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A state-of-the-art large scale model testing technique for ship hydrodynamics at sea

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ABSTRACT

The development of large scale model measurements for ship hydrodynamic tests in natural environment in China is presented in this paper. Previous works of testing large scale monoblock models for seakeeping performance performed by Harbin Engineering University (HEU) are reviewed at first. To verify whether it is acceptable to perform tests near the shore instead of in deep-ocean, coastal waves were measured at different locations in the Bohai Sea and the Yellow Sea of China, and were compared with theoretical spectra. Then, a description of large scale model set-up, testing equipments, and experimental procedure regarding the segmented self-propelled model project is introduced and some typical results obtained from a recent sea trial are presented. Moreover, testing results by a corresponding small scale model in a laboratory basin as well as numerical results are compared with the large scale model experimental results to validate that the proposed testing method is reliable. Finally an overview of the ongoing large scale model laboratory plan and its future development directions is prospected.

1. Introduction

Model testing of ships plays an important role in the prototype design stage and also can be used to verify numerical predictions of ship hydrodynamic behaviors (Hirdaris and Temarel, 2009). Generally, there are some disadvantages of the classical hydrodynamic tests performed in laboratory basins. The models are usually restricted to be towed in two-dimensional, artificially generated waves. Another aspect is that the scale effects and boundary effects are pronounced when performing relatively small scale model tests in restricted laboratory basins.

To address these issues, state-of-the-art testing measurements are performed by naval architects. For example, large or full scale ship measurements are carried out in natural environment, and the relating techniques were highlighted in the reports of ITTC (2008, 2011). As is well known, the advantages of performing tests in natural environment are obvious. The testing environments are large, open and realistic enough, and scale effects can be reduced by using large or full scale ships. On the other hand, these testing approaches avoid the construction of large and expensive towing facilities.

Real ship sea trial is the most reliable testing method which provides valuable data for what happens on ships. Lee et al. (2010) used a hull stress monitoring system to record loads of an 8063 TEU container carrier. The Vertical Bending Moment (VBM) components in severe seas and the corresponding statistical characteristics were studied. Andersen and Jensen (2014) recorded the VBM amidships of a 9400 TEU container ship in rough seas when in a storm. Whipping and slamming loads were studied in particular.

The cost of real ship sea trial is enormous, and therefore make it not a general testing method for scientific research. Moreover, the severe waves acting on ships may result in irreversible damage to ships as well as risk the lives of the crew. It is also hard to achieve testing schemes in high seas since the weather is not controlled and it may take an extremely long time to wait for the high seas (Shi, 2007).

Based on the above situation, tests are carried out in natural environment by using large scale models. In this field, remarkable progress has been made by some European researchers. Measuring procedures for seakeeping performance by large scale models at sea was presented by Grigoropoulos and Katsaounis (2004). The model was designed as man-steered and was propelled by two motors. Coraddu et al. (2013) studied the asymmetric propeller behavior of a twin screw ship model by means of a large free running model, about 7.2 m long, in a flat lake. A full scale measurement of a sailing yacht with length overall 9.99 m was developed and performed by Fossati et al. (2015). The reason that the yacht dimension was defined in 10 m is that navigation document is not needed in this case according to Italian regulation. The US

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navy developed a large scale model of DDG-1000 with a scale ratio of 1:4. A series of tests were conducted and the human factors related to its greatly reduced crew size were simulated based on the model (Quintana et al., 2007).

In this paper, an overview of the development of large scale model tests in China is presented. In the year 2006, the Institute of Naval Architecture and Ocean Engineering Mechanics (INOM) and the Environment Adaptability Research Center of Ships (EARCS), both of which are at Harbin Engineering University (HEU), collaborated and made the first step of testing large scale models in natural environment in China. The large scale model project was initially proposed and sponsored in the Chinese 11th Five-Year-Plan. The project involved the investigation of seakeeping performance of two large scale monoblock models. A series of sea trials were performed using two models during years from 2006 to 2009.

Five years later, with the improvement of testing techniques and laboratory facilities, INOM developed a large scale segmented model for ship hydroelasticity tests in the year 2014. The project was aimed at investigating the nonlinear wave load behavior of ship in actual sea waves. Several sea trial measurements were successfully carried out near the shore in Huludao Harbor of China by INOM in October 2014 and August 2015. Measurement details of the large scale segmented model are introduced in this paper.

According to Chinese ship organizations and community, in the future more and more ships will be tested by large scale model before final construction. Although testing large scale model at sea avoids the construction of large and expensive towing tank facilities, the transportation fee of large models, testing equipments and a team of testing staff is a cost issue, especially for research institutions located inland. Moreover, the long distance road transportation may induce some unexpected effects on the assembled model, such as deformation or damage of the model. In order to address these issues and enhance operational efficiency, an experimental base was built in Qingdao city by INOM. This is reported in Section 7.

2. Review of previous work for seakeeping tests

In this section, a brief review of the authors' previous works with large scale models seakeeping tests is reported. This laid the foundation for the recent project of testing a segmented model for hydroelastic and seakeeping behaviors at sea.

2.1. Background

According to modernized navy requirements, the development of high seakeeping performance stealth monohull was of great necessity. High seakeeping performance of stealth hybrid monohull was required to be developed in this project. The project was mainly aimed at achieving the following two targets:

- Develop a kind of high seakeeping performance stealth monohull of deep-V section, which has better seakeeping performance compared with the classical round bilge monohull of equivalent displacement.
- Develop a novel testing technique and numerical calculation tool of seakeeping response for ships under severe short-crested sea waves.

2.2. Coastal wave research

As a matter of fact, sea trials of large scale models are restricted to be performed near the shore for mainly safety reasons. However, coastal waves in sheltered waters are slightly different from those of deep-ocean, where real ships sail. Large scale model tests were planned to be conducted about 5 km distance away from the beach as a compromise between the potential risks and the experimental requirements.

The validation of whether it is reasonable to conduct tests in coastal waves instead of deep-ocean was one of the key points before model tests. For this purpose, several measurements of coastal waves were carried out at different sites in the Bohai Sea and Yellow Sea of China in particular. Four testing sites (see Fig. 1),

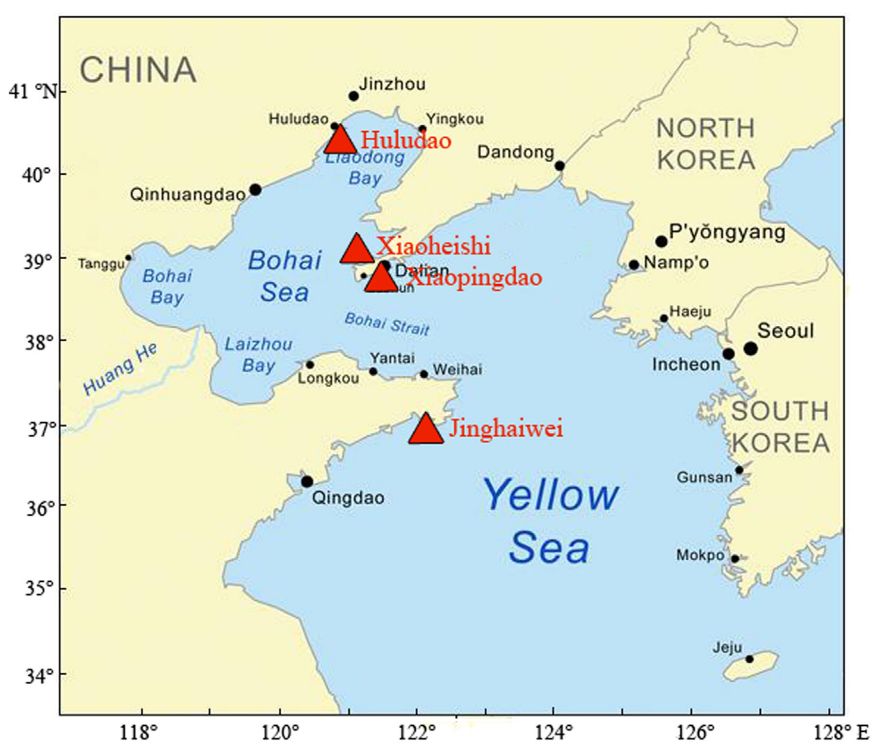

Fig. 1. Locations of coastal wave measurements.