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Motion Responses of Ship Shape Floating Structure using Diffraction Potential

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ABSTRACT

This paper reviewed the capability of the proposed programming coded based on diffraction potential theory to predict a ship shape floating structure's motion response.This paper briefly presents the procedure to apply the diffraction potential theory to simulate the ship shape floating structure's motion response. As case study, the proposed programming code was applied to prediction motion responses of ship shape floating structure in surging, heaving, pitching, swaying, rolling and yawing directions.Results of simulation were compared with ANSYS AQWA software as bench mark. It found that the simulation results by the proposed programming code are similar with the ANSYS one.

KEY WORDS:*Wave Response, Diffraction Potential, ANSYSAQWA; Ship Shape Floating Structure.*

NOMENCLATURE

$\Phi(x, y, z)$	VelocityPotential in x, y, z directions
$G(P; Q)$	GreenFunction
F_D	Drag Force
R	Horizontal Distance
K	Wave Number

1.0 INTRODUCTION

Behavior or a floating structure using Round Shape FPSO was studied by Lamport and Josefsson in year 2008. They were carried a research to study the advantage of round shape FPSO over the traditional ship-shape FPSO [1]. The comparisons were made to compare motion response, mooring system design, constructability and fabrication, operability, safety and costing between both the structures. One of the finding on their study is the motions of their designed structures are similar at any direction of incident wave with little yaw excitation due to mooring and riser asymmetry. Next, Arslan, Pettersen, and Andersson (2011) are also performed a study on fluid flow around the round shape FPSO in side-by-side offloading condition. FLUENT software was used to simulate three dimensional (3D) unsteady cross flow pass a pair of ship sections in close proximity and the behavior of the vortex-shedding around the two bluff bodies [2].Besides, simulation of fluid flow Characteristic around Rounded-Shape FPSO by self-develop programming code based on RANs method also conducted by A. Efi et al.[3].

As presented by Siow.et al. [6], their finding found that the diffraction potential theory is less accurate to predict the floating structure heave motion response when the wave frequency is close to the structure's natural frequency. In this situation, the heave response calculated by the diffraction potential theory is significantly higher compared to experimental result due to the low damping represented by the theory [9].

In order to improve the heave motion predict by the diffraction potential theory, Siow.et al. tried to increase the damping coefficient by adding viscous damping into the motion equation. In his study, the viscous damping is treated as an extra matrix and can be added into the motion equation separately [6]. Besides this,Siow etal. also tried to integrate the linearized Morison drag equation with diffraction potential theory. The linear Morison drag equation would modify both the damping term and exciting force in the motion equation compared to the viscous damping correction method which only modified the damping term in motion equation. The accuracy of the modification solutions are also checked with the semi-submersible experiment result which was carried out at the towing tank of the UniversitiTeknologi Malaysia [10]. The 6-DOF Round Shape FPSO motion result calculated by this method and the comparison of result between the proposed methods with experiment result was published by Siow et.al in year 2015 [11].

This paper is targeted to review the accuracy of diffraction potential theory in order to evaluate the motion response of a ship.The diffraction potential theory estimates wave exciting forces on the floating body based on the frequency domain and this method can be considered as an efficient one to study the motion of large size floating structure with acceptable accuracy. The accuracy of the diffraction potential method to predict the structures response was also detailed studied. The good accuracy of this diffraction theory applied to large structures is due to the significant diffraction effect that exists in the large size structure in wave [4].In this study, the motion response of ship shape floating structure ship is simulated by the diffraction potential theory and compared with ANSYS AQWA.

2.0 NUMERICAL CALCULATION

2.1 Diffraction Potential

In this study, the diffraction potential method was used to obtain the wave force act on the ship shape FPSO, also the added mass and damping for all six directions of motions. The regular wave acting on floating bodies can be described by velocity potential. The velocity potential normally written in respective to the flow direction and time as below:

$$\Phi(x,y,z) = Re\left[\phi(x,y,z)e^{iwt}\right] \qquad (1)$$

$$\phi(x,y,z) = \frac{g\varsigma_a}{iw}\{\phi_0(x,y,z)+\phi_7(x,y,z)\} + \sum_{j=1}^{6} iwX_j\phi_j(x,y,z) \qquad (2)$$

where,

g : Gravity acceleration
ς_a : Incident wave amplitude
X_j : Motions amplitude
ϕ_0 : Incident wave potential
ϕ_7 : Scattering wave potential
ϕ_j : Radiation wave potential due to motions
j : Direction of motion

From the above equation, it is shown that total wave potential in the system is contributed by the potential of the incident wave, scattering wave and radiation wave. In addition, the phase and amplitude of both the incident wave and scattering wave areassumed to be the same. However, radiation wave potentials are affected by each type of motions of each single floating body in the system, where the total radiation wave potential from the single body is the summation of the radiation wave generates by each type of body motions such as surge, sway,heave,roll, pitch and yaw,

Also, the wave potential $\emptyset$ must be satisfied with boundary conditions as below:

$$\nabla^2\emptyset = 0 \quad for\ 0 \le z \le h \qquad (3)$$

$$\frac{\partial\emptyset}{\partial z} + k\emptyset \quad at\ z = 0 \quad \left(k = \frac{w^2}{g}\right) \qquad (4)$$

$$\frac{\partial\emptyset}{\partial z} = 0 \quad at\ z = h \qquad (5)$$

$$\emptyset \sim \frac{1}{\sqrt{r}}e^{-ik_0 r} \quad should\ be\ 0\ if\ r\ \infty \qquad (6)$$

$$\frac{\partial\phi_7}{\partial n} = -\frac{\partial\emptyset_0}{\partial n}\ on\ the\ body\ boundary \qquad (7)$$

2.2 Wave Potential

By considering the wave potential only affected by model surface, S_H, the wave potential at any point can be presented by the following equation:

$$\emptyset(P) = \iint_{S_H}\left\{\frac{\partial\emptyset(Q)}{\partial n_Q}G(P;Q) - \emptyset(Q)\frac{\partial G(P;Q)}{\partial n_Q}\right\}dS(Q) \qquad (8)$$

Where$P = (x, y, z)$ represents fluid flow pointed at any coordinate and $Q = (\xi,\eta,\varsigma)$ represent any coordinate, (x, y, z) on model surface, S_H. The green function can be applied here to estimate the strength of the wave flow potential. The green function in eq. (8) can be summarized as follow:

$$G(P;Q) = -\frac{1}{4\pi\sqrt{(x-\xi)^2+(y-\eta)^2+(z-\zeta)^2}} + H(x-\xi, y-\eta, z+\zeta) \qquad (9)$$

where $H(x-\xi, y-\eta, z+\zeta)$ in eq. (9) represent the effect of free surface and can be solved by second kind of Bessel function.

2.3 Wave Force, Added Mass and Damping

The wave force or moment act on the model to cause the motions of structure can be obtained by integral the diffraction wave potential along the structure surface.

$$E_i = -\iint_{S_H}\phi_D(x,y,z)n_i dS \qquad (10)$$

where, ϕ_D is diffraction potential, $\phi_D = \phi_o + \phi_7$

Also, the added mass, A_{ij} and damping, B_{ij} for each motion can be obtained by integral the radiation wave due to each motion along the structure surface.

$$A_{ij} = -\rho\iint_{S_H}Re\left[\phi_j(x,y,z)\right]n_i dS \qquad (11)$$

$$B_{ij} = -\rho w\iint_{S_H}Im\left[\phi_j(x,y,z)\right]n_i dS \qquad (12)$$

$n_i$in eq. (10) to eq. (12) is the normal vector for each direction of motion, i = 1~ 6 represent the direction of motion and j = 1~6 represent the six type of motions. The motion equation is shown as follows:

$$(m + m_a)\ddot{X}_z + (b_p)\dot{X}_z + kx = F_p \qquad (13)$$

3.0 SIMULATION RESULTS OF SHIP SHAPE FPSO

The objective of this paper is reviewing motion responses of a sship shape floating structureestimated by the diffraction potential theory. As a case study, the designed KVLCC2 has 320 meter of length between perpendiculars in full scale. The model was constructed from wood following the scale of 1:110. Upon the model complete constructed, inclining test, androll decay test were conducted to identify the hydrostatic particular of the dimension and measured data of the model was summarized as in Table 2 and Figure.1.

Table 1: Particular of KVLCC2 Ship

Symbol	Model
Length between Perpendicular(m)	2.9091
Length Water Line (m)	2.9591
Breadth (m)	0.5273
Draught(m)	0.1891
Displacement (m^3)	0.2349
Block Coefficient	0.8098
Wetted Surface Area (m^2)	2.2906

Figure 1: Model of KVLCC2 ship

The sample of mesh of the model used in simulation by the diffraction potential theoryand ANSYS AQWA are showed in Figure 2. The motion responses of KVLCC2 ship calculated by the diffraction potential theoryand ANSYS AQWA are presented in Figures 3 ~ 8. From the figures, it can be seen that tendency by the diffraction potential theory the diffraction potential theory return the same result as the result predicted by ANSYS AQWA. The observation also proved that the self-developed diffraction potential coding is developed based on the diffraction potential theory correctly.

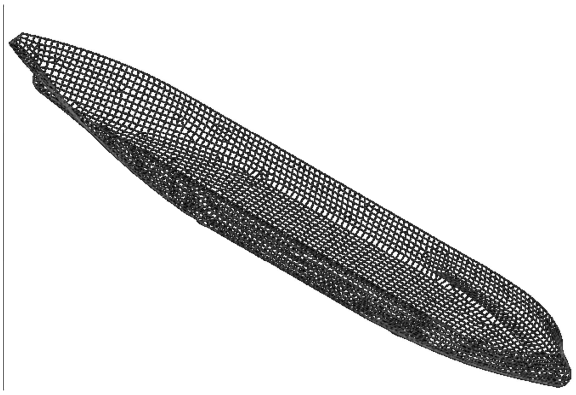

Figure 2: Mesh of KVLCC2 applied in the simulation

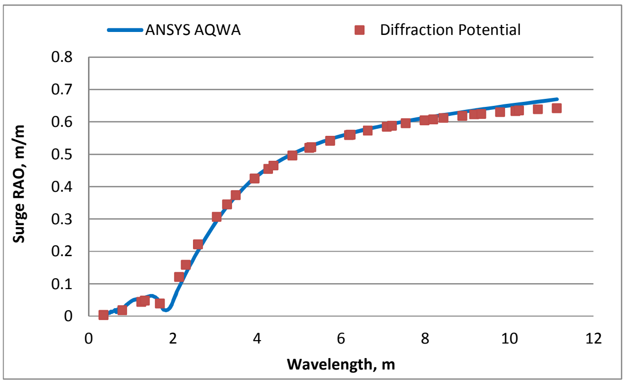

Figure3: Surge motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA.

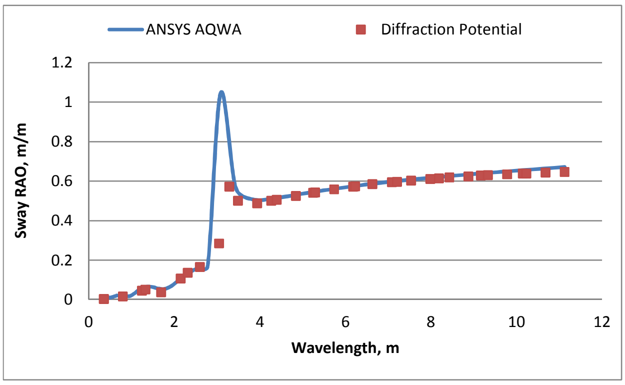

Figure4: Sway motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA software

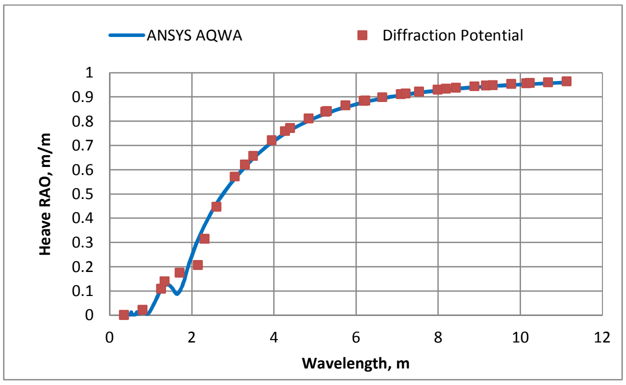

Figure5: Heave motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA software.

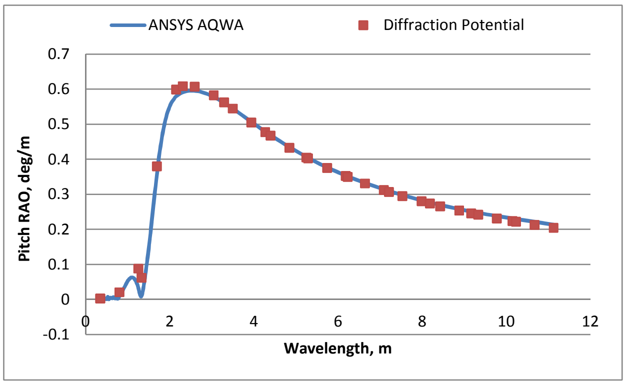

Figure6: Pitch motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA software

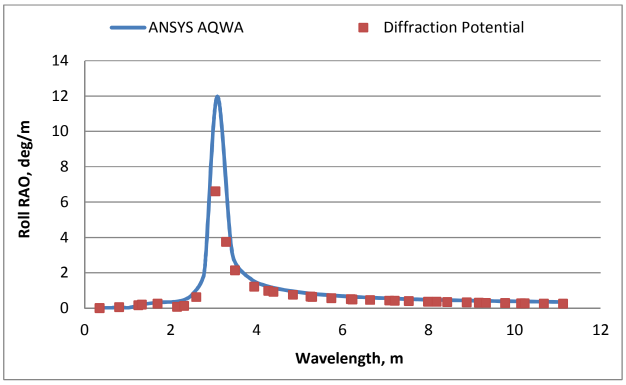

Figure7: Roll motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA software

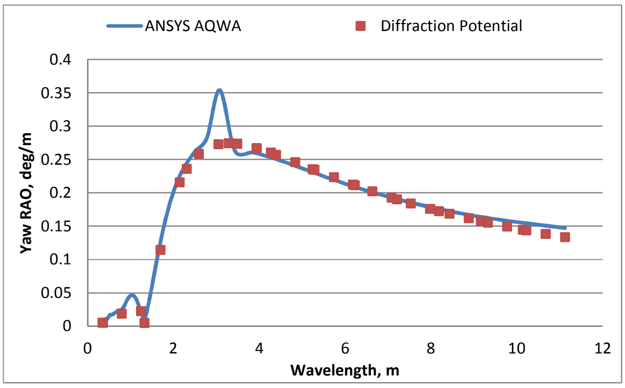

Figure8: Yaw motion response of KVLCC ship predicted by Diffraction Potential theory and ANSYS AQWA software

5.0 CONCLUSION

In conclusion, this paper reviewed the tendency of heave motion response predicted by the proposed diffraction potential theory with Morison drag term correction method. In the beginning, the FPSO heave motion response predicted by the self-developed programming was compared to the predicted result by ANSYS AQWA. The comparison showed that the self-developed diffraction potential coding have the same performance as ANSYS AQWA software where both method provided same tendency of result and almost similar response amplitude at any wavelength. After that, the study was focused in compared the effect of the drag effect in the motion response prediction. By involved the Morison drag term in the calculation, the peak heave response predicted by the diffraction potential theory with Morison Drag correction method is lower compared to the diffraction potential theory and ANSYS AQWA. This shown that by involved the drag effect in the calculation would help to avoid the diffraction potential theory predict the FPSO heave motion response with the significant higher magnitude in the damping dominate region.

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