TU Delft

Technische Universiteit Delft

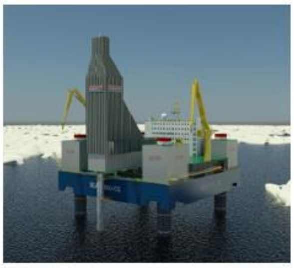
Offshore & Dredging Engineering

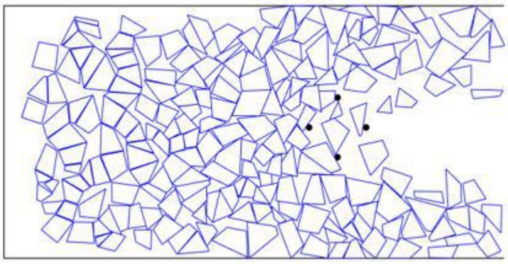
Numerical modelling of managed ice loads on the legs of a jack-up structure

GustoMSC, a leading offshore design and engineering firm, is designing cylindrical legged jack-ups, intended for drilling purposes in the Arctic and able to withstand early season ice conditions. If the industry wishes to extend explorations further into the ice season, more severe ice conditions can be expected. In order to reduce the ice loads in these conditions, ice breaking vessels are often used to physically manage large ice floes and reduce their size. To investigate the effects of these managed ice fields on the legs of a jack-up structure, GustoMSC requires a model which can quantify these loads numerically.

In 2012, a numerical model was developed based on the discrete element method in order to simulate managed ice loads on the legs of a jack-up. As there was no experimental data was available at that time, this numerical model was never validated. In 2013, model basin tests have been performed at the HSVA Ice Model Basin in Hamburg, in a cooperation between GustoMSC and the TU Delft. These tests have been performed with the aim of quantifying ice loads on the legs of a jack-up. Hence, the next step is to compare, improve and validate the existing numerical model with the experimental data.
First a comparison was made between the initial model and the experiments. From this it was found that the simulated ice loads were underestimated significantly. Low peak loads, no force build-up and a low sliding resistance between particles resulted in a large difference between numerical and experimental results. Based on these conclusions, changes were implemented in the model. Firstly, the interaction model was revised, describing the collisions between particles. Furthermore, a new contact force model was introduced by taking into account the physical crushing of ice during collisions. Also, the friction model was changed by implementing an additional friction component due to shear.

The comparison of the improved model with experimental data resulted in significantly higher peak loads on the structure, approaching the experimental results. It was concluded that the peak loads are directly related to severity of accumulation due to simultaneous floe impacts on the accumulated ice mass in front of the jack-up structure. Furthermore, it was found that the accumulation is related to the initial floe distribution of the ice field.
Another observation that was made during the experiments was the occurrence of splitting failure of ice floes. Splitting was shown to be very important for the clearance of accumulated ice floes, resulting in lower ice loads on the structure. In order to describe splitting failure, an analytical method was implemented in the numerical model, which was derived from splitting in level ice. It was found that the implementation of this theory resulted in too frequent splitting of ice floes compared to observations from the model tests.
The improved numerical model shows very good potential. With the implemented changes, the simulated ice loads approach the ice loads from the experiments. However, with different initial floe distributions, different loads were obtained. Therefore, an in-depth statistical analysis on the simulations is recommended. Furthermore, more model scale and full scale data are required to verify the experimental and numerical techniques for predicting managed ice loads on the structure. With only one run per test setup, the experimental data lacks statistical solidity. Also, it is recommended to perform an experimental study for splitting failure with regards to managed ice for the numerical model.





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