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Coupling analysis of finite element and finite volume method for the design and construction of FPSO crane

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ABSTRACT

The aim of this study is to establish a procedure for systematic design and performance evaluation of an offshore platform (FPSO; Floating, Production, Storage and Offloading) crane using a computational approach. Coupling analyses of the finite element and finite volume methods, which are applicable for ensuring robust design under the consideration of nonlinear environmental effects, were carried out. In order to investigate the effects of dynamic loading, the boundary conditions of an offshore platform crane having a lifting capacity of 100 tons were studied. In the finite volume method, a series of analyses were carried out using the computational fluid dynamics code, FLUENT. The crane's weight, maximum lifting load, calculated wind pressure and boundary conditions such as the inclination of the deck due to the extreme roll motion of FPSO were also considered in the finite element analyses using the commercial code, MSC/NASTRAN. Deformation, stress distribution, as well as fatigue life estimation were conducted under the unified computational environment. An advanced procedure for evaluating design concept validation was proposed for the application of FPSO design and construction.

1. Introduction

Cranes are widely used in ports and on large ships for the loading/unloading of containers and bulk materials. They are also common in civil engineering for the construction of buildings. Recent advances in this field include automated robotic crane erection processes and automated generating methods of workspace requirements. These advances increase the efficiency of the crane operations due to the enhancement of the crane's performance [1,2]. Due to the recent industrial demand for the exploitation of ocean resources, these application fields of onshore cranes have been extended to offshore platforms such as FPSO (Floating Production, Storage and Offloading unit).

In general, it is well recognized that detailed information of operating loads should be considered for the design or construction of offshore platforms. However, an automatic or systematic procedure for establishing a design concept that includes an in-situ operation condition is not available yet. In this study, an automatic design procedure for an FPSO crane as well as a structural safety evaluation was carried out based on the numerical analysis in conjunction with coupling FEM (finite element method) and FVM (finite volume method).

The lifting operation of a crane on an FPSO is much more complex than that on a fixed (onshore) platform. Due to the motion of the FPSO at sea ocean, the offshore crane is subjected to dynamic forces as well as wind loads. As ocean exploitation expands to harsher environment, the offshore crane is longer exposed to environmental loadings. In this context, the robust design of offshore cranes is recognized to be a major challenge.

While it is well known that the understanding of wind effects on various industrial structures is crucial to maintain structural integrity during the designed life, design purpose research activities are limited to somewhat typical fields.

A practical method for the calculation of wind loads on ships and offshore structures was presented by Haddara and Soares [3]. They proposed an expression for the estimation of wind force coefficients on ships and compared this with experimental results. Other advanced studies regarding wind load identification based on CFD (computational fluid dynamics) simulation include the development of CFD techniques by Huang et al. [4], Blocken et al. [5] and Diego et al. [6] . They presented a reliable numerical treatment technique that takes into account various wind effects on structures.

The motion of FPSO at sea is a very important factor that contributes to the static and dynamic responses of the crane. The motion of FPSO can induce dynamic loads on the crane even if the crane is not in operational condition. Therefore, a precise understanding or treatment should be incorporated into design activities of the FPSO crane. In relation to this research field, Wits presented the effects of parametric excitation of the

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