Numerical study of hydrodynamic coefficients of multiple hulls by large eddy simulations with volume of fluid method

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Introduction

In Fukushima FORWARD project [1], one floating substation and one 5MW floating wind turbine adopt the advanced spar which combines traditional spar and multi-hulls.

In this study, hydrodynamic coefficients of multiple hulls are numerically studied. Large eddy simulations with volume of fluid method are performed to predict the hydrodynamic force on a forced vibrated model with multiple hulls. A systematic study are performed on the effects of geometric parameters, such as spacing ratio, diameter ratio and aspect ratio on the hydrodynamics of octagonal hull.

Formulas of added mass and nonlinear hydrodynamic damping coefficients are proposed for a single and double hulls with circular, octagonal and square cross-sections to cover a wide range of application of the hull.

Governing equation in numerical simulations

- Governing equation
- Forced oscillation
- Morison's equation
- Hydrodynamic coefficients

The added mass coefficient (Ca) and nonlinear hydrodynamic damping parameter (Cd) are estimated by Fourier averaged method [2].

Validation and Mechanism

- Validation of numerical results

The predicted hydrodynamic force matches well with the measurement in terms of both amplitude and phase. The predicted and measured Ca exhibits negligible oscillating periods dependence.

- Effect of geometric parameters on hydrodynamic forces

Table 1. Ca and Cd dependence

<table>
<thead>
<tr>
<th>Spacing ratio</th>
<th>Diameter ratio</th>
<th>Thickness ratio</th>
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</thead>
<tbody>
<tr>
<td>Ca</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Cd</td>
<td>O</td>
<td>X</td>
</tr>
</tbody>
</table>

Ca depends on spacing ratio and diameter ratio, while Cd is a function of spacing ratio and thickness ratio.

Formulas for hydrodynamic coefficients

- Single hull

The Ca and Cd for single hull is proposed as follows:

\[ C_a = k^4 \frac{1.7 \pi \rho a^3}{k^2 + 2k + 2.5} \]

- Double hulls

The Ca and Cd for double hulls is proposed as follows:

\[ C_a = \min \left\{ \frac{1.7 \pi \rho a^3}{k^2 + 2k + 2.5}, \frac{2.7 \pi \rho a^3}{k^2 + 2k + 2.5} \right\} \]

Conclusions

In this study, hydrodynamic coefficients of multiple heave plates are investigated by numerical simulation and water tank test. The conclusions are summarized as follows:

1. Added mass and drag coefficients of multiple hulls predicted by large eddy simulations with volume of fluid method show a good agreement with the experimental data by the water tank test.

2. The added mass coefficient, Ca, increases as the spacing ratio and the diameter ratio increase, while the drag coefficient, Cd, increases as the spacing ratio increases and is independent of the diameter ratio.

3. Shape correction factor and KC number factor are proposed in the formulas of Ca and Cd for a single hull and double hulls.

References