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Institute of Naval Architecture and Ocean Engineering Mechanics

Investigation of a ship's hydroelasticity and seakeeping performance by means of large-scale segmented self-propelling model sea trials

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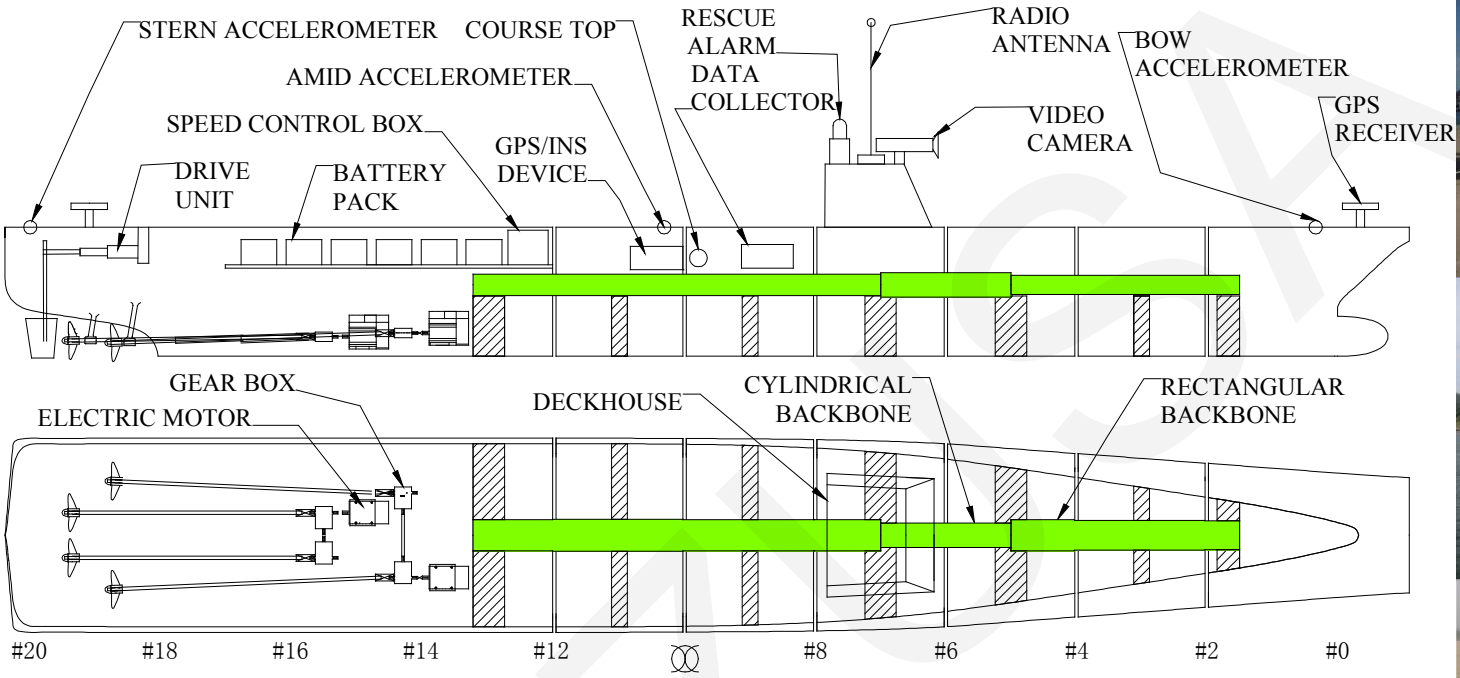
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Paper content overview

The traditional laboratory models for the hydroelasticity and seakeeping performance of ships are tested in calm water and in uni-directional, artificially generated waves. A new alternative to the tank model measurement methodology is to conduct experiments using large-scale models in actual sea conditions. There are many advantages of the new testing method, such as eliminating the need to construct expensive towing facilities, the reduction of scale effects by using larger models, etc. The waves which the model encounters are three-dimensional non-linear sea waves since it is conducted under natural sea states. In this condition the motion and wave load responses of the model are of full non-linear effects. The following work were undertaken in this paper:

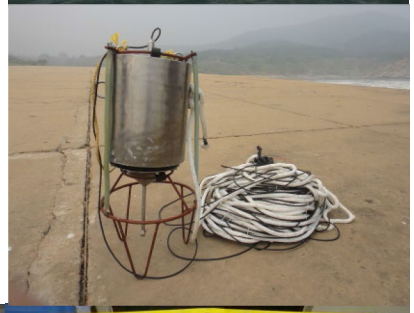
- First, for the hydroelastic and seakeeping performance tests in actual sea states, a self-propelled large-scale ship model is adopted. The designs of the ship model and the testing system are introduced in detail.
- Second, experimental procedures and results are described, including the wave measurement and the model's response results.
- Then traditional tests using small-scale models were carried out in a towing tank, and the results from the large-scale and small-scale model tests are compared.
- Lastly, in-house-developed wave load software is used to calculate the responses of the ship under equivalent sea states for the comparative study of large-scale model tests.

Large-scale model set-up

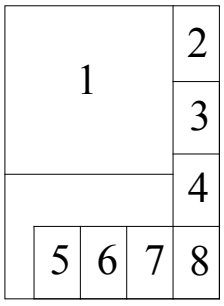








(1) Scheme of model set-up; **(2)** Auxiliary yacht; **(3)** Wave measuring boat; **(4)** Wave buoy; **(5)** Backbone model; **(6)** Electronic apparatus; **(7)** Propulsion system; **(8)** Autopilot device.



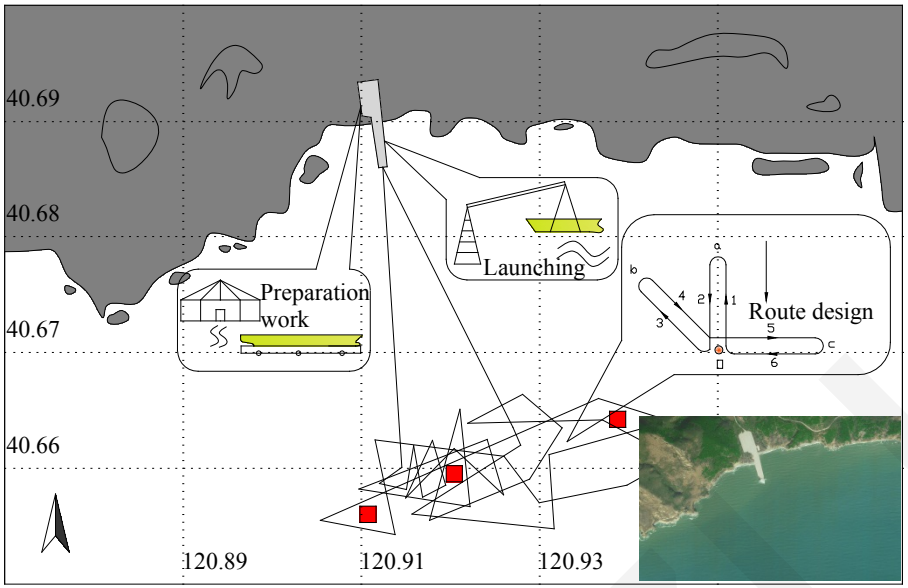








Experimental campaign

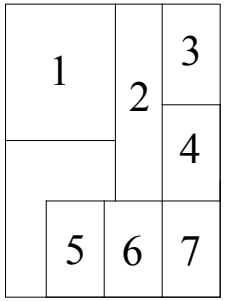








(1) Scheme of field test; **(2)** Navigational software interfaces; **(3)** Model view; **(4)** Launching of model; **(5)** Graduate students at HEU involved in the trial; **(6)** Sailing at sea; **(7)** Controlled by the yacht.







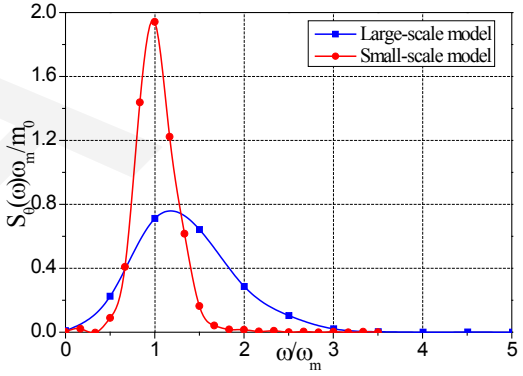


Comparison with tank test



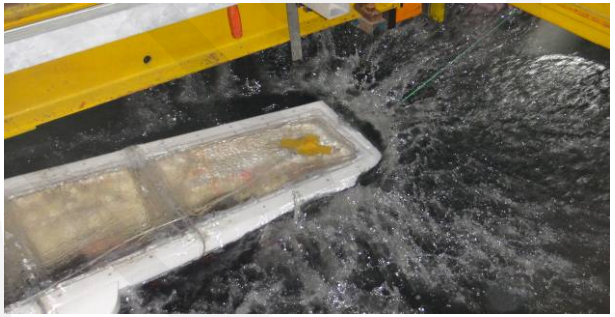
VS.

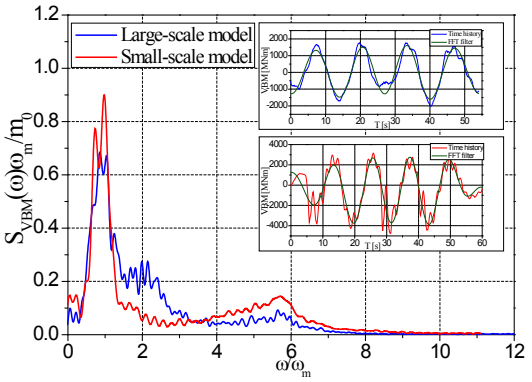






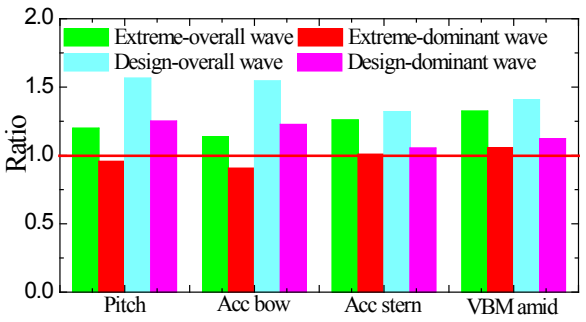
VS.





Main differences between the two tests

Large-scale model	VS.	Small-scale model
At sea		In tank
3D waves		2D waves
Wind, wave & current		Only wave
6-DOF motion		4-DOF motion



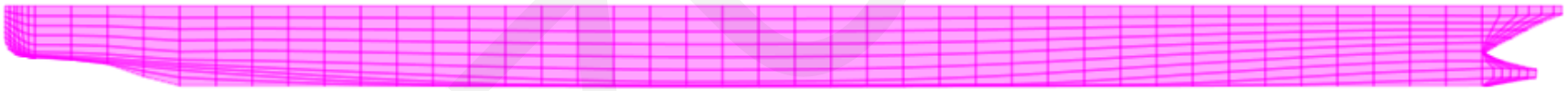
Numerical simulation



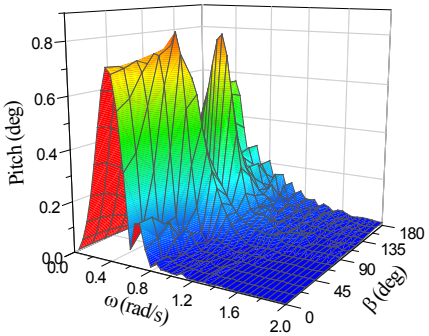
Interface of WALCS software

In-house-developed software named the **Wave Loads Calculation System (WALCS)** is adopted to calculate the responses of the ship under three-dimensional sea waves. The software is based on three-dimensional frequency-domain potential theory.

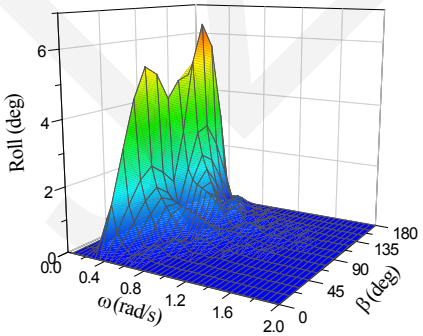
The software is used to calculate the Response Amplitude Operators (RAOs). By combining the two-dimensional wave spectra and the RAOs, two-dimensional response spectra of the ship are obtained. Then the significant amplitude values of motion and load can be obtained as per the response spectra obtained.



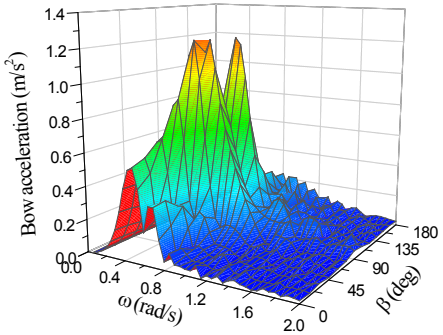
Hydrodynamic mesh model



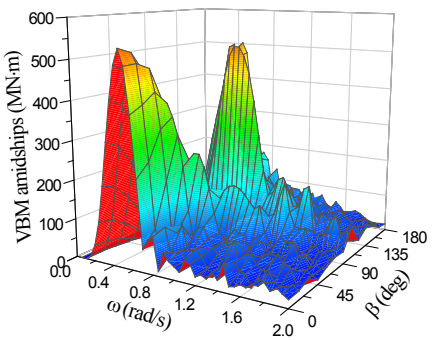
(a) Pitch



(b) Roll



(c) Bow acceleration



(d) VBM amidships

Response amplitude operators of 5 knots forward speed

Conclusions

- By comparing and analyzing the results of the large-scale model test at sea and the small-scale model test in the tank, we find that there exist distinct differences in the model responses even at the equivalent sea state. Longitudinal responses of the ship in the tank environment are more pronounced than when at sea. The longitudinal responses of a ship sailing in head seas are mainly induced by the on-coming waves. However, the roll motion of the ship is largely induced by component waves.
- In this study, it was shown that six-degrees of freedom coupled motions of the large-scale model test are similar to actual conditions of real vessels. The traditional model test under long-crested waves in the towing tank over-estimates the motion and wave load response. However, the results of motions and wave loads from large-scale model tests carried out at sea are more reasonable for ship design and research.
- Compared with the large-scale model experimental results, the linear calculation code WALCS over-estimates 13~18% of the roll and VBM responses of the ship for the directional spreading function case of n=2. The pitch and acceleration results show good agreement between test and calculated results.
- According to the numerical approach, the spreading functions have considerable influence on roll motion, moderate influence on VBM, and mini-mum influence on pitch and acceleration.