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Numerical Simulation of Flow Around Forced-Rolling Barge Buoyancy

Kyung-Jin Kim[1)] Tea-Jin Kang[2)] Jang-Keun Cho[3)] *Warn-Gyu Park[4)]

[1), 2) 4)] *School of Mechanical Engineering, Pusan National University, Busan 609-735, Korea*
[3)] *Research Institute for Future Wind Energy Technology, Pusan National University, Busan 609-735, Korea*
[4)] wgpark@pusan.ac.kr

ABSTRACT

The present study is numerical simulation result to solve two-phase flow around a two-dimensional (2D) barge platform in forced-rolling. A platform with a draft equal to one half of its height was hinged at the center of gravity and free to roll with waves that had the same period as the natural roll period of a barge platform. In order to simulate the 2D incompressible viscous two-phase flow in a wave tank with the barge platform, the present study used the volume of fluid (VOF) method based on the finite volume method with a standard turbulence model. In addition, the dynamic mesh technique was used to handle the motion of the barge platform induced by the fluid-structure interaction. Consequently, the present results are able to predict the relevant aspects of the flow field and roll motion of the barge platform structure.

1. INTRODUCTION

Recent depletion of fossil fuels and nuclear energy due to safety concerns has been actively performed to develop new energy resources. Among them, wind power is research and development into alternative energy sources. As a result, reliable energy for the production of wind turbines size is bigger. And increasingly installed in deep sea areas are being expanded. Accordingly research on deep sea wind turbines and offshore wind turbines being installed on the floating structure research is being. In the field of shipbuilding plant was conducted large study on barge type floating structures. In this study, a commercial code ANASYS Fluent of VOF (Volume of Fluid) method using on the two-phase flow in a barge floating structures when subjected to forced rolling behavior of the barge is numerical analysis. And that applies to the barge type floating structures of bilge keel using the reduction of degrees of freedom to design and

[1),2)] Graduate Student
[3)] Research Professor
[4)] Professor

has been analyzed. Bilge keels are appendages to the bottom sides of the barge (Fig. 1). The flow separation and the vortices generated at sharp edges such as keels increase the damping force of the barge in motion and bilge keels would also give additional friction resistance. Traditionally, hydrodynamic coefficients used in the prediction of rolling motions have been obtained from empirical formulas based on the experimental test results (e.g. Himeno, Ikeda et al.). Braathen and Faltinsen refined vortex tracking method for inclusion of the free-surface effect and a moving separation point. They do so because free-surface waves have an effect on the vortex generation. Their numerical results for the roll damping overestimated the experimental results by Vugts. A fractional step method was used to solve the vorticity equation for the vortical part. Kinnas et al. employed a finite volume method to discretize and a predictor-corrector scheme to solve the Navier-Stokes equations and continuity equations. Their viscous solver incorporated a viscous fluid with a linearized free-surface effect. Under the same framework of the Navier-Stokes equations and the linearized free-surface condition, a solver was developed by Bangun and Utsunomiya to evaluate the hydrodynamic coefficients of a forced rolling barge.

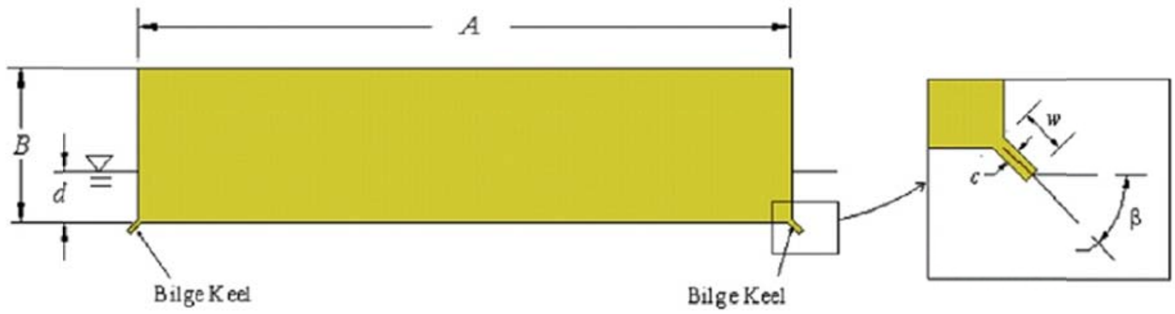


Fig. 1 Sketch of the barge with bilge keels

2. Mesh Generation and Boundary Conditions

Fig .2 is grid and boundary conditions of the water tank. As shown in figure, grid consists of about 60,000 pieces. And near the barge of the grid is relatively tightly configuration to minimize the impact of the grid was moved. Installed wave absorber at both end of the water tank makes dissipation wave that occurs when the forced rolling. And by using the dynamic mesh around the cylinder to rotate forces. After six degrees of freedom expression is split to fit rolling motion, substituting the mass and moment of inertia forces and moments obtained by pressure (Eq. 1-4). Rolling motion of the barge equal to Eq. 5.

$$m\frac{d^2 x_{CGi}}{dt^2} = F_{CGi} \tag{1}$$

$$\frac{d}{dt}(I_{ij}\frac{d\theta_{CGi}}{dt}) = L_{CGi} \tag{2}$$

$$\frac{V^{n+1} - V^{n}}{\Delta t} = \frac{F_{CGi}}{m} \tag{3}$$

$$\frac{\dot{\theta}^{n+1} - \dot{\theta}^{n}}{\Delta t} = \frac{L_{CGi}}{I_{ij}} \tag{4}$$

$$\phi = \phi_a \sin wt \tag{5}$$

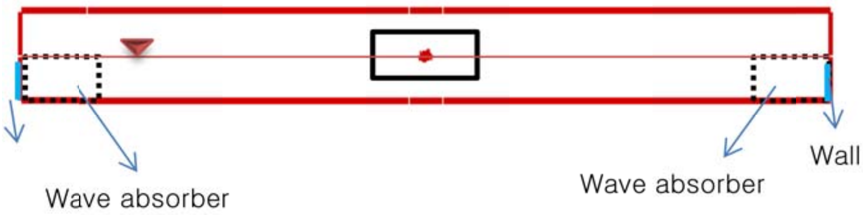


Fig. 2 Computational meshes and boundary condition

Water tank length is 24m. The free surface height is 0.9m. Wave absorbers length is each 2m. Barge size is 0.5m*0.1m. Bilge keel length is 0.02m and thickness is 0.005m. Bilge keel angle are each 0°, 15°, 45°, 60°, 75°, 90°.

3. RESULT AND DISCUSSION

Fig. 3-6 is shown when forced rolling the velocity field around the barge. Depending on the direction of barge rotation velocity field is formed. In the barge edge occurred vortex that affects the degrees of freedom. Influence of the bilge keel occur vortices at the bilge keel position and thereby reducing the degrees of freedom made.

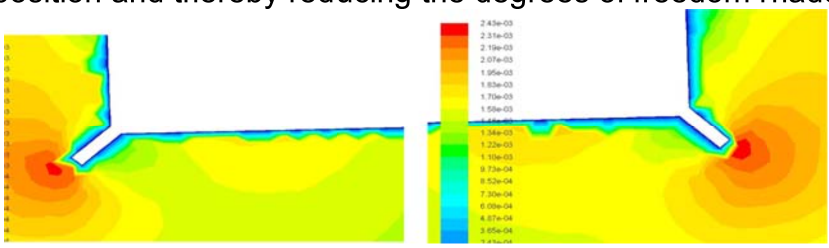


Fig. 3 Velocity contour at 1.7°

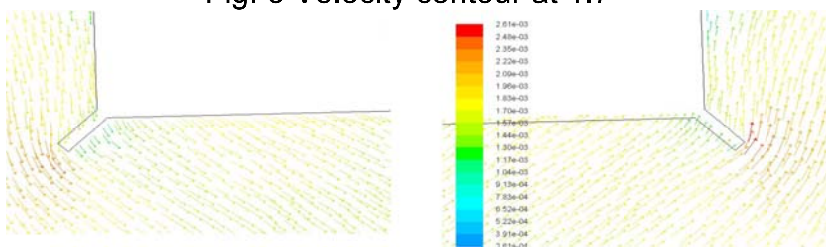


Fig. 4 Velocity vector at 1.7°

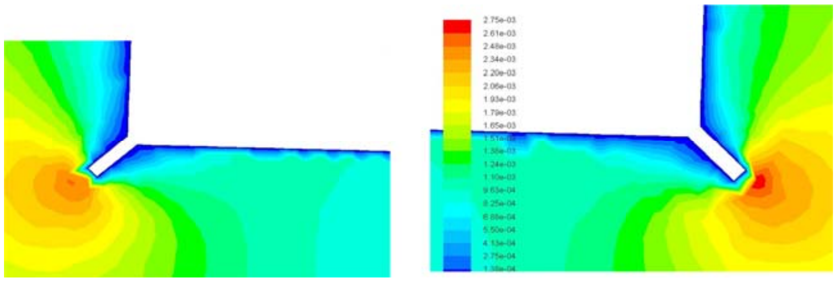


Fig. 5 Velocity contour at -1.7°

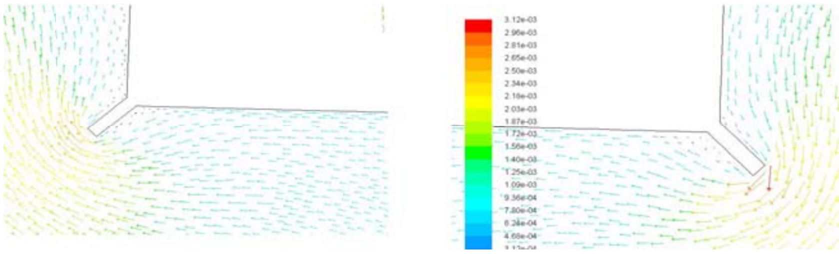


Fig. 6 Velocity vector at -1.7°

For the validation experiment, the roll added-mass and the damping coefficients of the bare hull type and the barge fitted with bilge keels(β=0°, w=0.02m) are compared with the experimental data obtained by Yago et al. The tested angular amplitudes vary from 0.01 radians up to 0.05 radians and the angular frequencies range from 0.7 Hz to 1.5 Hz. The hydrodynamic moment may be decomposed into the inertia and damping terms, i.e. where A_{44} is the roll added-mass and B_{44} the roll damping coefficient. The moment which is obtained from the present integration may be expressed as an equivalent sinusoidal harmonic function having a phase angle from the roll amplitude function in Eq.(5), i.e. where M_0 is the equivalent moment amplitude. Where κ is the wave number and a is the half-width of hull section.

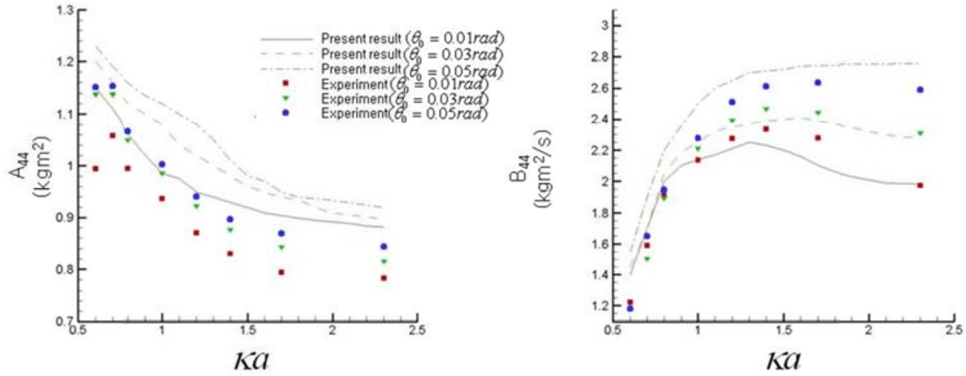
$$M = -A_{44}\ddot{\theta} - B_{44}\dot{\theta} \tag{6}$$

$$M = M_0 \sin(wt + \gamma) \tag{7}$$

$$A_{44} = M_0 \cos\gamma / \theta_0 \omega^2 \tag{8}$$

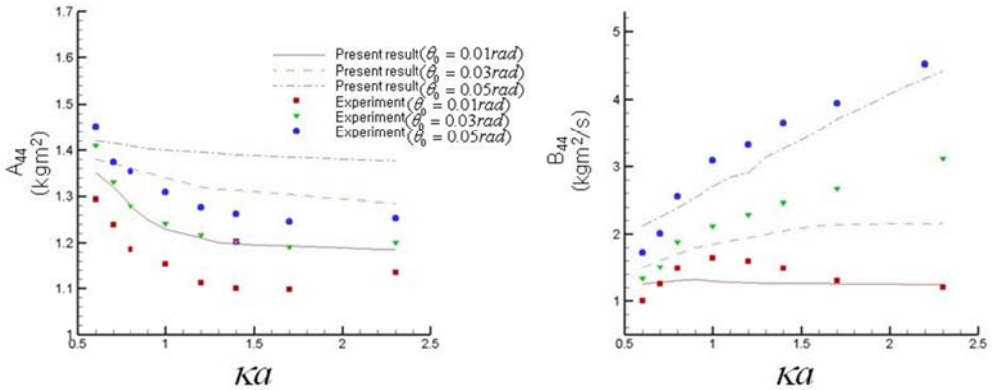
$$B_{44} = -M_0 \sin\gamma / \theta_0 \omega \tag{9}$$

The numerical result and experiment result the bare hull type and the barge with bilge keels (β=0°, w=0.02m) are compared with the experimental data obtained by Yago et al. The tested angular amplitudes vary from 0.01 radians up to 0.05 radians and the angular frequencies range from 0.7 Hz to 1.5 Hz. The hydrodynamic moment may be decomposed into the inertia and damping terms, i.e. where A_{44} is the roll added-mass and B_{44} the roll damping coefficient. The moment which is obtained from the present integration may be expressed as an equivalent sinusoidal harmonic function having a phase angle from the roll amplitude function in Eq.(5), i.e. where M_0 is the equivalent moment amplitude. Where κ is the wave number and a is the half-width of hull section.



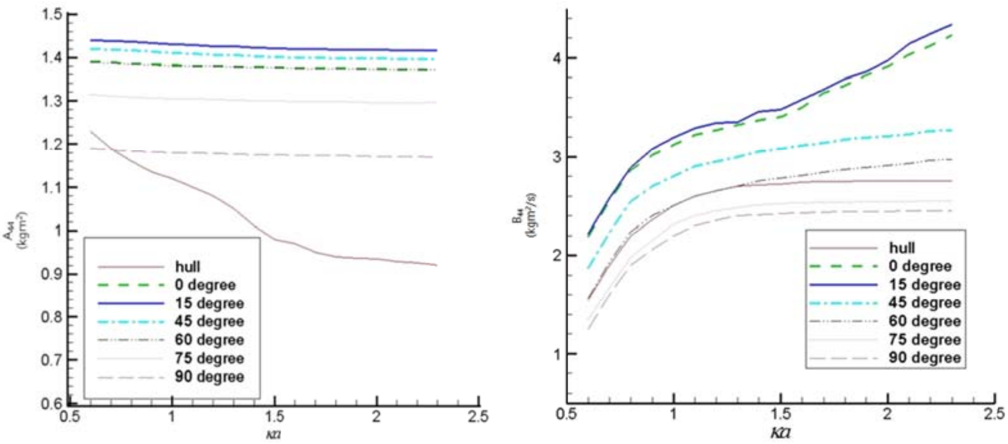
(a) Roll added-mass coefficient (b) Roll damping coefficient

Fig. 7 Roll added-mass coefficient and roll damping coefficient (without bilge keel)



(a) Roll added-mass coefficient (b) Roll damping coefficient

Fig. 8 Roll added-mass coefficient and roll damping coefficient
(with bilge keel) β=0, w=0.02



(a) Roll added-mass coefficient (b) Roll damping coefficient

Fig. 9 Roll added-mass coefficient and roll damping coefficient

The numerical result and experiment result have a similar trend where the damping coefficients in Fig. 7 and Fig.8. The roll added-mass increases slightly as the angular amplitude also increases, while the roll damping coefficients change significantly even in high wave frequencies. Fig. 9 shows that effect of bilge keels. Horizontal bilge keels(β=0°−45°) are better than vertical bilge keels(β=45°−90°). Barge with bilge keels at β=15° will appear to provide the largest roll damping coefficients.

CONCLUSION

In this study, VOF (Volume of Fluid) method using on the two-phase flow in a barge type floating structures when subjected to forced rolling motion of the barge is computational analysis. When barge has a rolling, Depending on the direction of barge rotation, velocity field is formed. The flow separation and the vortices generated at sharp edges such as keels increase the damping force of the barge in motion and bilge keels would also give additional friction resistance. Therefore, bilge keels are effective in damping the rolling motion of barges.

ACKNOWLEDGMENT

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