Technische Universiteit Delft

Offshore & Dredging Engineering

Development of a cutter ladder vibration model

Structural vibrations are a known cause of damage to offshore structures and equipment. A Cutter Suction Dredger (CSD) is a dredge vessel known to vibrate heavily during operation. Primary cause of these vibrations is the cutting process, performed to cut and excavate soil from the seabed. A component prone to damage is the cutter ladder, a component of the CSD used to position the cutter head at the seabed. Cutter ladders are known to suffer from failures including large cracks in the structural members, of which the cause is sometimes unclear.

Current methods for developing a cutter ladder involve detailed quasi-static finite element modeling for strength analysis and sometimes modal analysis to identify natural frequencies and mode shapes. Structural vibrations due to dynamic loading are usually not taken into account. In 2015 Boskalis performed extensive vibration measurements on its Taurus II CSD, hereby setting the stage for research into the dynamics of cutter ladders. By taking a closer look at dynamics of the cutter ladder, a cause for structural damage might be identified. This thesis therefore aims to investigate the vibrations of a cutter ladder as a possible cause for damage.

In order to obtain knowledge about the dynamic behavior of the cutter ladder in operation, data obtained during the vibration measurements were investigated using operational modal analysis. This investigation gave further insight in how to approach the development and validation of a vibration model.
A vibration model using finite beam elements was developed to take a closer look at the characteristics of the cutter ladder structure. This vibration model was obtained through simplification of a detailed plate-element model, which was developed in an earlier project. The dynamic characteristics of the obtained vibration model where validated to the detailed plate element model by comparison of modal analysis results.
It was chosen to update the vibration model using the measurements obtained on the cutter ladder, as it was hereby possible to investigate the influence of dynamic parameters on which uncertainties exist, such as the water added mass surrounding the structure, the damping and the stiffness parameters at the boundary conditions.
Use was made of the transmissibility of vibrations between the locations where measurements were obtained. Measured transmissibility was compared to modeled transmissibility, as in this manner it was possible to look into dynamic behavior of the cutter ladder, apart from the external loading. The model was updated by varying various dynamic parameters on which uncertainties existed, including water added mass, damping and stiffness parameters at the boundary conditions.

Investigating the data obtained during measurements showed that the forced vibrations caused by the cutting process dominate the dynamic behavior in the cutter ladder. Natural vibrations of the cutter ladder were found to be minor.
Updating the model revealed that the water surrounding the structure has a significant influence on the dynamic behavior. In vertical direction, a quantity of water close to the weight of the cutter ladder itself had to be added to have the vibration model meet the design parameters. Quite an amount of structural damping had to be added too, for which the cause is again sought for in the water surrounding the structure.
Using transmissibility functions as design parameters was found to yield accurate results, especially at the sections where no external loading was introduced.

It is recommended to continue investigating the influence of the forced vibrations on the fatigue life of the cutter ladder on a more local scale, as this might provide new insights for future cutter ladder designs.

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