Automated Optimization of Mooring Systems for Deep Water

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Objective

The overall objective of this master thesis is to assess and perform automated optimization for the ultimate limit state design of the deep water mooring system of the semisubmersible unit DEMO2000. Mooring systems based on chain and steel wire rope as well as a system based on chain and polyester rope is to be optimized and compared using SIMA Workbench.

Optimization of Two Different Mooring Systems

The engineering process for mooring systems has become more complicated and cumbersome with advances in the design of mooring systems, more complicated rules and a tendency to increase utilization. Automated optimization algorithms refer to the application of mathematical search algorithms in the optimization process. In the optimization of a mooring system, this may contribute with considerable gains (I. J. Fylling, 2013).

The work done in this master thesis can be seen as a first step in the optimization of the mooring system. Two different mooring systems for DEMO2000, presented in Figure 1, are studied.

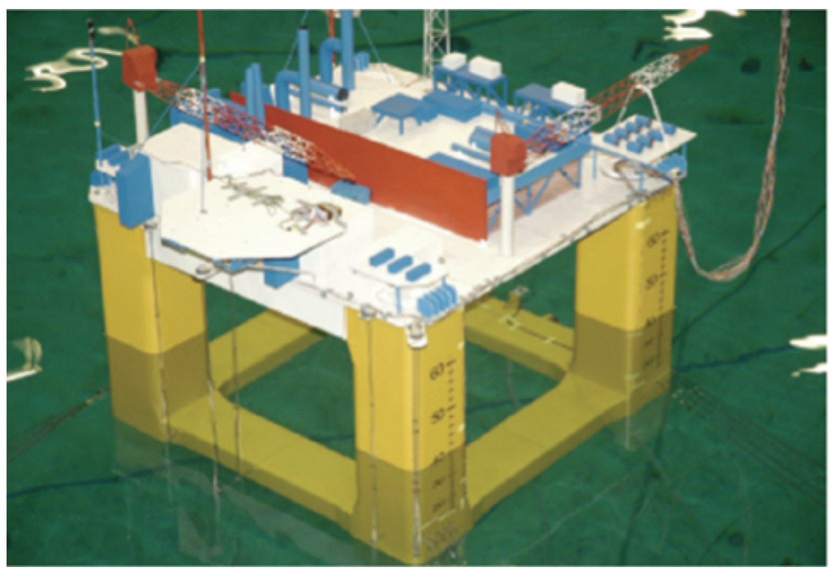


Figure 1: DEMO2000

The mooring lines of both systems consist of three segments. The top and bottom segment are for both systems constructed of chain. The last segment is either polyester rope or steel wire rope, depending on the mooring system.

Defining the Optimization Problem

Mathematically, optimization of a mooring system is the minimization of a function defining the overall cost subjected to constraints on its variables (J. Nocedal and S. J. Wright, 2006).

The optimization problem is defined by specifying

1. The design *variables* to be varied
2. The *cost function* to be minimized
3. The *constraints* or requirements to be satisfied

The variables are for this optimization problem the diameter and length of the three different segments composing the mooring line. The pretension of the mooring line is also set as a variable.

The cost function is the sum of the cost of the segments, depending on the length and diameters.

Two constraints are applied to the optimization. The first constraint requires a safety factor above 2.2 for the most loaded line, in accordance with ISO requirements for NCS. The second constraint requires a maximum offset of the semisubmersible to be less than 10 % of the water depth, corresponding to 150 m.

Polyester Rope and Chain Most Cost Efficient

The work performed in this master thesis presents the first step in the optimization process for the mooring system of DEMO2000. The optimization was here restricted to the length and diameter of the mooring line segments, in addition to the pretension in the mooring lines. However, the work has shown that including a simple optimization may reduce the cost of the system significantly, which currently is an major focus within the oil and gas industry.

It can be concluded that the most cost efficient option for DEMO2000 is a polyester rope and chain mooring system. This alternative is observed to be approximately 57 % less expensive than the steel wire rope and chain mooring system.

References

I. J. Fylling (2013). *Optimisation of Mooring and Riser System for Deep Water Floating Production Systems Including Fatigue Life Requirements.*
J. Nocedal and S. J. Wright (2006). *Numerical Optimization.*

Performing Optimization in SIMA Workbench

The optimization is carried out in SIMA Workbench following the procedure presented in Figure 2.

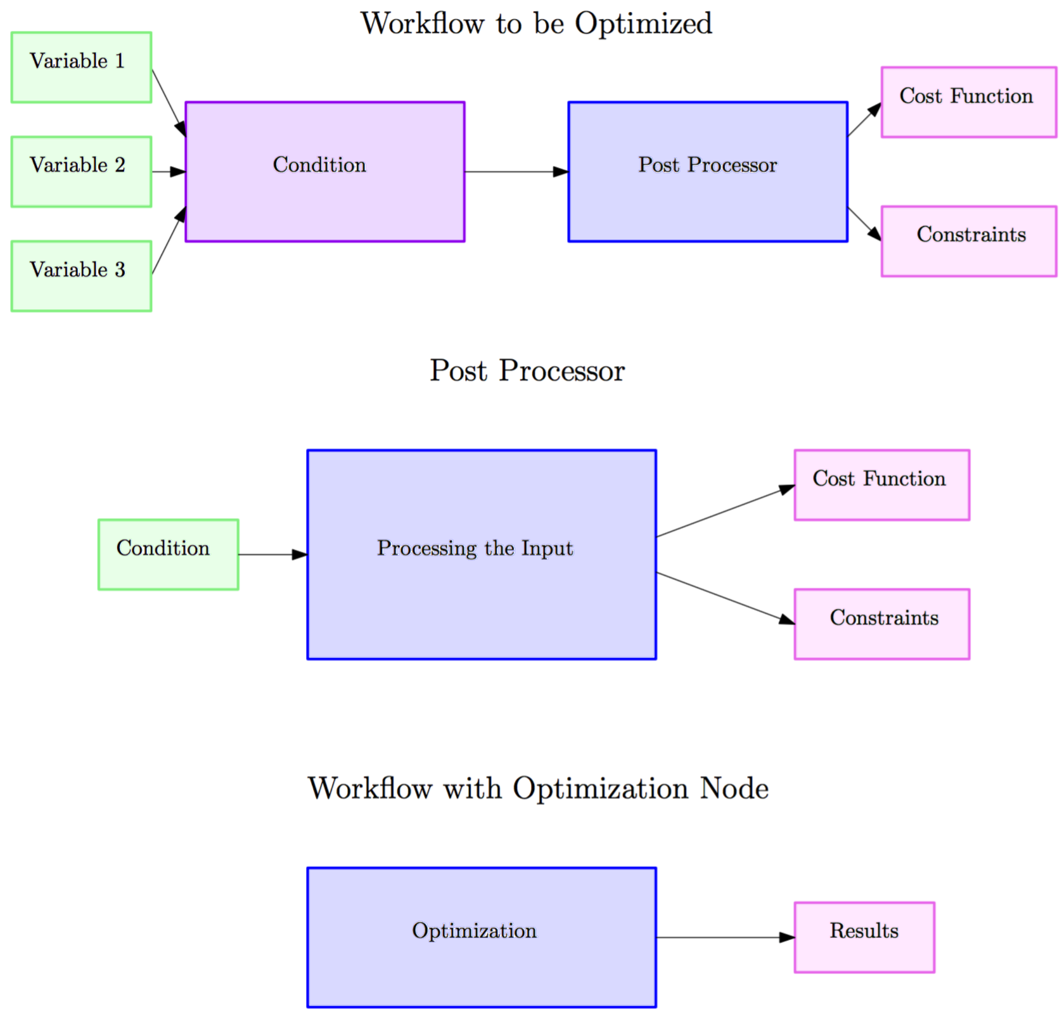


Figure 2: Schematic of optimization workflow in SIMA Workbench

The optimization variables are provided as input to the mooring system in a specified weather condition. The results from the simulation in the given weather condition is then fed to a post processor where the constraints and cost function is defined in terms of mathematical formulations. The resulting cost and constraints are then sent to a workflow with an optimization node.

An iterative process is carried out in the optimization node in order to minimize the cost, while satisfying the constraints. This is done by adjusting the optimization variables within a predefined range.

Optimization Provides Significant Reduction in Cost

The optimization of the cost function for the two mooring systems is presented in Figure 3.

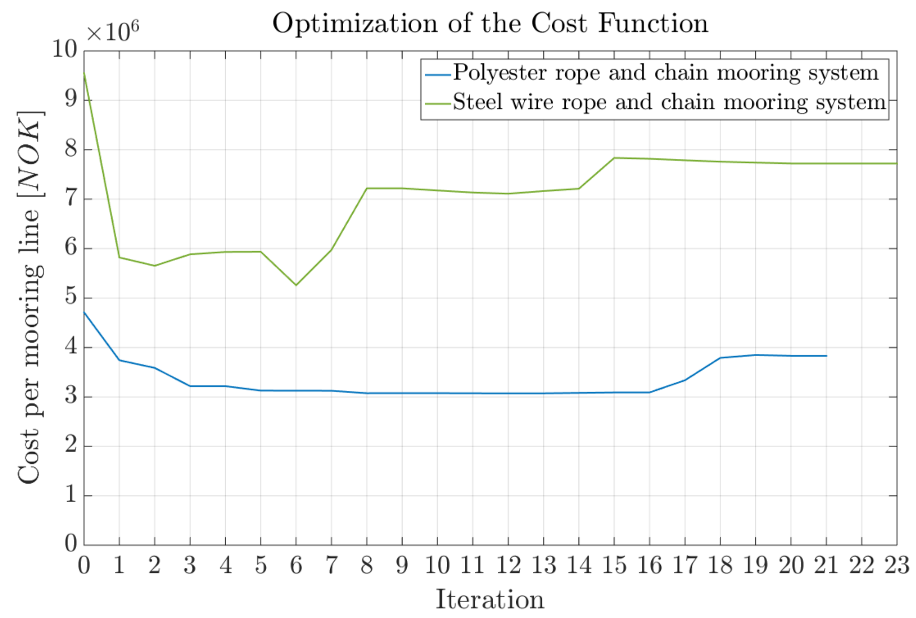
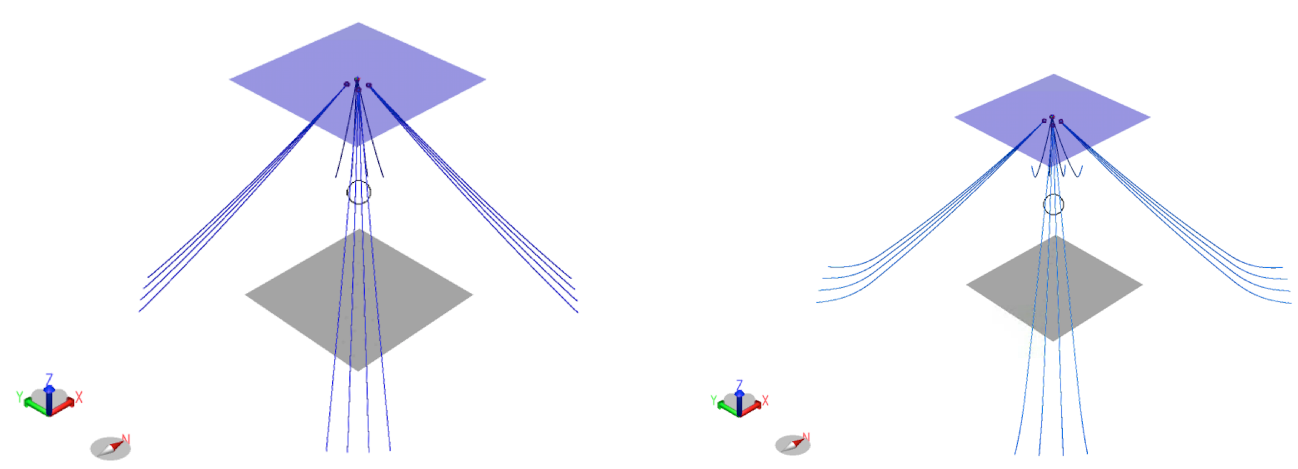


Figure 3: Optimization of cost function

For both systems, a significant decrease in the cost is present. The configuration of the resulting mooring systems are presented in Figure 4.



(a) Polyester rope and chain

(b) Steel wire rope and chain

Figure 4: Optimized mooring systems

The mooring lines in both systems have decreased lengths of all segments. Several of the segment diameters are also reduced. Generally, a tendency to reduce length and diameter for the chain segments are observed.