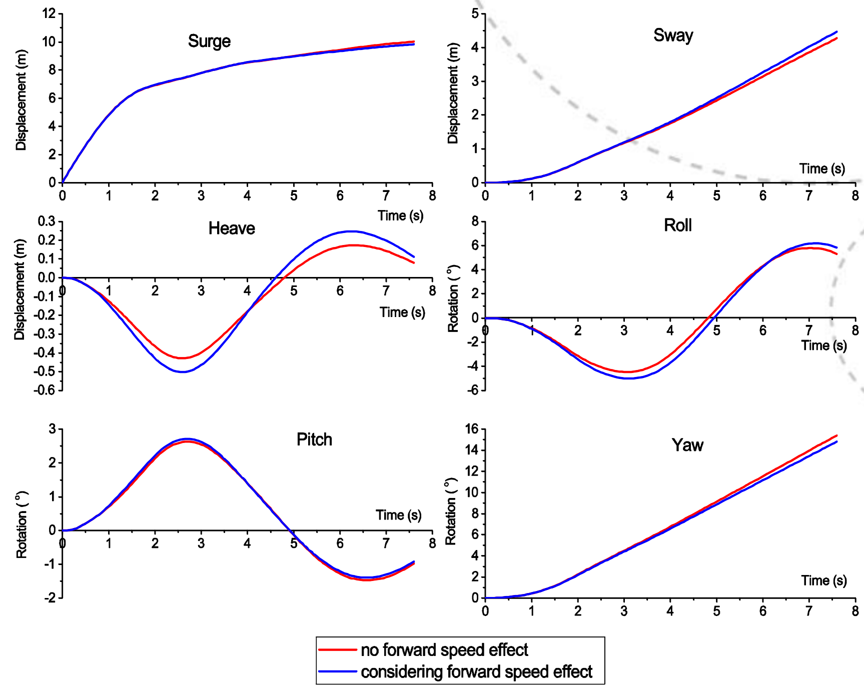
Influence of forward speed effect

case H2-2.78, Fn=0.1



case H2-5.56, Fn=0.2



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Advantages of the 6DOF coupled method

1. Improved accuracy in both hydrodynamic forces and structural mechanics

2. 6DOF global ship motions and oblique collisions can be well considered

3. The transient effects are well captured

4. It can be extended to further include the forces of waves, current and hydrodynamic interactions in the future

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Future work

- Implementation of the hydrodynamic forces into USFOS (coupled analysis for large platforms)
- Considering the hydrodynamic coupling between the striking and struck objects

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Thanks for your attention!

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