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Hull Form Optimization of a Tension-Leg Platform Based on Coupled Analysis

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ABSTRACT.

This paper presents an advanced hull form design for a tension leg platform (TLP), which has displacement of 35000m^3 and is targeted for operation in a water depth of 1829m (6000ft) off the Gulf of Mexico. By using a fully automated hull optimization procedure, fatigue damage to the most loaded tendon due to top tension was minimized. During optimization fatigue damage was assessed based on the frequency-domain coupled dynamic analysis including first-order wave forces, mean drift forces and linearized viscous forces. As a result, the optimized hull form of the TLP based on coupled analysis showed remarkably improved dynamic performance with minimized top tension of the tendon compared to the reference design. By comparing the previous results of TLP optimization, where top tension of tendons were evaluated by equivalent linear spring method, it is shown that a better design can be achieved when the optimization is performed with the objective function which is evaluated based on coupled analysis instead of linear approximation. Finally, superior dynamic behaivours of the optimized TLP were illustrated by a fully coupled time domain analysis for a survival condition, where second order wave forces and nonlinear viscous forces were considered.

KEY WORDS: TLP, Hull Shape Optimization, Fatigue Damage, Tendon Tension, Coupled Analysis

INTRODUCTION

Hydrodynamic hull optimization provides an efficient tool for the improvement of existing and the development of new design in a short span of time. Because the design process is controlled by an optimization algorithm, the resulting hull shape represents an optimum solution with respect to the specified boundary conditions and the objective function.

The hull optimization procedure was established in previous research work (Birk, 1998; Clauss and Birk, 1994, 1996, 1998). The combination of an efficient form parameter based shape generation tool, numerical hydrodynamics, stochastic analysis and formal optimization strategies enables the automated design of arbitrary hull shapes for offshore structures with optimum hydrodynamic performances. Optimization of technical systems is often characterized by multi-modal objective functions, i.e. many local minima exist apart from the global minimum. Therefore, in addition to local optimization algorithms, which usually trace optima of the objective function next to the starting points, global optimization strategies are integrated to the hull optimization procedure in order to determine the overall best design within the design space (Lee, 2004; Birk et al., 2002, 2004).

Hydrodynamic performance of the optimized design relies on the specified constraints and the selected objective function. In earlier studies, the objective function had been evaluated based on linear theory only. Nonetheless, the verification of global dynamics for the optimized semi-submersible and for the optimized tension-leg platform showed that linear seakeeping models for the assessment of downtime as well as fatigue damage suffice to identify the main trends for hydrodynamic hull optimization (Lee et al., 2007; Lee and Clauss 2007)

However, better design may be achieved if the objective function is evaluated based on coupled dynamic analysis. For offshore structures such as tension leg platforms, the dynamic behaivour is nonlinear, which has a significant effect on tendon fatigue damage. Furthermore, the interaction between platform and tendon dynamics plays an important role in the global TLP motion. In this study, therefore, the top tension of the tendons is evaluated based on the coupled dynamic analysis (Ran and Kim, 1997) considering the motion of the entire platform as an integrated system. Since fatigue damage of the tendon as the objective function is assessed based on spectral analysis, the coupled dynamic analysis is performed in the frequency domain only during the optimization.

The main objective of this paper is to ascertain whether the quality of the optimized design based on coupled analysis can be improved compared to the case of hull optimization in which the objective function is evaluated based on linear approximation. For this purpose, hydrodynamic hull optimization is performed for the same type of TLP by using a Genetic Algorithm (Houck et al., 1995) with the same constraints and the objective function as in the previous optimization study (Lee et al., 2007). Finally, the responses of the resulting optimized TLP are compared to those of the former optimized design which was determined based on the equivalent spring method.