ANALYSIS OF SHIP DEFORMATION UNDER SAILING

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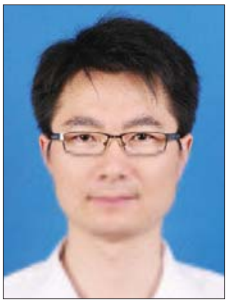

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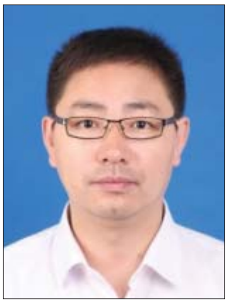

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Abstract. With the help of the three-dimensional potential flow theory and the hydrodynamic analysis of the loaded ship, the wave pressure distribution and the design wave parameters of the ship under loading conditions have been analyzed. Using the method of AQWA and ANSYS co-simulation, the stress level, stress distribution and deformation of the whole ship under loading conditions are obtained. The numerical analysis results can provide an effective basis for the assessment of ship navigation safety.

Keywords: ship structure; whole ship strength; ship deformation.

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Problem statement. With the rapid development of global trade, the size and technical parameters of self-propelled deck barges have been increasing. The development of large-scale ships has led to weakening of the local rigidity of the hull and obvious deformation of the ship itself. When the ship is sailing, the hull will be deformed by the impact of the waves. In particular, as an example of large-scale ocean-going transport, the self-handling deck barge has long distances for navigation, long time of sailing and complicated environment variables. It is of great significance to consider the effect of deformation in order to ensure the safety of large-scale ocean-going vessels. In the hull structure design, the longitudinal strength is an important indicator, and the use of a real ship test is the most accurate way of obtaining it. Due to the complicated structure of the hull, the hull strength test on a real ship is a sophisticated and laborious problem requiring tremendous financial and human resource expenditure. Thus, the use of theoretical calculations of the hull longitudinal strength is a relevant, realistic and feasible method. The traditional method of the hull beam theory discriminates the total intensity. With the emergence of the finite element method and the rapid development of computer hardware and software technology, they have been applied to this sphere, and the whole ship finite element analysis could be performed. At present, the finite element strength analysis of the whole ship is widely implemented to verify the strength of the ship structure theoretically in the most accurate and efficient way.

BASIC MATERIAL

1. Marine meteorological parameters

Using the information on the conditions of the route, season and period of navigation of the ship, the worst parameters of marine meteorological environment can be obtained. The wave height is 5.9 m and the peak frequency is 8.5 – 14.0 Hz.

2. Ship hydrodynamic analysis

In order to obtain the design wave parameters of the ship in the set route, the hydrodynamic model of the ship is established by means of AQWA software using the three-dimensional potential flow theory, as shown in Fig. 1

According to CCS Rules for Construction of Domestic Navigation Vessels, the direction and frequency of the design wave are obtained from the curves of the frequency response function of the main load control parameters at different heading angles of the regular wave [1].

The wave direction of the equivalent design wave is the wave direction at which there occurs the maximum frequency response function of the main load parameter.

Frequency is calculated from the frequency response function that determines the main load control parameters to reach the extreme wave angle frequency ω_a. The amplitude of the equivalent design wave is determined by the long-term forecast extreme value of the load parameter and the peak value of the frequency response function, which is calculated as follows:

$$a_w = L_j / A_j, \quad (1)$$

where a_w is the design wave amplitude, m; L_j is the long-term forecast value of the main load control parameters, the probability level of 10 – 8, shown in Fig. 2; A_j is the extreme value of the main load parameter; j is the main load control parameter number, such as j = 1, which stands for vertical wave bending torque.

The ship's hydrodynamic analysis and the design wave method have been applied to obtain the design wave parameters provided in Table 1.

3. Whole ship finite element analysis

The establishment of the whole ship finite element model is the basis for its structural strength analysis. This section introduces the main structural features and main dimensions of the ship, briefly describes the entire process of modeling, illustrates the setting of boundary conditions, and finally establishes a finite element model of the ship's entire structure. The features under study: single-aft stern, double-bottom bow, smaller square coefficient, more deck, superstructure, and deck openings. The deck, bottom skeleton, and side frame of the ship are used as the vertical skeleton.

The finite element model of the whole ship was established with the help of ANSYS. The origin of coordinates is taken at the intersection of tail vertical line, mid-longitudinal section and hull outer panel. The x axis is positive along the ship's head and the y axis is positive along the ship's breadth. The shaft along the depth of the vertical direction is positive.

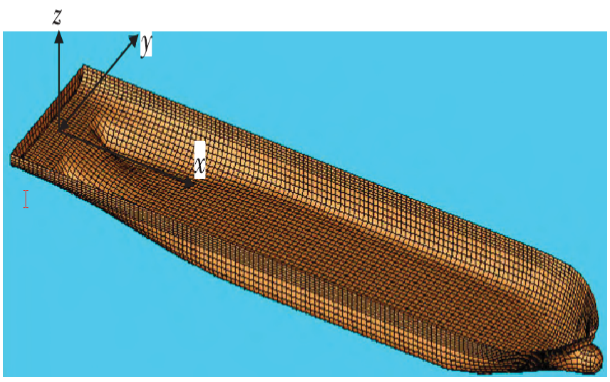

Fig. 1. Ship hydrodynamic model

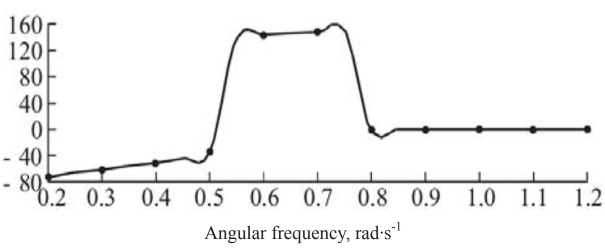

Fig. 2. Relationship between the wave phase angle frequency and the vertical bending torque

Table 1. Design wave parameters

Wave height, m	Angular frequency, rad·s^{-1}	Phase angle, deg
8.45	0.76	–39.0
8.45	0.76	141.0

The scope of the model is the structure of the whole ship, and the small components such as the longitudinal keel are reasonably simplified. The grids are arranged according to the CCS Rules for Classification of Sea-going Steel Ships of China Classification Society [2], as shown in Fig. 3.

4. Calculation results and analysis

Taking into account its actual state, the structure of the whole ship is divided into the following types according to the thickness of the construction:

– shell and shell unit, including the deck, side shell and bottom plating, inner bottom plating, bottom stringers, hatch coaming, longitudinal bulkheads, transverse bulkheads, stiffeners, strong frames, longitudinal bimodal platforms, etc.

– beam elements, such as longitudinal and transverse members on board and stiffeners on watertight bulkheads, incorporated into the grid boundary of the plate element;

– rod elements, such as stringer, rib, beams and other strong components on the wing, struts, etc.; quality point unit, adjustment of the weight distribution.

Under the established route and known loading conditions, the maximum sag deformation of the ship occurs in the vicinity of the ship, being equal to 31.78 mm (see Fig. 4).

The maximum mid-arch deformation also occurs in the vicinity of the ship, near the mid-ship; it makes up 61.339 mm (see Fig. 5).

Overall, under the four threshold conditions, the entire ship is subject to considerable bent or twisted deformations. As shown by the simulation results, the deformation and stress characteristics of the hull are almost equivalent to the beam as a whole.

From the perspective of each structure, the superstructure does not participate in the longitudinal deformation; as a whole, the stress and deformation are small. Meanwhile, the deck is subject to the longitudinal deformation, affected by greater stress.

The areas with high stress are mostly concentrated in the stern of the hull, since it is associated with a large share of the total longitudinal moment or total torque. Overall, the stress level at the bow of the ship is relatively small.

There is also a phenomenon of local stress concentration caused by the fact that the superstructure cannot participate in the longitudinal deformation. As a result, the part of the superstructure connected to the main deck is deformed forcibly, resulting in greater stress.

CONCLUSIONS. In order to ensure that the ship has a sufficient safety margin during operation, the strength of the whole ship must be evaluated prior to sailing. In this paper, after the design wave load is determined and the finite element model of the ship structure is established, the direct calculation based on the design wave method is applied to evaluate the whole ship's strength under loading conditions. The calculation results show that the total strength of the ship meets the safety requirements under known loading and navigation conditions.

External forces affecting the ship (gravity, hydrostatic pressure, etc.) are easy to cause draft conditions. The wave load is difficult to determine. The accuracy of the wave load calculation directly defines the accuracy of the calculation of the ship's structural strength. Therefore, it is very important to predict the ship wave load correctly and reasonably. One of the viable indicators determined by the law is the maximum wave load that a ship may experience throughout its service life. If the ship is not destroyed under this load, the ship structure is regarded as safe. However, due to various navigational environmental conditions and random operational situations, it is difficult to give accurate estimates of the maximum wave loads that may occur during the entire life of the ship. Therefore, the issue requires further research elaboration.

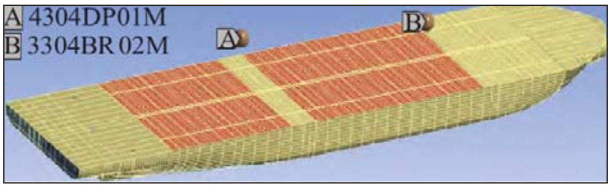

Fig. 3. Network partitioning model

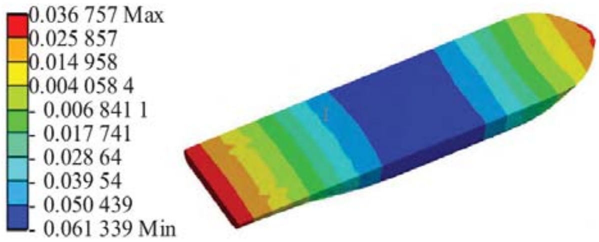

Fig. 4. Middle vertical deformation results

Fig. 5. Mid-arch deformation results

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