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Modeling of fluid resonance in-between two floating structures in close proximity

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- Hydrodynamic interaction effect become important for multiple floating structures arranged side by side with small separation.

- Practical interest is confined not only to the forces and motions of the closely spaced vessels but also to the free surface elevations.

- The resonant frequency is another key concern, which is closely related to that of moonpool.

- The present study focuses on the fluid resonances between two floating structures based on fairly perfect fluid potential theory(taking the effect of fluid viscosity into consideration). Additionally this paper also seeks to analyze methods used to estimate the fluid resonant frequencies.

METHOD

- Potential flow taking the effect of fluid viscosity

$$f = -\mu V, \qquad g\Phi_z + \Phi_{tt} + \mu\Phi = 0. \qquad \eta = -(\Phi_t + \mu\Phi)/g.$$

$$P = \rho \mathrm{i}\omega_e \left(1 - \frac{\mu}{\mathrm{i}\omega_e}\right)\phi \mathrm{e}^{-\mathrm{i}\omega_e t}.$$

$$\begin{cases} -A_{aaij}\omega_e^2 - B_{aaij}\omega_e = -\rho \mathrm{i}\omega_e \iint_{S_a} (1 - \frac{\mu}{i\omega_e})\phi_{aaj} n_{ai} \mathrm{d}s, \\ -A_{abij}\omega_e^2 - B_{abij}\omega_e = -\rho \mathrm{i}\omega_e \iint_{S_b} (1 - \frac{\mu}{i\omega_e})\phi_{abj} n_{bi} \mathrm{d}s, \\ -A_{baij}\omega_e^2 - B_{baij}\omega_e = -\rho \mathrm{i}\omega_e \iint_{S_a} (1 - \frac{\mu}{i\omega_e})\phi_{baj} n_{ai} \mathrm{d}s, \\ -A_{bbij}\omega_e^2 - B_{bbij}\omega_e = -\rho \mathrm{i}\omega_e \iint_{S_b} (1 - \frac{\mu}{i\omega_e})\phi_{bbj} n_{bi} \mathrm{d}s, \end{cases}$$

$$\begin{cases} F_{wai}(t) = f_{wai}\mathrm{e}^{-\mathrm{i}\omega_e t} \\ \quad = -\rho \mathrm{i}\omega_e \mathrm{e}^{-\mathrm{i}\omega_e t} \iint_{S_a} (1 - \frac{\mu}{\mathrm{i}\omega_e})(\phi_7 + \phi_0) n_{ai} \mathrm{d}s, \\ F_{wbi}(t) = f_{wbi}\mathrm{e}^{-\mathrm{i}\omega_e t} \\ \quad = -\rho \mathrm{i}\omega_e \mathrm{e}^{-\mathrm{i}\omega_e t} \iint_{S_b} (1 - \frac{\mu}{\mathrm{i}\omega_e})(\phi_7 + \phi_0) n_{bi} \mathrm{d}s, \end{cases}$$

METHOD

- Analysis of resonant frequencies and associated Eigen modes

$$\Phi = \sum_{m=0}^{\infty}\sum_{n=0}^{\infty} f_m(x) g_n(y)[C_{mn}\cosh(v_{mn}z) + D_{mn}\sinh(v_{mn}z)]\cos(\omega t).$$

$$\omega_{mn}^2 = g v_{mn} \frac{1 + J_{mn}\tanh(v_{mn}H)}{J_{mn} + \tanh(v_{mn}H)},$$

$$J_{mn} = \frac{v_{mn}}{2\pi} \cdot$$

$$\frac{\int_0^{L_g}\int_0^{L_g}\int_0^{B_g}\int_0^{B_g}(1/R) f_m(x) f_m(x') g_n(y) g_n(y') \mathrm{d}x\mathrm{d}x'\mathrm{d}y\mathrm{d}y'}{\int_0^{L_g}\int_0^{B_g}(f_m(x))^2 (g_n(y))^2 \mathrm{d}x\mathrm{d}y}.$$

$$I = \int_0^{L_g}\int_0^{B_g}\left\{ f_m(x) g_n(y) \int_0^{L_g}\int_0^{B_g}\frac{\mathrm{d}x'\mathrm{d}y'}{R} + \int_0^{L_g}\int_0^{B_g}[f_m(x') g_n(y') - f_m(x) g_n(y)]\frac{\mathrm{d}x'\mathrm{d}y'}{R}\right\} f_m(x) g_n(y)\mathrm{d}x\mathrm{d}y.$$

- Numerical results

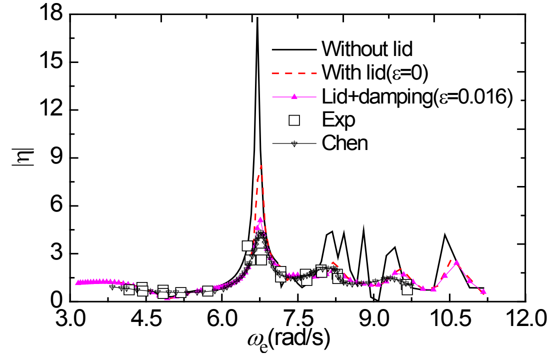

Fig.2 Wave elevation in the gap center of two barges: total wave elevation for free floating bodies for D_y=0.716 m.

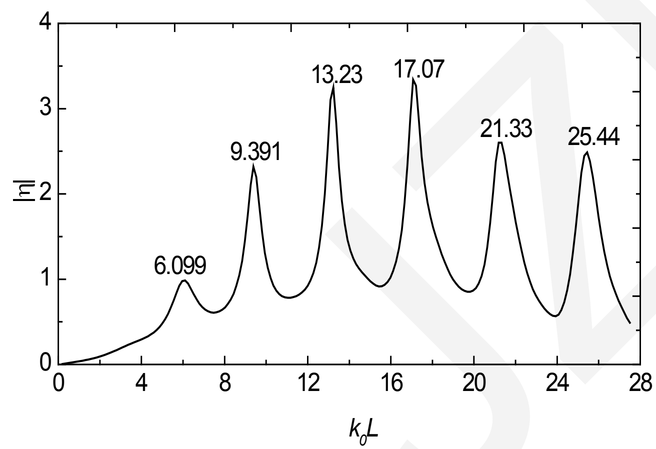

Fig. 11 The radiation elevation of P1 with Dy=1.797 m

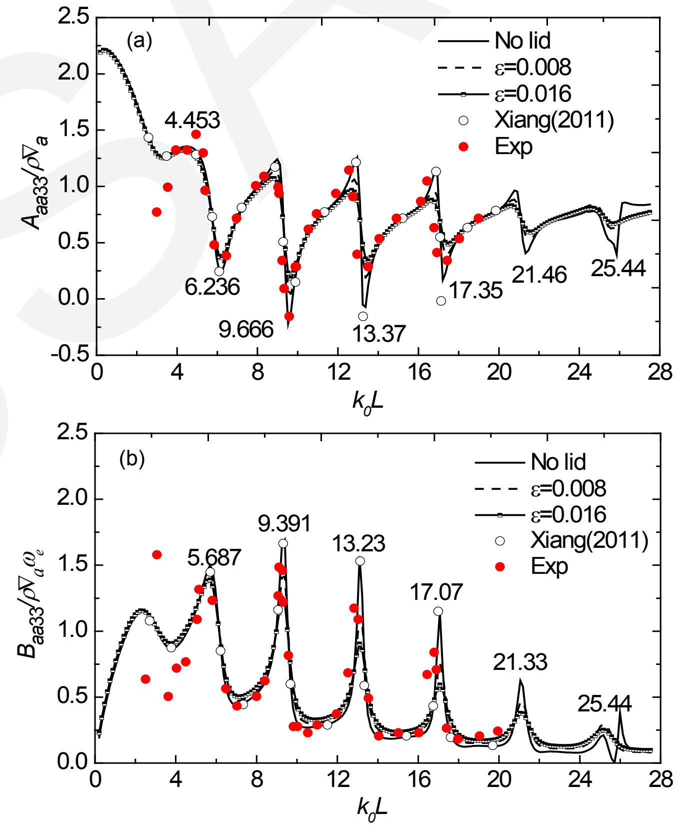

Fig. 10 Added mass and damping of Wigley with Dy=1.797 m
(a) Added mass; (b) Damping

RESULTS AND CONLUSIONS

- The numerical results from present potential theory with appropriate damping coefficients produce results which corroborate experimental data both for forces and wave elevation. The accuracy of the predicted resonant wave height and force can thus be greatly improved. In addition, the dissipate parameter can be calibrated by comparing the wave elevation results of potential theory to those of measurements in experiments or the viscous fluid model, the latter is more convenient and practical.

- With regards to the two side-by-side Barges system and side-by-side Wigley-Barge system, the frequencies and magnitude of the peaks in the wave elevations and forces are generally dependent on the spacing and body's motion. With an increase of gap width, the peaks occur at lower frequencies.

- The semi-analytical model gives reliable predictions of the peak frequencies calculated by the present 3-D panel method at different lateral clearances of the two Barges system. Additionally, the fluid resonant mode in the gap corresponding to each resonant frequency has also been confirmed. This model can be used to predict the peak frequencies for ship hulls with complex geometries, such as Wigley and Barge system.