Technische Universiteit Delft

Offshore & Dredging Engineering

**Improvement of fatigue damage prediction for the Balder J-lay tower during transits**

Heerema Marine Contractors (HMC) is a contractor that transports and installs large structures at sea. For this purpose, HMC operates four crane vessels of which three are semi-submersibles (Thialf, Balder and Hermod) and one is a mono hull (Aegir). The Balder is equipped with a J-lay tower for pipelay in deep water. During transits, when the Balder sails at a shallow draught over the open ocean from continent to continent, wave-induced motions of the Balder result in fatigue damage to the tower, as the tower angle with the horizontal can only be reduced to 75 degrees.

In order to ensure safe operations and prolong the period that the tower can be profitably used for projects, HMC has installed several sensors on critical locations on the tower to monitor the fatigue damage during transits and pipelay operations. Alongside the measurements, HMC has developed a numerical tool to predict damage during transits. During a Balder transit from West-Africa to Europe, it was noted that the *a priori* prediction of the tool overestimated the wave-induced fatigue damage as was measured during the transit. The goal of this graduation study is to determine how to improve the prediction of wave-induced fatigue to the Balder J-lay tower during transits by comparing the results of predictions with actual measurements.

By comparing the fatigue damage procedures used for determining the fatigue via the different models and analysing the intermediate steps, it was concluded that the major contributor to the inconsistencies between the measurements and the predictions were the incorrect response amplitude operators (RAOs) used for determining Balder's response in waves. The inconsistent RAOs result from the fact that the diffraction software used to calculate them is not capable off accurately assessing the vessel motion behaviour for the case of shallow draughts used during transits. The problem was tackled by identifying new RAOs for the transit draught based on the available measurements and hindcast data. Among other parameters investigated, a major one is the historical weather database, which is the basic input of the prediction tool.

The updated RAOs result in a much better agreement between the measured and the calculated vessel motions. This in turn enables a great improvement in the accuracy of the fatigue calculations, quantified to be at least an order of magnitude. Furthermore, it was concluded that the prediction tool does not assess correctly the probabilistic fatigue output due to the fact that it is not able to capture the weather persistency. A new numerical model developed for the purposes of the assignment is able to capture the effect by using hindcast time series instead of wave scatters. The last part of the research concerns a preliminary assessment of the high-frequency fatigue induced by vibrations of the tower in its eigenmodes. The knowledge gained during this project will allow HMC to make more accurate predictions of fatigue damage to the Balder tower during transits and plan mitigation actions accordingly.

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August 31st, 2016

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