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Automated Development of Floating Offshore Structures in Deepwater with Verified Global Performances by Coupled Analysis

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ABSTRACT

This paper presents efficient hull design of floating offshore structures developed by fully automated hull optimization procedure. Optimization algorithms vary selected form parameters of the hull shape and find an optimum of the objective function within the provided constraints ensuring the resulting design to be technically feasible. For the location of the Gulf of Mexico, a semi-submersible production platform is optimized with regard to downtime due to heave motion. The optimized offshore structure shows remarkably enhanced design quality with minimized wave loads and motions compared to the selected reference design. Furthermore global dynamic performance of the developed design is investigated as an integrated system by a fully coupled analysis including hull/mooring/riser for harsh environmental conditions in order to verify the feasibility of the total system.

KEY WORDS: Hull Shape Optimization; Semi-Submersible; Downtime; Coupled Analysis; Global Performance.

INTRODUCTION

The formal optimization process is one of the key technologies to advance design process. In contrast to traditional hull designs where hull shapes are often generated by varying existing similar parent design, the automated design process based on parametric hull design generates hull lines according to specified form parameters without user interaction. The computer integrates hull lines development and subsequent hydrodynamic analysis into an automated process. Thus more design alternatives can be studied on a large scale in shorter periods. Because the design process is controlled by an optimization algorithm, it is sure that the resulting hull represents at least an local optimum with respect to the specified constraints and the objective function.

A hull shape optimization procedure has been established in previous research works (Birk, 1998; Clauss and Birk, 1994, 1996, 1998). The combination of an efficient parameter based shape generation tool, numerical hydrodynamics, stochastic analysis and formal optimization strategies enables the automated design of arbitrary hull shapes of offshore structures with optimum hydrodynamic performances. In addition to local optimization algorithms, which usually trace optima of the objective function next to the starting points, the global optimization strategies are integrated to the hull shape optimization procedure such that the overall best design within the design space of multi-modal optimization problems can be obtained (Lee, 2004; Birk et al., 2002, 2004).

This paper presents the new design of a semi submersible platform developed automatically by the hull shape optimization procedure. For the target area of the Gulf of the Mexico in the water depth of 6000ft the hull shape is optimized with regard to downtime due to heave motion. However, hydrodynamic performance of the final design relies on the specified constraints and the selected objective function which is evaluated based on linear theory considering only first-order wave forces. If second-order wave forces and the coupled effects of hull/mooring/risers are considered, the optimized hull shape may not represent the desired global performance. Consequently, it is necessary to investigate the global dynamic performance of the total system including mooring and risers for the verification of the feasibility of the final design. Therefore, in this paper the global dynamics of the optimized design is studied by a fully coupled analysis considering hull/mooring/riser in harsh environmental conditions.

In the verification study of the total solution, the optimized semi submersible hull shape is further designed with a Steel Catenary Riser (SCR) of 8 inch and with taut mooring system for the water depth of 6000ft. As the developments now extend to deeper water, SCR technology is being introduced as an alternative to flexible risers, especially for field developments with high pressure and high temperature (Arnesen et. al., 2006). Because the riser fatigue initiated by the riser curvature at the touch-down area has been main issues, the riser bending moment in the touch-down area is especially compared with the referenced design.

HULL SHAPE OPTIMIZATION

Constrained Minimization Problems

An optimization task is usually expressed as a constrained minimization problem. The optimization problem can be stated as follows: Find a set of free variables such that the measure of merit or