Offshore & Dredging Engineering

Technische Universiteit Delft

A parameter sensitivity study for a Soft Yoke Mooring System (SYMS)
Developing a design tool

Figure 1. Soft Yoke Mooring System

Floating production units require to be permanently moored offshore. For shallow water field developments, typical designs include soft yoke mooring systems which is a single point mooring technology. Produced fluid is transported via a geostatic tower along the transfer hoses to the production unit. Single point mooring systems will weathervane into the offshore environment (wind, waves and current) and can often be considered as surge dominant induced by low frequency wave drift forces. Due to low damping at these low frequencies, an oscillation close to the natural surge frequency appears causing dominant mooring loads. By connecting the floating structure to the tower with various rigid steel frame components, including multiple hinges, unconstrained motions are preserved. This results in dynamically complex systems requiring advanced numerical methods for time domain simulations, in order to deliver the mooring design loads. By selecting mass and dimensions of the soft yoke mooring system, the stiffness of the mooring system can be adapted to influence the response of the floater.

Currently, mass and dimensions of new soft yoke mooring designs are established using proven mooring solutions by conducting small adjustments of mooring components in time consuming dynamic simulation software. Improvement in efficiency of the design process is accomplished by developing a computational efficient design tool, to be used before dynamic modelling, to provide the designer with an optimized set of mooring design parameters in a given environment. The developed design tool contains an integrated single degree of freedom model including given vessel properties and extreme collinear offshore environment, in order to produce estimates of the maximum surge response based on the given mooring characteristics. Eventually, by adapting the mooring stiffness accordingly, the design tool is able to provide an optimum set of mooring design parameters which minimizes the maximum mooring load.

The mooring characteristics are implemented using a linear and non-linear approach. A validation of surge response results has been performed for three collinear extreme offshore environments including wind, waves and current using state-of-the art dynamic modelling software OrcaFlex. Results showed that the linear model can capture the sensitivity of the surge response related to mooring design parameter variation. It was demonstrated with the Runge-Kutta method that the achieved accuracy with the proposed non-linear model will be similar or even worse than using the linear model without the relevant computational costs. Therefore, the linear model was implemented in the design tool and accomplishes surge response calculations of 10,000 sets of mooring design parameters within a few minutes.

Results showed that the consequence of the linear mooring force and single degree of freedom assumptions in the design tool leads to an underestimation of the surge response in an extreme collinear environment. Despite the surge dominance, especially heave and pitch motions induce high mooring loads at maximum surge offset. Analyses of two moderate collinear environments in OrcaFlex revealed less underestimation and even overestimation of the surge response by the design tool, which indicates the high dynamic complexity of soft yoke mooring systems. However, the surge response validation procedure using OrcaFlex affirmed that the design tool provides the correct set of mooring design parameters resulting in a minimum mooring load within 2~10% accuracy for all three environments. By implementing the proposed set in OrcaFlex and obtaining the design loads, a 25% decrease in absolute maximum mooring load is demonstrated when compared to the benchmark mooring design parameters. This indicates the increased efficiency of the design process by using the developed design tool.
An additional graphical user interface is programmed where the designer can import their own vessel properties, environmental conditions and can vary desired mooring design parameters. Conclusively, a design tool has been developed for preliminary estimations of the set of mooring design parameters that have been shown to minimize the mooring loads and to limit the number of time domain analyses in future projects.

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