

### Cost optimization of decommissioning offshore structures with the Pioneering Spirit using model order reduction and genetic algorithms

Over 450 oil platforms need to be removed from the North Sea in the next decade. Each of these platforms is custom designed for installation and service lifetime, but not for decommissioning. Allseas' Pioneering Spirit is the largest heavy lift vessel in the world, capable of lifting complete topsides in a single-lift operation. The vessel's lift system places up to eight lift points against the bottom of the platform and uses hydraulic cylinders to transfer the weight from the substructure to the vessel in a matter of seconds. But even with this vessel, removing an oil platform is technically challenging; the structural integrity needs to remain guaranteed, while minimizing the lift preparation cost as the structure will be scrapped. The goal of this thesis is to define a general approach that uses cost optimization for the platforms' lift preparation scope.

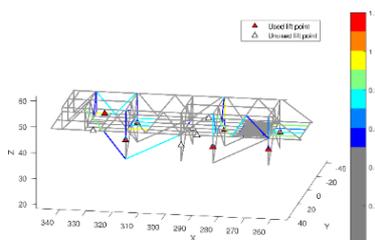
The costs of the platform's lift preparation scope consists mainly of two things; installation of lift points and reinforcement of the structure to avoid exceedance of their design resistance. In order to minimize the cost, the challenge is to find a lift configuration which minimizes the combined cost of the number, type and location of the lift points and the amount of reinforcement. A solution should not exceed constraints such as the allowable load per lift point, the number of lift points and the relative height difference between lift points. A lift configuration is statically undetermined, and the relative height difference between lift points is used to get different load distributions for the same configuration. In this way, forces are redistributed to strong points in the structure.

Detailed finite elements models are used to prove the structural integrity of a topsides during decommissioning. The number of degrees-of-freedom of such models is far too large for them to be used in an optimization algorithm. Model order reduction is used to condense the mass and stiffness matrix to the possible lift points, while keeping internal forces of interesting elements related to these points to check the structural integrity of a solution. The reduction allows for hundreds of lift configurations to be solved per minute.

The minimal costs for a lift configuration in the defined domain is found with the genetic algorithm. The optimization can include an excess amount of lift locations of different possible types. The location and load distribution over the lift points are used to define the cost function. The algorithm makes a selection that suits the constraints. The cost function gives the sum of the cost of the number and type of lift points and the number and type of structural failures.

This thesis presents a systematic approach for finding the optimal lift configuration for any offshore structure. The method is tested on a case study topsides by comparing the standard configuration with the optimized configuration. It is shown that by using the proposed method, the areas that need structural reinforcements are reduced from ten to zero and the amount of lift points is reduced from eight to seven, leading to a cost reduction of 27% on the offshore preparation scope.

The algorithm shows promising results for this topsides removal project. It is possible to include a new finite element model into the algorithm, which together with a generic cost function, makes sure the algorithm is conveniently applicable to other topsides removal projects.



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