TU Delft

Offshore & Dredging Engineering

Technische Universiteit Delft

Control of an active mooring system, mooring a vessel to shore

Mooring a vessel is generally still done by means of ropes. The main disadvantages of mooring with ropes are that the process of mooring a vessel can take up to 90 minutes, it involves unsafe situations for, and cargo handling efficiency can be suboptimal. Mampaeys goal is to provide an active mooring system that adresses these challenges. It has designed and built a system for mooring ship to ship in the benign conditions of the port of Rotterdam, called the DockLock (DL). The design of the current DL is such that it counteracts vessel movement in surge, sway and yaw directions. The vessel is free to move in heave, pitch and roll direction. The goal of this thesis is to determine the optimal control of the DLs mooring an LNG Carrier (LNGC) to a jetty, minimising the maximum displacement of the vessel,the maximum force in the DLs and the energy dissipation from the vessels response.

Two models are analysed: the first is a model in the time domain in ANSYS AQWA (AQWA), where the current DL is used to moor a 170.000m3 capacity LNGC to a jetty. The same LNGC is moored with the new PD-controlled DL in the second model. Ideal PD-control is assumed, allowing the new DL to be modelled as linear spring and damper. To enable analysis of a large amount of different situations this is modeled in Matlab in the frequency domain. The models are subjected to first and second order wave forces coming from -1800, -1350 and -900.

The simple AQWA model shows that the structural part of the current DL is subject to large deformations, which will quickly consume fatigue lifetime. The current DL design is considered to be insufficient to moor a 170.000m3 capacity LNGC to a jetty.

To determine the optimal control of the new DL, three objectives are evaluated: the 3-hour Most Probable Maximum (MPM) COG displacement in x and y, the MPM force in all four DLs, and the average energy dissipation in all four DLs. The MPM responses to the combined first and second order wave forces are calculated with an empirical method proposed by Naess, known as the modified SRSS combination formula. The average energy dissipation is computed taking the average of a time realisation of the frequency spectrum. The three objectives are combined with the weighted sum method to a scalar objective function. From the Matlab Optimisation Toolbox, the Multi Start Local Optimisation with the SQP algorithm has been used find the optimum, varying DL damping and stiffness in x and y direction.

For the defined problem the optimisation tool finds an optimum, keeping displacements and energy dissipation within requirements, but exceeding force requirements for wave direction 900. This can be solved by increasing the number of DLs, or by changing the influence of maximum displacement, force and energy dissipation, adapting their weights. The optimisation tool shows to be able to find an optimum allowing smaller or larger displacements, or smaller forces. As such the optimal settings of the DL can be tuned to what the situation requires. The optima found are insensitive to changes of ±10% in DL stiffness in x and y, and damping in x, but sensitive to changes in damping in y. This is because the energy dissipation has been normalised with a low value, resulting in a large influence on the objective function.

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