Research on motion characteristics of floating breakwater with pneumatic chamber

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Introduction

The main purpose of the study is to realize the motion characteristics of floating breakwater with pneumatic chamber.

This type of floating breakwater has a pressurized pneumatic chamber and buoyancy tanks. The great advantage of the breakwater is that the resonant period and the motion can be easily adjusted only by changing the air pressure in the pneumatic chamber without changing the geometrical type of breakwater.

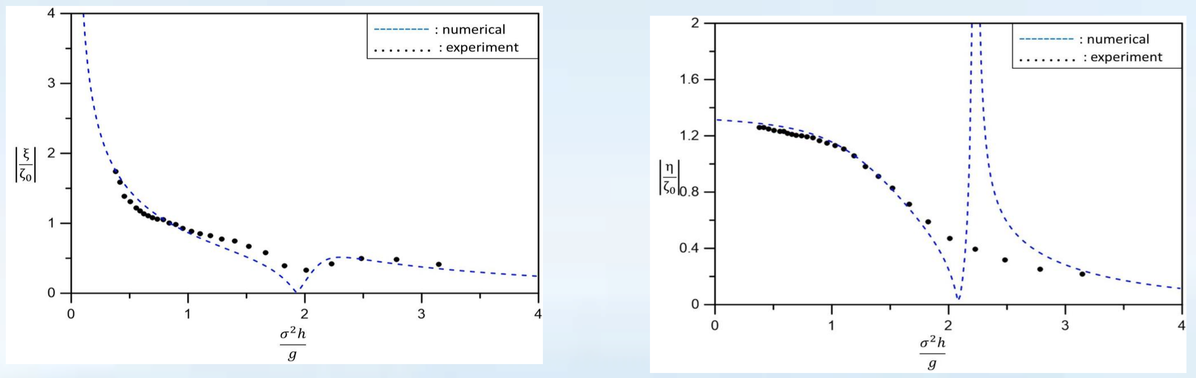
This study focuses on the difference in stability of the structure. Numerical simulation is based on small amplitude wave theory, constructing numerical model with three-dimensional boundary element method and discussing the Response Amplitude Operators (RAO) of the structure under the action of waves.

Motivation

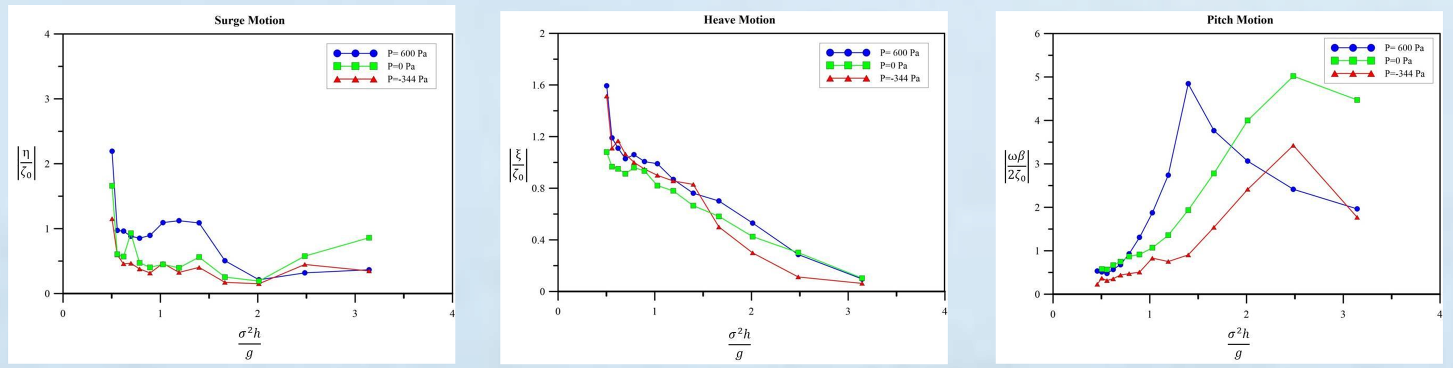
Most of the previous studies focused on the motion characteristics of floating bodies under the action of waves, and the scale was relatively large. In addition, most of the studies assumed that the free water surface inside the air cushion was at the same level as the free water surface outside the air cushion, and didn't consider the internal and external pressure difference caused by buoyancy, so it's impossible to more accurately describe the motion characteristics of the floating body. Through the results of this study, the floating body with pneumatic chamber can be applied to the foundation of offshore wind turbines, floating breakwaters, floating platforms, etc. in the future.

Theoretical verification

- Comparison of experimental and numerical results.
- Assume the internal and external water levels are equal. ($q_2 h = 0$)
- Surge and Heave motion are consistent with the experimental results.



- Changing the pressure in the chamber has a significant effect on **pitch motion**.
- When the pressure in the chamber is lower than the atmospheric pressure, its vibration suppression effect is the best.

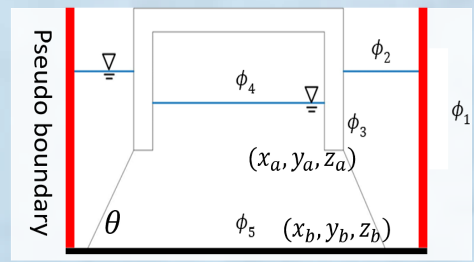


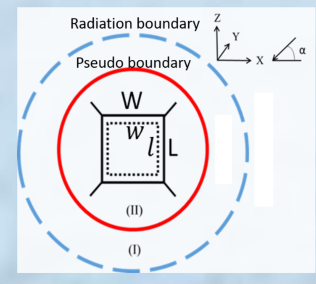
Numerical Methods

Govern Equation

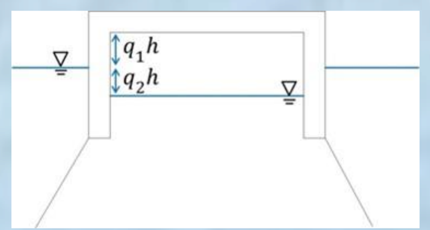
$\nabla^2 \Phi(x,y,z,t) = 0$ Laplace equation

$\Phi(x,y,z,t) = (g\zeta_0/\sigma)\phi(x,y,z)e^{i\sigma t}$





Six degrees of freedom equation of motion



$m_b\ddot{X} + F_{cx} = \iint_{sb} P\frac{\partial x}{\partial n}dA$ Surge Motion Equation

$m_b\ddot{Y} + F_{cy} = \iint_{sb} P\frac{\partial y}{\partial n}dA$ Sway Motion Equation

$m_b\ddot{Z} + F_{cz} = \iint_{sb} P\frac{\partial z}{\partial n}dA + R_z + \bar{p}_0 e^{i\sigma t} lw$ Heave Motion Equation

$I_{xx}\ddot{\delta}_1 + F_{c\delta_1} = \iint_{sb} P[\frac{\partial z}{\partial n}(y_0 - \overline{y_0}) - \frac{\partial y}{\partial n}(z_0 - \overline{z_0})]dA + M_x$ Roll Motion Equation

$I_{yy}\ddot{\delta}_1 + F_{c\delta_2} = \iint_{sb} P[\frac{\partial x}{\partial n}(z_0 - \overline{z_0}) - \frac{\partial z}{\partial n}(x_0 - \overline{x_0})]dA + M_y$ Pitch Motion Equation

$I_{zz}\ddot{\delta}_3 + F_{c\delta_3} = \iint_{sb} P[\frac{\partial y}{\partial n}(x_0 - \overline{x_0}) - \frac{\partial x}{\partial n}(y - \overline{y_0})]dA$ Yaw Motion Equation

The pressure in the pneumatic chamber

$$\hat{p}_a = \bar{p}_0 + p_0 e^{i\sigma t}$$

Kinematic and Dynamic Boundary Conditions of Water Surface in Pneumatic Chamber

$$\frac{\partial \zeta^*}{\partial t} = \frac{\partial \Phi}{\partial z}$$

$$\rho\frac{\partial \Phi}{\partial t} + \rho g \zeta^* + \hat{p}_a = 0$$

Boundary Conditions of Water Surface in Pneumatic Chamber

$$\frac{\partial \phi}{\partial z} = \frac{\sigma^2}{g}(\phi - i\frac{p_0}{\rho g \zeta_0})$$

Results and discussion

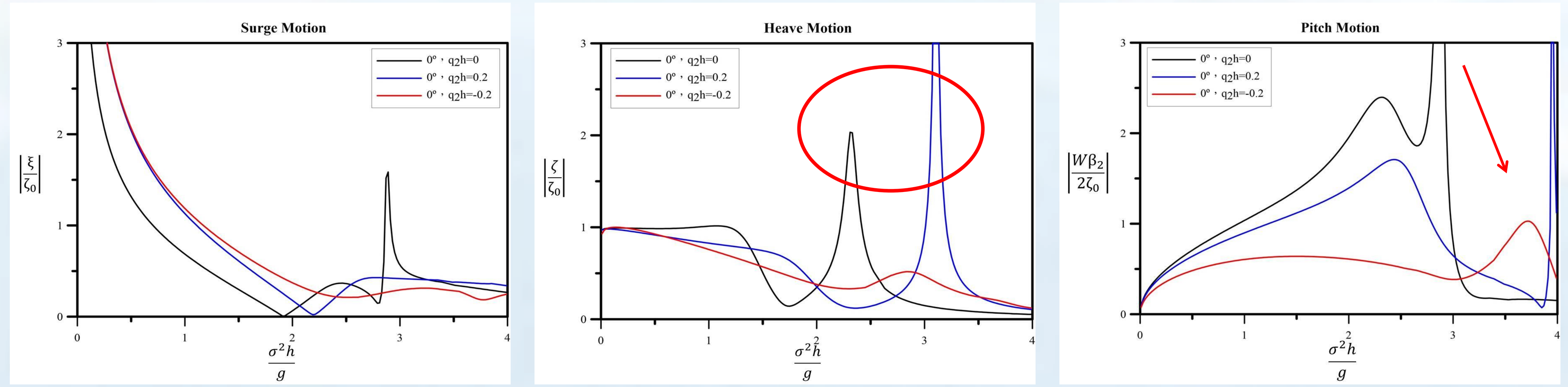
The floating body changes the internal pressure of the pneumatic chamber

- The water depth is h, the submerged depth of the floating body is 0.4h, the length is 2h, and the width is h. Three kinds of internal pressure of the pneumatic chamber are set.

$q_2 = 0$ The pressure inside and outside the chamber is equal.

$q_2 = 0.2$ The pressure inside the chamber is greater than outside the chamber .

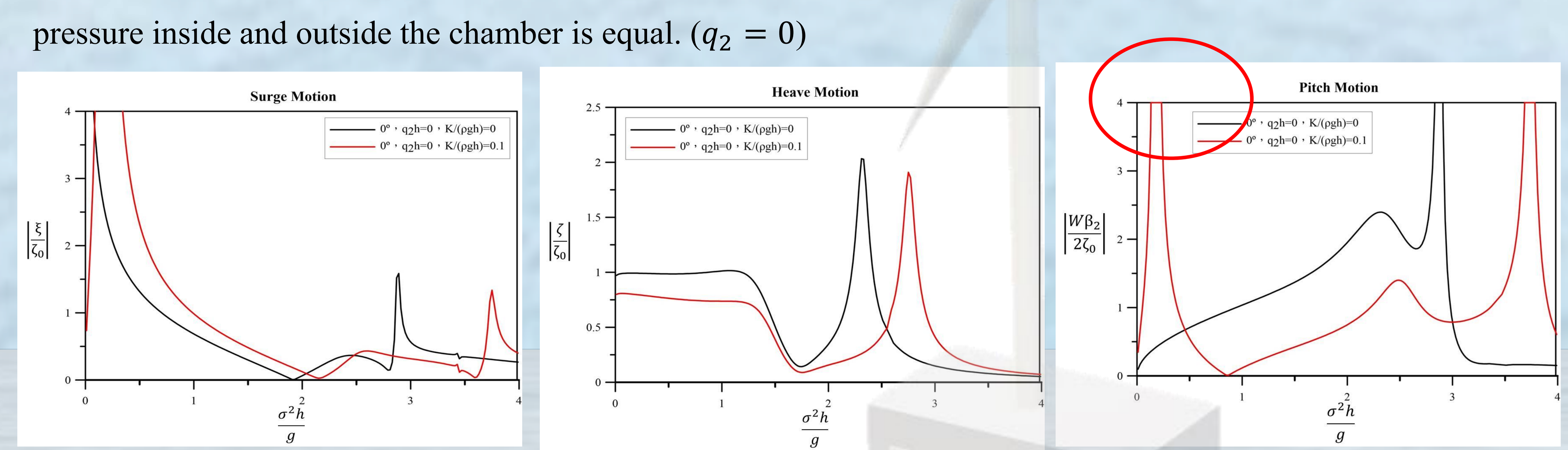
$q_2 = -0.2$ The pressure inside the chamber is less than outside the chamber .



- Surge motion amplitude decreases with increasing frequency, and a second resonance frequency is generated due to the influence of the pneumatic chamber.
- Heave motion amplitude decreases as the internal pressure of the pneumatic chamber decreases; the second resonance frequency is generated due to the influence of the pneumatic chamber, and its frequency moves to high frequency and the amplitude increases as the internal pressure of the pneumatic chamber decreases.
- Pitch motion amplitude decreases as the internal pressure of the air chamber decreases; the second resonance frequency is generated due to the influence of the air chamber, and its frequency moves to high frequency and the amplitude increases as the internal pressure of the air chamber decreases.

Comparison between floating body and mooring cable

- The water depth is h, the submerged depth of the floating body is 0.4h, the length is 2h, the width is h, and the pressure inside and outside the chamber is equal. ($q_2 = 0$)



- The Surge motion amplitude decreases as the frequency increases; the second resonance frequency is generated due to the influence of the pneumatic chamber, and its frequency moves to high frequency and the amplitude decreases as the internal pressure of the chamber decreases
- Pitch motion amplitude is reduced with mooring cables compared with free floating body; the second resonance frequency is generated due to the influence of the air chamber, and its frequency moves to high frequency with the decrease of the internal pressure of the air chamber and the amplitude decreases

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