Optimization of local hull structure geometry for a floater subjected to ice loading

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Introduction

The Arctic is one of the last regions that may hold a large extent of undiscovered oil and gas reserves, as much as 25% of the world's remaining hydrocarbons are assumed to be located in the Arctic. With the significantly increasing demand for oil and gas worldwide, the interest for exploration activities towards "the final true frontier for hydrocarbon exploration" intensifies. However, the Arctic environment present extremely difficult physical challenges such as excessive ice loading, extreme cold temperatures and long periods of darkness. To meet these challenges for exploration and production to have a safe, reliable, cost-efficient and possibility for a year-round operation it is proven that a combination of traditional and innovative technology is the key.

While there is considerable experience in near-shore, shallow water Arctic developments, much of the deep water offshore Arctic regions are yet to be explored which will require floating systems. In designing of floating systems, in addition to global loads applied from the ice feature to the vessel, design also poses significant challenges given to hull and mooring system strength. One key design challenge for Arctic floating drilling systems is the need to resist potentially sever ice load for year-round operations. Thus one key design driver is to optimize the hull shape to minimize ice load.

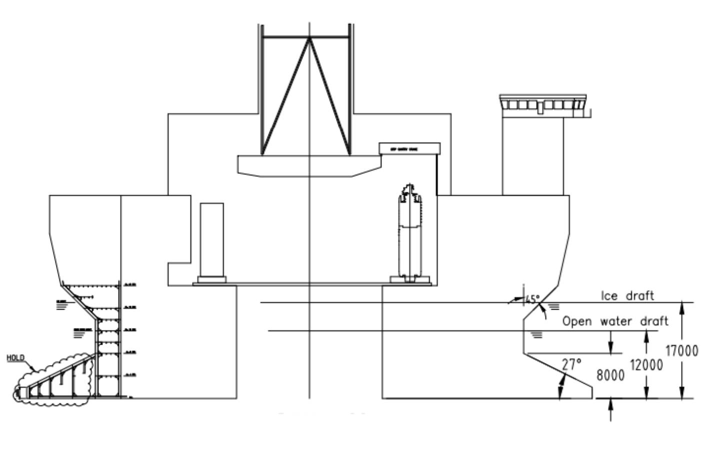
Background study

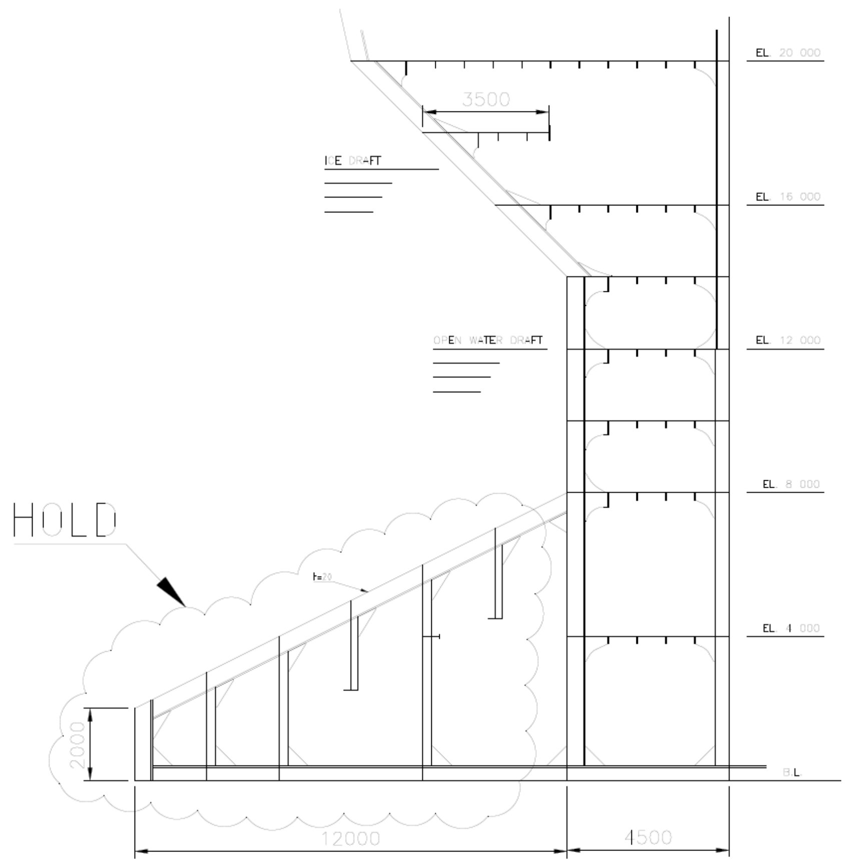
The most challenging hazard in the Arctic is the presence of large ice features of multi-year ice and iceberg. The presence of ice will demand a technical need for the floating structure to have the opportunity to detached from the drilling and production risers and mooring lines so the structure can avoid large ice loads. High reliability ice management capability will be a key technology parameter for exploration drilling. The ice management icebreaking fleet's purpose is to continuously reduce the size of incoming ice floes . On the other hand, because there will always be multi-year ice features that cannot be broken even by the largest icebreakers and presence of icebergs, the development of offshore structures that have the capability to disconnect and then reconnect in dynamic ice conditions is crucial. A coupling of ice management and mooring line capacity will together determine the governing maximum ice action an Arctic platform can handle. The Terra Nova FPSO with a mooring system that has a capacity of 20MN.

The best hull design for Arctic ice and open water condition is a design that require a single point detachment which will reduce time and effort to disconnect and reconnect to risers and mooring lines, such a design is a buoy shape. Structures with sloping walls in the waterline region will generally experience less ice actions compared to vertical walls because the ice feature bends by flexural bending compared to crushing.

Sevan design

Sevan Marine has solved this issue by introducing a design that operated with two drafts, one draft for wave action and one draft for ice action. The hull is designed in accordance with Polar Class PC4 and will operate in typical 1st year sea ice conditions.



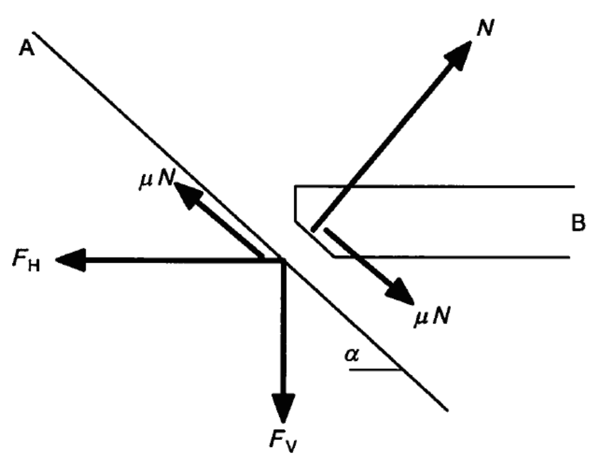


Investigation of ice actions

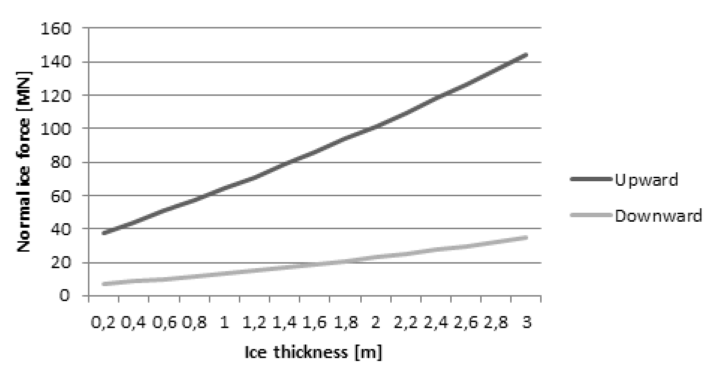
Three different global ice loading conditions were considered and evaluated towards upward sloping versus downward sloping structure. Local ice actions was also investigated. The resulting global ice action can be decomposed to a vertical and horizontal component mathematically and are illustrated below for a upward sloping wall.

$$F_H = N\sin\alpha + \mu N\cos\alpha$$

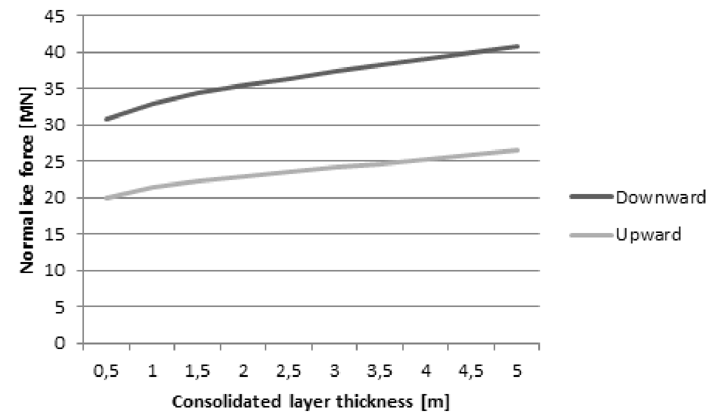
$$F_V = N\cos\alpha - \mu N\sin\alpha$$



- **Level ice**, [ISO 19906, 2010]. Level ice interacting with a sloping structure will fail by bending. The interaction process is very complicated and includes failure of the ice sheet, ride-up of broken ice pieces, accumulation of ice rubble on the slope and clearing of the rubble accumulation. ISO 19906 provides two methods for determining ice actions from level ice. In the figure below the most preferred method's global forces for upward sloping and downward sloping are compared for increasing ice thickness.



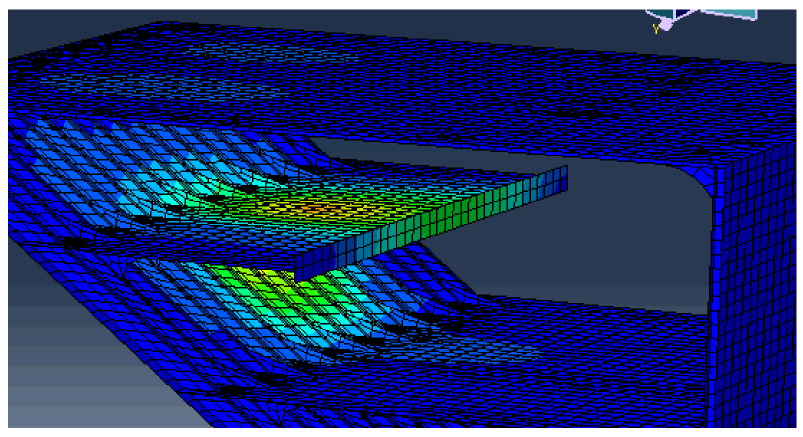
- **First-year ridge**, [Croasdale, 2012]. A recently published paper by [Croasdale, 2012] possesses a simple method for calculating first-year ridge loads on sloping structures. The new approach assumes that the ridge is a composite beam with an upper layer based on solid ice and a lower layer based on the keel being week porous solid ice. The new method reduces the total ridge load with 34% compared to the conventional method used in ISO19906 for vertical structure. In the figure below the global forces for upward sloping and downward sloping is compared for increasing consolidated layer thickness.



- **Managed ice,** [ISO]. According to ISO 19906, ice actions from managed ice on floating structures are best determined from full-scale load data from the Kulluk drilling platform which is a similar shaped offshore structure as the Sevan ICE design operated in ice . Even though managed ice actions gives lower forces than for instance ridges it is useful to estimate loads on floaters from unmanaged ice to help define limits
- **Local ice action**, [Palmer & Croasdale, 2013]. Compared to the global ice actions that are calculated from average pressure over a nominal contact area, the local ice actions consider smaller areas that are subjected to higher local pressures and used in the design of plates and stiffeners of a structure. However, there is actually nothing in the literature or codes that consider the local ice pressure on a sloping structure. According to [Palmer & Croasdale, 2013] there will be no structural design significance in specifying ice pressures grater than 1.5MPa.

ABAQUS analysis

A simple local analysis of a downward breaking structure based on a Sevan Marine design was performed in ABAQUS. The analysis is a static linear analysis with a nonlinear material. A pressure of 1.5MPa and hydrostatic pressure were applied. More investigation of parameters and results are to be done.



Conclusion

The hull geometry of a floating structure that is located in sea ice infested areas should be optimized with a downward sloping face in the waterline region to reduce loads from ice. The Sevan structure is designed with a 45 degree sloping face and scantling with Polar Class PC4. A local analysis of 1.5MPa ice pressure concludes that the design will hold locally for ice actions. Further investigation should be done towards collision loads with ice features.

References and acknowledgment

[ISO 19906, 2010] Blanchet, D., et al. (2011). ISO 19906: An International Standard for Arctic Offshore Structures. OTC Arctic Technology Conference.

[Croasdale, 2012] Croasdale, K. R. (2012). A simple model for first-year ridge loads on sloping structures.

[Palmer & Croasdale, 2013] Palmer, A. and K. Croasdale (2013). Arctic offshore engineering. Singapore, World Scientific.

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