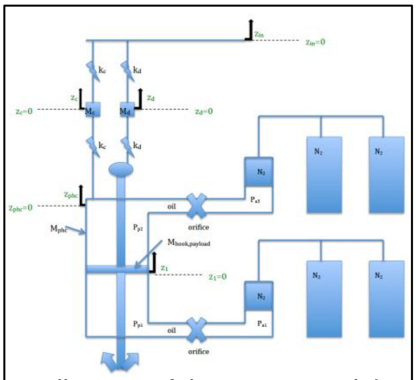
Offshore & Dredging Engineering

Technische Universiteit Delft

Design a complete active heave system based on an existing concept

The handling of a payload by a crane at sea poses numerous challenges. One of the main technical challenges is the movement of the vessel due to the hydrodynamic forces exerted by the waves. The resulting heave, pitch, and roll of the vessel results in time-varying crane-tip motion. This motion propagates to the payload through the rope and this motion needs to be attenuated for safe handling of the payload. One way to do this is through heave compensation. Active heave compensation (AHC) and passive heave compensation (PHC) can be distinguished. AHC means energy external to the system is used to compensate heave motion. PHC means only energy within the system is used to compensate heave motion. The combination of AHC and PHC is hybrid heave compensation (HHC). The objective of the thesis is to produce a numerical time-domain model of a HHC system coupled with an existing vessel model. With this model the performance of the coupled system is investigated. The approach to obtain the model is described below and the performance is then discussed.

The methodology to achieve the goal of the thesis is described in three parts. First, the equations of motion for the PHC system were developed taking into account the non-linear accumulators. The accumulators of the PHC system were sized so the natural period of the system is outside the wave period range to avoid resonance effects. The PHCS system was linearized and the natural frequencies and frequency response obtained. The natural periods and frequency response were verified by examining the time-domain response. The time-domain performance of the PHCS was examined and showed effective performance of the PHCS. At the natural periods there was an amplification of the motion, as expected. Secondly, the PHCS was coupled with the vessel model through the crane-tip model to form a coupled model, called the C-PHCS. The C-PHCS exerts small forcing moments on the vessel. However, the effect on the vessel is negligible. Thus, the effect of coupling between the PHCS and vessel is negligible. Thirdly, the AHC system was designed and equations of motion developed. This was coupled with the PHC system to form the HHC system. The HHC system was coupled with the vessel model through the crane-tip model to form the C-HHCS model. This formed the final model. Furthermore, the Dyneema rope in the final model is modeled as a discrete mass. As a sensitivity study of the final model, the Dyneema rope was modeled as a continuous structural element with a coupled string-rod model. This took into account the damping from water at the large water depths considered, such as 2500m. With the AHC system disconnected, this additional damping attenuated the motion of the Dyneema rope leading to smaller hook/payload motion.



A diagram of the PHCS model

The performance of the final model was investigated. The effect of enabling the AHC system is that the compensation performance is lowered across the wave periods 3s to 12s. The effect of enabling the AHC system does not lead to a change in the natural period of the HHC and vessel system leading to resonance. Instead, the lower performance can be attributed to the controller parameters and the controller strategy and possibly the controller type. To obtain the controller parameters, the optimization algorithm within Simulink was used. This was trusted to provide effective controller parameters although they may correspond to local and not global optimum points, meaning they are not truly optimal. Instead, the controller strategy likely has a stronger role. The strategy employs two control loops, one to control displacement of the hook/payload and one to control the tension in the Dyneema rope. The displacement disturbances are lower frequency than the tension disturbances meaning ideally the control loops do not interfere with one another. There could be interference leading to a counter-productive effect and explaining the lower performance. Various controllers within the PID scope were tried to obtain the PI control for both control loops. For further work, it is suggested a different type of controller (outside PID control) could be used with a different controller strategy to obtain better performance.

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September 13th, 2016

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