Analysis of accidental iceberg impacts with large passenger vessels and FPSOs

Master Thesis by Gowtham Radhakrishnan

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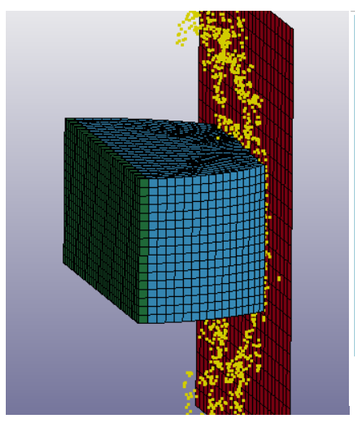
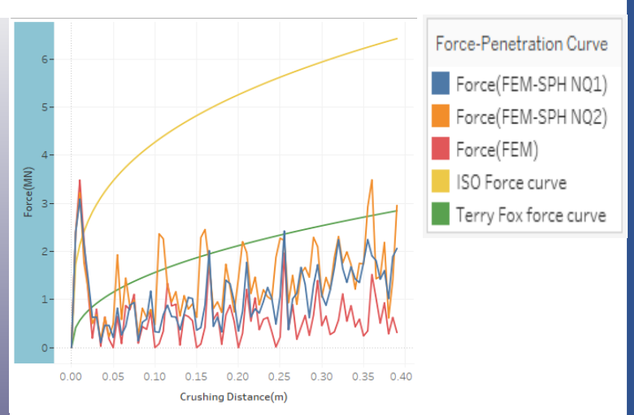
Introduction: The sea ice extent and thickness in the Arctic have diminished over the past few years due to global warming.The diminishing ice may provide access to new sailing routes in these waters in the years to come. Thus, the Arctic waters are increasingly becoming attractive due to the large reservoir of oil&gas, ship transport in the NE or NW passage as well as tourist attractions. Activities in such areas will meet with harsh environmental conditions such as ice loads and low temperatures. The probability of collisions between ships and ice bergs may increase due to these activities. The assesment of the loads caused by iceberg impacts is an impotant issue for ship designers.

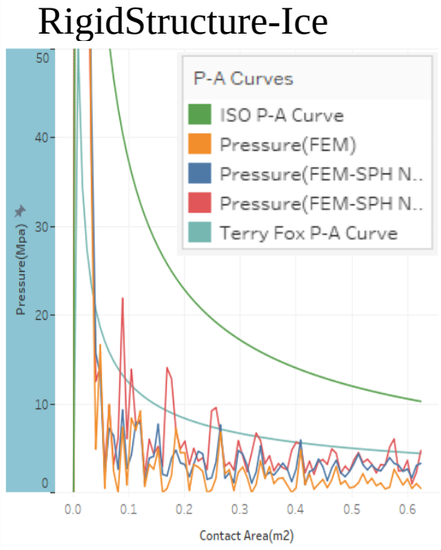
Aim: The objective of the master thesis is

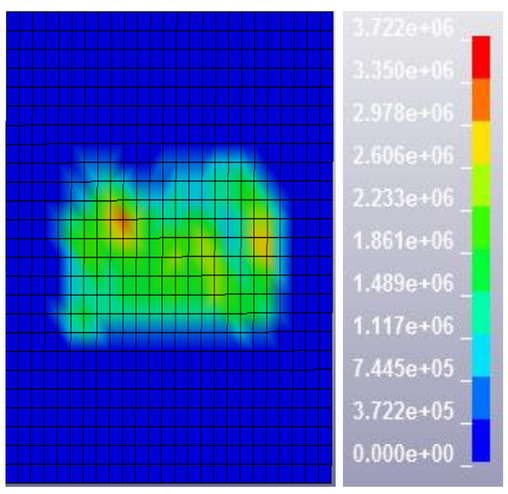
- To study the application of FEM-SPH coupled approach in ice modelling
- To assess the resistance of an ice-strengthened passenger vessel and FPSO to ice impacts





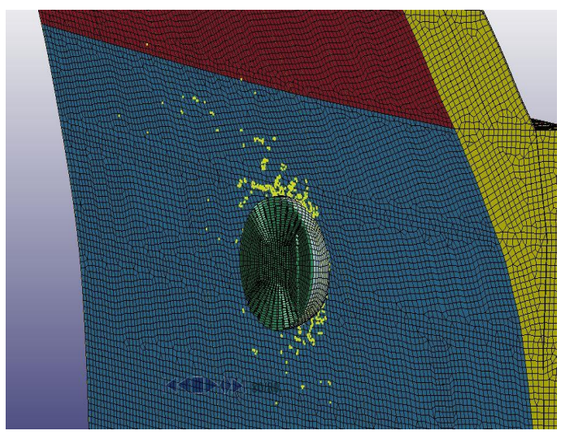
RigidStructure-Ice



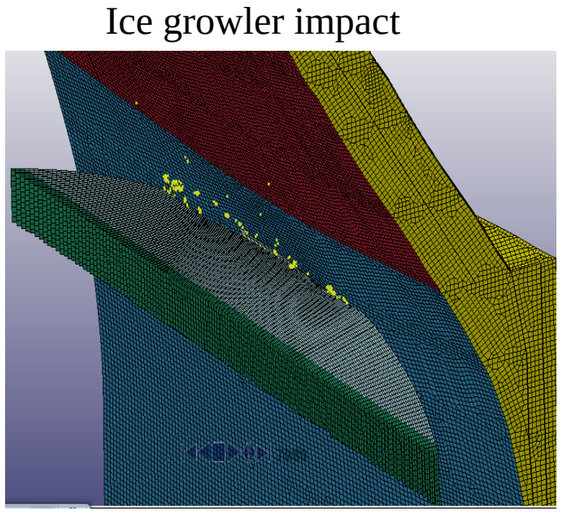


Model and Analysis:

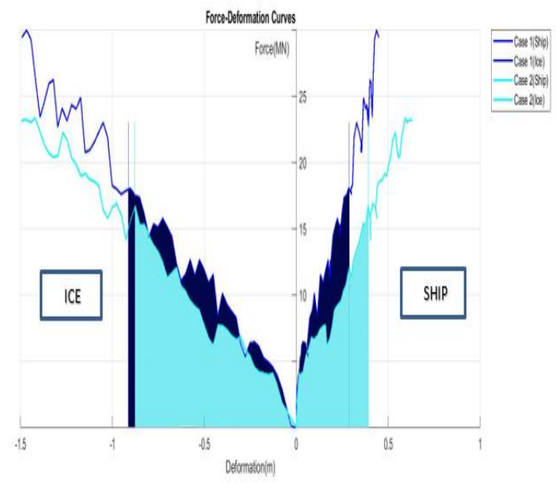
- In this thesis, ice has been modelled using both FEM and FEM-SPH technique using Kim's ice implemented LS DYNA solver. In FEM modelling, the ice elements, after reaching their failure criterion will get removed from the simulation whereas in FEM-SPH approach, after surpassing the erosion condition, the ice elements are converted into SPH particles. Initially, in order to verify the FEM-SPH coupled technique, simple ice models are crushed against rigid plates and validated with respect to P-A curves. This analysis is representative of strength design condition.
- Nextly, shared energy analysis has been carried out for the case of ice collisions against stiffened panel to study both the ice and structural response before commencing large scale simulations.
- SeaRoseFPSO which is in operation in WhiteRose field, Newfoundland, Canada has been chosen for the analysis. As part of the thesis, side panel of this FPSO is constructed and the ice is modelled really hard to make significant impact on the structure. Ice Floe, bergy pit and growler are considered for the analysis.
- The FEM model of a passenger vessel MS Colour Magic is provided, and the collision analysis is being performed using an ice floe.



Ice growler impact



Ice Floe impact



Results and Discussion: Strength design analysis with rigid plates is an ULS based design analysis. Since verification using ice model testing is expensive, both FEM and FEM-SPH models are compared with respect to analytical P-A curves. The force deformation, process P-A and spatial P-A curves are presented here. The force level increased with increase in the crushing distance of ice. FEM-SPH coupled ice model yielded better and wide spread distribution of interface pressures in comparison with FEM models. The design of local ship components like stiffeners, brackets etc require details of the interface pressure distribution, hence for such analysis FEM-SPH coupled modelling of ice is recommended.

In large scale simulations, hard ice is modelled by varying certain input parameters of kim's failure strain equation. The hard ice produced considerable deformations of ship structures, thus activating different failure modes like buckling, tripping of individual structural components. Since the study of accidental ice impacts is the main motive, numerous analysis involving both decoupled and coupled collision approaches are performed.

- From the simulations performed using three ice features, it can be concluded that tabular bergy pit yielded maximum deformation on the side structure because of the larger contact area which induced maximum compression on the ship structure. Growler, though smaller in size produced significant localized deformation due to its shape and confinement.
- Direct and oblique impacts are conducted using ice floe by orienting the ship side to simulate sticking and sliding of ice. The strain energy dissipated in direct impacts is higher than in oblique impacts on account of the large deformations associated with the former. The force-deformation curves of ice floe and ship side for direct impact case is shown.
- In addition, force-deformations are studied by varying the structure's thickness and steel grades. With increase in steel grades, the structure deformed less.
- Some collision simulations are also performed based on coupled approach and the results are compared with simplified external mechanics.Also,simulations above ice-strengthened performed.

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