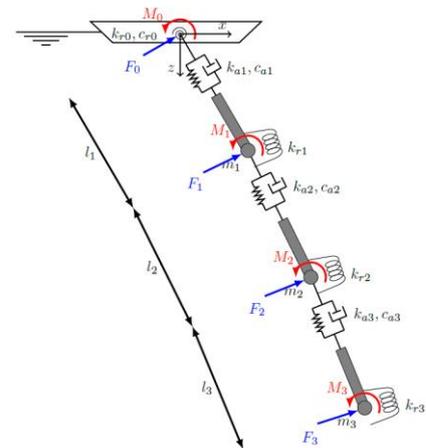


Optimization of dynamical behavior of deep sea mining vertical transport comprising booster stations

As the demand of metals, minerals and rare earth metals continues to rise due to different circumstances among which the growing world population is the main one. It is not uncommon that the companies are expanding their search area from land to the seafloor and developing new methods for exploitation. One of these companies is Royal IHC (IHC). As a designer, builder and supplier of innovative mining vessels and advanced equipment, IHC wants to be the reference company for the development and construction of technical solutions for deep sea mining purposes by using their knowledge and experience to provide complete deep sea mining solutions.

A complete deep sea mining solution comprises a deep sea Mining Support Vessel (MSV), a Vertical Transport System (VTS) with centrifugal pump booster stations and a Subsea Mining Tool (SMT). The deposits are mined using the Subsea Mining Tool by using high power pump(s) and specially designed suction nozzles. A pumping system then pumps the excavated mineral resources through a flexible riser to the VTS, which will transport the resources from the ocean floor to the MSV using several booster stations, that will provide for sufficient pressure.

The vertical transport system is subjected to dynamic loads caused by ship motions (due to wind and waves), waves, current, internal fluids, VIV, flow-induced torsional moments and interaction with flexible hose (and crawler). Given these loading mechanisms, a simulation tool called VIVID was developed by IHC. VIVID simulates the dynamical behaviour of a vertical transport system and gives a description of the internal forces as well as resulting stresses in the pipe due to prescribed loading mechanisms. Since this is a comprehensive model, the use of a simpler and quicker model during the preliminary design stage is preferred. Therefore, the desire arose from IHC to develop a model, which can not only be used to optimize the fatigue life time of a specific configuration, but that is also suitable to easily implement a modification.



The model is based on the articulated pipe model of Brooke Benjamin, which comprises a chain of articulated pipes, in essence rigid rods which are connected in between by rotational springs (and dampers) with the exception of top and the bottom. The top is connected to the MSV, while the bottom side is free. This system is under the action of multiple forces, for example gravity and the hydrodynamic forces. These forces are introduced into the model as moments of force.

In order to validate the model, the simulations results were compared with those of VIVID. The articulated pipe model showed comparable shapes in comparison to VIVID. Unfortunately, there are differences in deflections at certain moments, which can be explained by the amount of articulated pipes that are used against the amount of nodes used by VIVID. However, as the deflections are in the same order and an increase in the amount of articulated pipes would be time-consuming it was chosen to perform the optimization of the booster station placement with 54 articulated pipes and the optimization of the clump weight with 27 articulated pipes. Following from the optimization of the booster station placement regarding three sea states, it was found that the configurations for which the booster stations are placed slightly above the bottom side of the VTS resulted in better fatigue life times. Furthermore, the optimization of the clump weight resulted in an optimum submerged mass and implementing a heavy compensator in the system results in a better fatigue life time. Both the optimization of the booster stations placement and the clump weight showed to have a significant influence on the fatigue life time.