Accidental Impact Resistance of non-disconnectable buoy type FPSO

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Scope of work

The main purpose of this Master thesis is to study the impacts from a offloading tanker on the non-disconnectable Octopus buoy. The goal is to perform realistic simulations where the ship, the platform and the surrounding water are modelled and where the interaction between them is taken into account. The results from the integrated analysis shall be compared with simplified methods based on decoupling of the problem into internal and external mechanics.
The effect of including ballast water in collisions shall also be explored by using integrated fluid structure interaction (FSI) analysis

Introduction

In a design situation the collision problem is often simplified by splitting it into external dynamics and internal mechanics. The external dynamics determine the rigid body motion of the structures and the energy that must be absorbed in the collision. The damage and energy absorption is determined from the internal mechanics. In this Masters thesis the effects of this simplification is investigated.

General principles

The ship collision action is characterized by kinetic energy, [2]. The kinetic energy is governed by the mass of the ship, including added mass, and the velocity of the vessel at the instant of impact. After the collision the energy must either remain as kinetic energy, or be absorbed in the structures. Absorbing the kinetic energy in the structures will generally cause large plastic strains and significant damage to one or both of the structures involved depending on their relative strength.

The amount of kinetic energy absorbed in the collision depends on the structures mass, mass distribution and impact position. The amount of energy to be absorbed can either be calculated in calculated using simplified formulas (decoupling of the problem), or by performing an integrated analysis. In an integrated analysis both the internal and external mechanics are calculated together. If the problem is decoupled, the internal mechanics can be calculated using NLFEA or by using simplified methods such as Amdahl's method [1].

Models

All of the finite element models are created using MSC-Patran.The analyses are created and post-processed using LS- Prepost. LS- DYNA is used to calculate the numerical simulations. The fluids

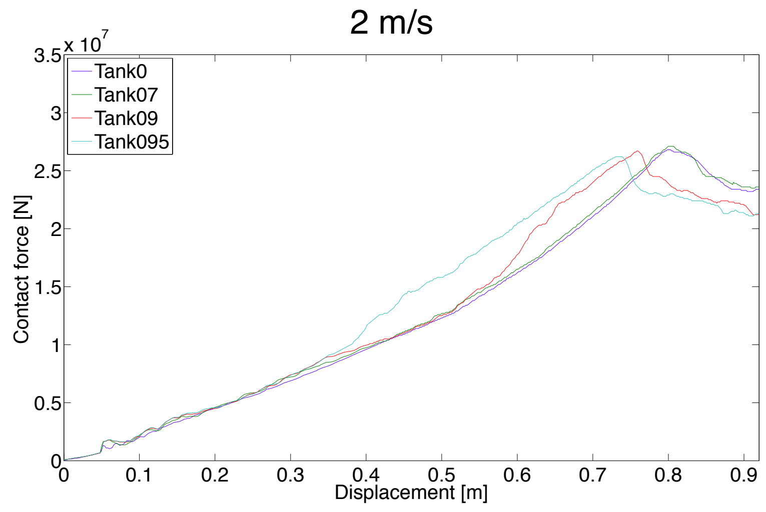
in the analysis are modelled using ALE (Arbitrary Lagrangian Eulerian Method). Creating a correct model using ALE proved to be much more difficult than expected. It was especially difficult to model the FSI correctly.

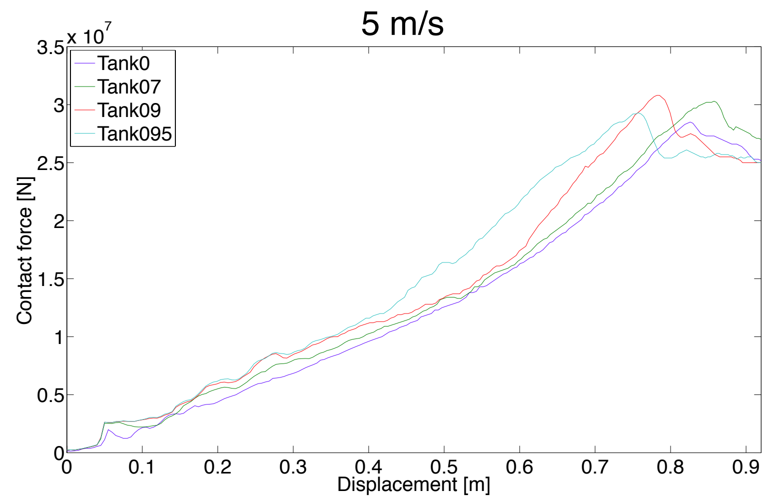
References

[1] Jørgen Amdahl. *Ph.d. thesis. EnergyAbsorbtion in ship-platform collisions.*
[2] *NORSOK N-004, Design of steel structures.*
[3] Zhenhui Liu *Ph. d. thesis. Analytical and numerical analysis if iceberg collisions with ship structures.*

Collision analyses with internal fluid structure interaction

Ballast water is traditionally not included in collision analyses and the effect of ballast water in collisions is therefore poorly documented. To clearly see the effects of including ballast water in collisions, a simple collision problem is created where a rigid solid sphere impacts a stiffened ballast tank. Analyses are performed for different impact velocities (2, 5 and 8 m/s) and filling levels (empty, 70 %, 90% and 95%).

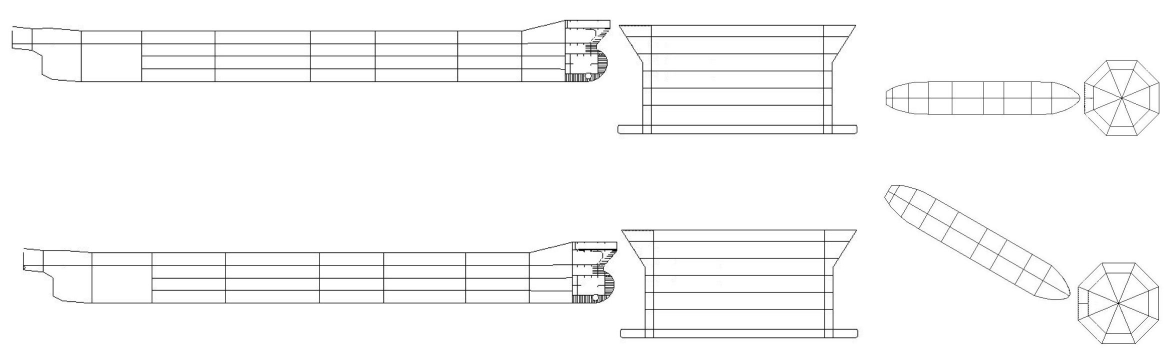




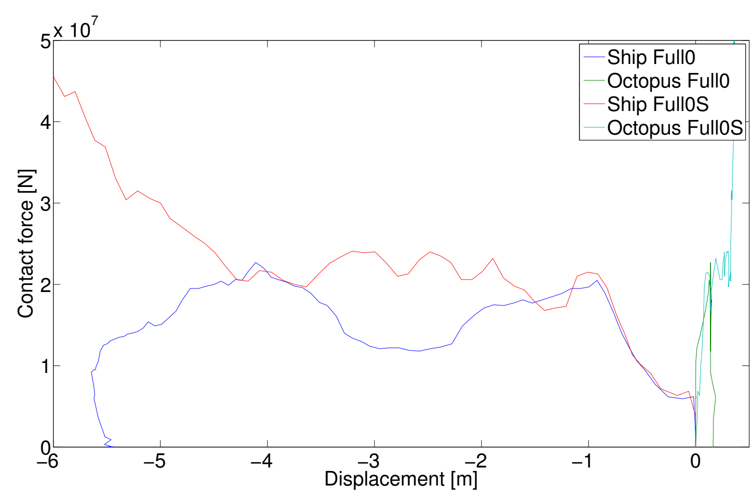
It is seen that the contact force is higher for a given displacement for the cases with ballast water. The analyses with filling levels of 90 % and 95% reach their maximum load at a smaller displacement. They fail earlier because the increased pressure inside the ballast tank changes the stiffeners buckling shape. The maximum load is however in the same range or slightly lower than the maximum load of the empty tank.
Integrating the force deformation curves it is seen that the energy absorption for the water filled tanks is higher than for the empty tank for a given displacement. The water filled tanks will therefore be capable of stopping the sphere, or a ship, with less damage to the ballast tank.
Since the maximum contact force is larger or in the same range, and the energy absorption is higher it is seen that it is slightly conservative for this case to neglect the effects of ballast water.

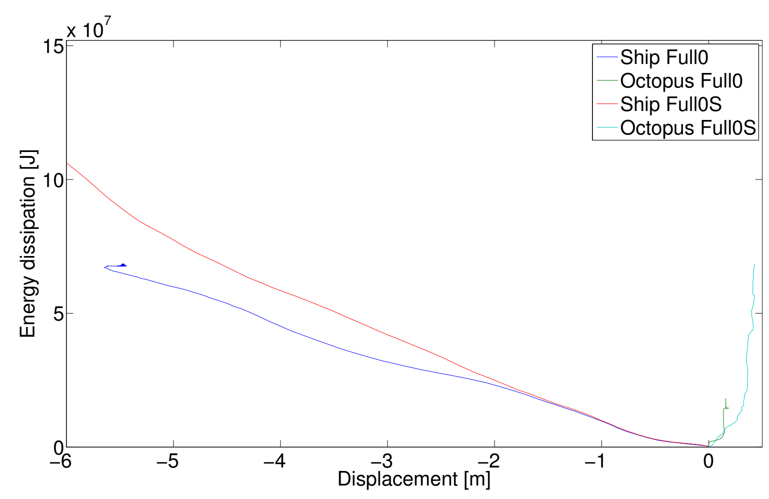
Ship- platform collisions

Realistic collision scenarios are determined for the ship platform collision. The collision scenarios involve different drafts and impact angles.



An analysis with external FSI has not been successfully perform to this date. However, an analysis in air has been performed and compared to a simplified analysis where the external and internal mechanics are decoupled. The force deformation and energy deformation curves are shown below. Full0 refers to an analysis where the ship is given an initial velocity of 2 m/s. The platform has no initial velocity. Both of the structures are free to move in all directions. Full0S refers to an analysis where the platform is fixed and the bow is pushed into the platform in a predetermined motion.





It is seen that there is an apparent difference in both the force deformation cures and in the Energy dissipation- deformation curves. Focusing on the ship, where there is the most damage and energy absorption, it is seen that the simplified analysis over predicts the strength of the bow.
Using Liu's matlab code, [3], which is an application of Stronge's impact theory, the energy dissipation is estimated to be 74 MJ. This is approximately 10% lower than the energy dissipation determined in the NLFEA Full0 which was 82 MJ.

Analysis	Energy Dissipation [MJ]	Deformation ship [m]	Deformation Octopus [m]
Full0	82	5.46	0.16
Full0S	82	4.39	0.33
Full0S	74	3.96	0.33

The results from the decoupled analysis give a smaller deformation than for the ship than the integrated analysis. The difference is however not as large as the numbers indicate. The extra deformation for in Full0 is concentrated at the top of the bow giving a larger indentation where the displacement is measured.