

Numerical Study for Topside Effect on Behavior of Deck Transportation Vessel and Seafastening Structure

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Abstract—Transportation method of offshore structures is important as offshore ones are larger and installation depths are deeper. Whereas lower supporting structure is possible to be transported by using its buoyancy, topside is transferred by transportation vessel due to equipment unfamiliar with water such as electric systems, chemical process instruments and so on. Transportation vessel moves in sea environment conditions. Vessel is affected by sea environment, and thus motions of vessel as well as environment have influence on topside structure. To prevent a damage of topside by these effects, additional equipment, seafastening structure is installed. Seafastening structure is installed between vessel and topside and has oblique 16 beam structures. Integration analysis of vessel, topside and seafastening structure is realized by Boundary Condition(BC) transfer method and coupled analysis method. The motions of transportation vessel are analyzed and load on the topside and stresses loaded on the seafastening structure are estimated. Results of analyses are compared each other and these results are also done with those of simplified computation.

Keywords—Ship motion; Topside; Seafastening; Load analysis; Coupled analysis; Boundary condition transfer method

I. INTRODUCTION

Offshore structures are installed to produce an oil, develop a renewable energy and so on at sea. These offshore structures are split into topside and lower supporting structure. In case of transporting the offshore structure from construction site to installation one, offshore structure could be transported by perfectly assembled form or split ones that are topside and supporting structure.

Offshore structure could be transferred by its own buoyancy. The lower supporting structure is able to be transported by this method using buoyancy. However, topside structure is impossible to be transported by using buoyancy virtually because this structure consists of equipment unfamiliar with water such as an electrical system, a chemical processing instrument and so on. Thus transportation vessel is used to transfer the topside to avert it from a direct contact with water.

Transportation vessel is in sea environment while transferring the topside. Accordingly, topside is affected by the motion of vessel as well as sea environment. Seafastening technique is needed to protect the topside from being damaged by these effects. Seafastening structure is used to fix the topside and installed between transportation vessel and the topside. It consists of 16 oblique beam and 4 beams each are installed in 4 parts.

In this work, fixing technique using seafastening structure is studied. Boundary Condition(BC) transfer method and coupled analysis are used to analysis the transportation vessel, the topside and the seafastening structures as an integrated analysis method. The results from BC transfer method and coupled analysis are compared with results from simplified computation. The motion of transportation vessel, loads on the topside and stresses loaded on seafastening structure are estimated numerically. Ultimately, by using these results the safety of seafastening structure is assessed.

II. NUMERICAL MODEL

A. Model for Analysis

Numerical model of the transportation vessel topside and seafastening structure is shown at Fig. 1.

Fig. 2 and Table 1 present information for dimension of the transportation vessel, the topside and seafastening structure. Seafastening structure is installed between the vessel and the topside and has 16 oblique beams. Seafastening structure is to support shear stresses loaded on topside structure mainly and, normal stress is held in by other support structure in normal direction. In this study, shear stress is only considered.

B. Environmental Condition

Sea environment applying to transportation vessel is presented at Table 2. Exciting direction of wave comes up for bow wave(180°), transverse wave(90°) and oblique wave(135°) directions.

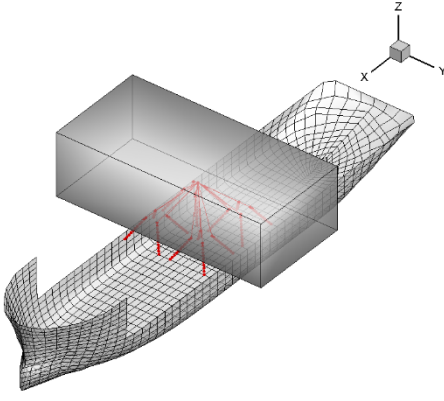


Fig. 1. Transportation vessel with topside and seafastening structure

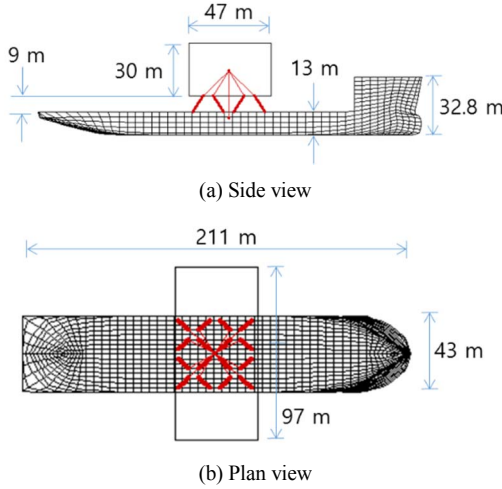


Fig. 2. Dimensions of transporation vessel

TABLE I. PROPERTIES OF TRANSPORTATION VESSEL AND SEAFASTENING STRUCTURE

Property	Value				
Transportation vessel	LBP × B × H _{top} × H _{deck}	211m × 43m × 32.8m × 13m			
	Draft	9.5m			
	Wight distribution	Item	Weight (ton)	COG (m)	K _{xx} / K _{yy} / K _{zz}
		Vessel only	52,144	(-0.663, 0, -0.192)	12.73/ 31.49/ 31.65
		Topside	20,000	(-0.633, 0, 26.5)	24.8/ 15.37/ 25.67
Sea-fastening structure	Total		72,144	(-0.633, 0, 7.208)	21.96/ 31.26/ 30.12
	No. of steel pipe	16			
	Diameter / Thickness	1m / 0.02m			
	Yield strength	345MPa			
	Allowable normal / shear stress	191MPa / 138MPa (Ref. API RP 2A WSD)			

TABLE II. ENVIRONMENTAL CONDITION

Property	Value
Water depth	130m
Hs (Significant height)	6.2m
Tp (Peak period)	14 sec.
Heading angle	90, 135, 180 degs.

III. NUMERICAL METHOD

Motion equation of transportation vessel for numerical analysis is followed as (1).

$$[M_B + M_{add}(\infty)]\{\ddot{x}\} + \left[\int_0^t R(t-\tau) d\tau \right] \{\dot{x}\} + [K_B]\{x\} = \{f_B\} \quad (1)$$

In this equation, $[M_B]$, $[M_{add}]$, $[R]$ and $[K_B]$ are mass, added mass, retardation function and stiffness matrices for the vessel respectively. And $\{x\}$ and $\{f_B\}$ are displacement and load vectors. Formulation of (1) is applied by HOBEM(high order boundary element method, Choi et al, 2000; Hong et al, 2005). (2) represents motion equation of beam element as seafastening structure, and FEM(finite element method, Kim et al, 2013; 2015) is used to formulate this motion equation.

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = \{f\} \quad (2)$$

In (2), $[M]$, $[C]$ and $[K]$ are mass, damping and stiffness matrices for beam element. And $\{x\}$ and $\{f\}$ are displacement and load vectors each.

As integration method for (1) and (2), BC transfer method and coupled analysis method are used and compared each other. BC transfer method assumes seafastening structure to a rigid body. After (1) is solved, the motion results at connection part between the vessel and the seafastening structure from (1) apply to boundary conditions of (2) and then seafastening structure is analyzed by using these boundary conditions. Coupled analysis method analyzes a motion of connection part and load on seafastening structure repeatedly at every time step until results converge to same value with previous step. Compared to BC transfer method, coupled analysis method would take longer computation time but have more accurate solution. Because BC transfer method takes 2-step analysis simply and doesn't consider a coupled effect of the vessel and the seafastening structure.

IV. NUMERICAL RESULTS

A. Motion Estimation of Transportation Vessel

Figs. 3-6 present motions of transportation vessel with topside and seafastening structures. The results from BC transfer method are compared with results from coupled analysis. Computation time for BC transfer method is faster than the time of coupled analysis like the explanation of numerical method. Heave motions of the vessel at transverse wave are shown to Fig. 3 and the results of BC transfer method and coupled analysis are almost same. Fig. 4 shows results on roll motion in transverse wave. As shown to figure, result of BC transfer method is larger than those of coupled analysis. Pitch motion at bow wave from both methods are presented at Fig. 5 and verified to make no difference. That is, whereas heave and pitch motions

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