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The effect of trimming and sinkage on the trimaran resistance calculation

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Abstract

The clam water resistance as well as the resistance components of a trimaran test model with and without appendage is calculated by CFD method in the different conditions, taking viscous effect and the free surface into account, in order to investigate the effect of trimming and sinkage on the resistance calculation. The viscous flow field around the trimaran without appendage restrained and free in 6 degrees of freedom is simulated at different velocities, the numerical results of the free model are compared with the test data and show good agreement. The total resistance and the resistance of the main hull, as well as the outriggers are calculated and the details of the flow field are discussed. Then, the numerical results of the free model and the captive model are compared in order to analyse the effect of trimming and sinkage. The analysis of the comparison suggests that some of the resistance components are susceptible to the gesture. After that, the viscous flow field of the trimaran with T-foil is simulated and the total resistance, resistance components as well as the gesture are calculated. The comparison of the numerical results of the free model with T-foil and the experimental data also shows good agreement, and the details of viscous flow field as well as the resistance components are analyzed.

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Keywords: resistance; trimaran; trimming; sinkage; T-foil

1. Introduction

For the past decades, the calculation of the ship resistance was performed while the gesture was assumed invariable. It may be acceptable for some low velocity vessels, but irrational for some high speed ship, the sinkage

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and trimming of which are variable along with the velocity. Varyani [1] paied attention on the squat of high speed craft in 2006, Carrica [2] developed a single-phase level set with dynamic overset grids method to predict the motion in 2007, these mean the gesture of the vessel begin to attract the researchers. Gourlay (2009) [3] studied the sinkage and trimming of two ships passing each other on parallel courses, Chong-ben (2011) [4] predicted the resistance of high speed vessels while taking gesture into account, Carrica (2011) [5] calculated a self-propulsion free to sink and trim container ship in head waves. These studies mean the prediction of the sinkage and trimming is used in a wide range of research. Then, some researches [6,7] show that the gesture is more important in resistance calculation. As trimaran is a slender fast ship appeared in recent years, the research about the gesture of trimaran is a hot spot, not only on the clam water resistance [8-10], but also on the wave resistance [11,12]. Meanwhile, the research on T-foil [13,14], which is a useful appendage in mitigating trimaran motion, is performed step by step. But the researches about the trimaran in the clam water had not obtained the effect of the gesture on the resistance, and the reason of the effect. The investigation of the T-foil ignored the effect of the vessel, and did not involve the conditions of clam water.

In the present paper, the clam water resistance as well as the resistance components of a trimaran test model with and without appendage, free and restricted in 6 degrees of freedom is calculated by CFD method in different conditions, taking viscous effect and the free surface into account, in order to investigate the effect of trimming and sinkage on the resistance calculation of the trimaran with and without appendage, analyze the reason of the effect.

2. Model and method

The length, the beam, and the draught of the main hull of the numerical model are 3.60 m, 0.28 m, and 0.13 m. The length, the beam, and the draught of the outrigger are 1.25 m, 0.05 m, and 0.04 m corresponding. The displacement of the model is 75.2 kg, the scale ratio is 27.5, and the distance between the central longitudinal planes of the main hull and the outrigger is 0.42 m. In order to investigate the effect of T foil on the hydrodynamic performance of trimaran, a T foil is fixed at the bow of the trimaran latter. The T foil is composed of a hydrofoil and a strut, both of which have a NACA type cross section. The chord length of the longitudinal section of the hydrofoil is 72.0 mm, the chord length at the tip is 54.0mm, and the wingspan of the hydrofoil is 144.0 mm. The attack angle of the T foil is 0 degree, and the length of the strut is 37.5 mm. The test model and the underwater part of the numerical model are shown in Fig. 1 and the numerical model of the T foil is shown in Fig. 2.

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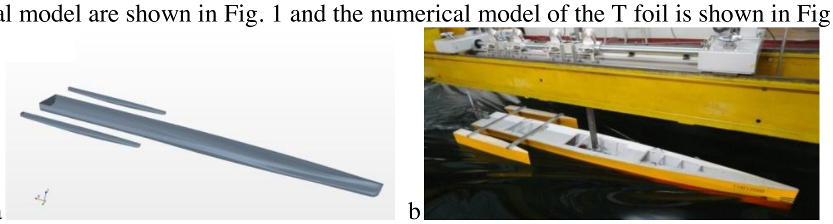
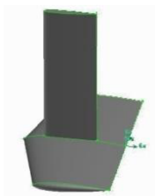

Fig.1. (a) Numerical model (under water part); (b) test model. Fig.2. T-foil.

The T foil is fixed at the 19th station, which is close to the bow and 1.62 m away from the middle of the ship model. The upper surface of the T foil is 15.1 mm under the base plane. The numerical model and the test model of the trimaran with T foil are shown in Fig. 3.

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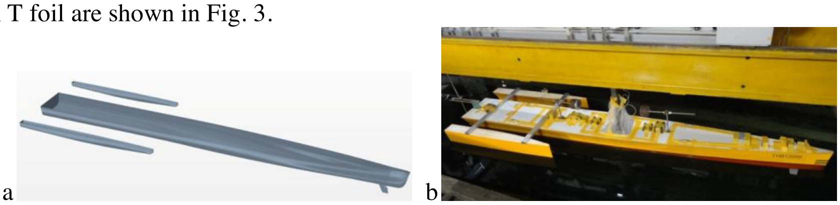

Fig.3. (a) Numerical model (under water part); (b) test model.

The viscous flow field around the trimaran with and without T-foil is simulated by the same mesh generation method in order to eliminate the difference caused by mesh generation, and about 1.93 million structural grids are used to discretize the flow field. $k-\omega$ SST turbulence model, first order upwind difference and VOF method are used. The velocities of the trimaran in the clam water are 0.500, 0.700, 0.900, 1.177, 1.766, 2.550, 2.943, 3.531, 3.924 m/s, and the F_r numbers are 0.084, 0.118, 0.151, 0.198, 0.297, 0.429, 0.495, 0.594, 0.660 correspondingly.

The experiment is performed in the towing tank of Harbin University. The length, width and the depth of the towing tank are 108.0 m, 7.0 m and 3.5 m. The carriage is controlled by computer, and the velocity range of the carriage is 0.100-0.650 m/s. The surging and rolling of the model is restrained in the experiment.

3. Trimaran without T-foil

The resistance of the captive trimaran model and the free trimaran model are calculated, the numerical results are compared with the experimental data in Fig. 4.

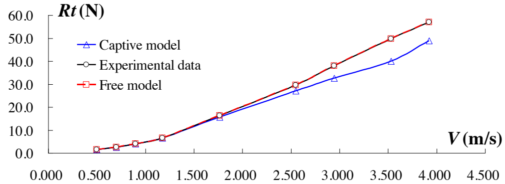

Fig.4. Comparison of the clam wanter resistance of the trimaran without T-foil.

R_t is the total clam water resistance of the trimaran without T-foil. It is shown in Fig. 4 that the calculated resistance of the trimaran model free in 6 degrees of freedom agrees with the experimental result much better than the captive model, especially at high velocity, it is suggested that the gestrue is important for the simulation of the trimaran without appendage. The sinkage and the trimming of the trimaran without appendage free in 6 degrees of freedom are also compared with the test data in Fig. 5.

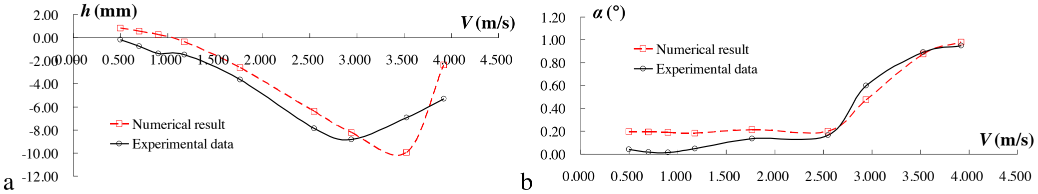

Fig.5. Comparisons of (a) sinkage; (b) trimming.

h represents the sinkage of the trimaran and α represents the trimming angle. The calculated sinkage and trimming are close to the experimental result, the amplitude and the trend agrees with the test data. But it is shown that there is a discrepance between the two results at low velocity, for the sinkage and trimming at low velocity are quite small, which are hard to measure and calculate, and may be a much finer grid is needed to calculate the tiny variation of the viscous flow field in order to improve the calcualtion precision. It is suggested that the total resistance is underestimated if the gesture of the vessel is ingored. In order to investigate the details, the increased resistance and lift force of main hull and outrigger are also compared in Fig. 6.

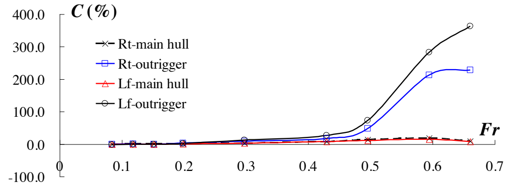

Fig.6. Comparisons of resistance and lift force increment rate.

C is the increment rate of the resistance and lift force. It is shown that, the resistance and the lift force of the main hull are increased about 18.0% and 15.5% at the maximum velocity, but the resistance and the lift force of the outriggers are increased more than 2 and 3 times at the same velocity, which means the effect of the gesture is more important for the outrigger than the main hull. The wave patterns at V =3.531 m/s ($F_r \approx$ 0.594) on the outrigger are shown in Fig. 7 in order to compare the effect of the gesture.

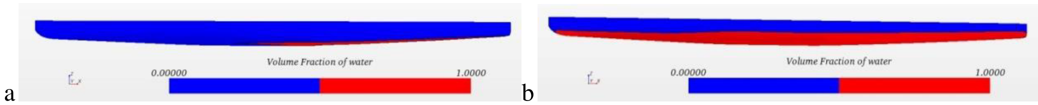

Fig.7. Comparisons of the wave patterns on (a) outrigger (captive model); (b) outrigger (free model).

0 reprents the phase of air, and 1 represents the phase of water. It is shown that the water line of the free model is higher than the captive model, which means the displacement of the free model is increased by sinkage and trimming.

4. Trimaran with T-foil

The clam water resistances of the captive and free trimaran model with T-foil are calculated, and the results are compared with the test data and shown in Fig. 8.

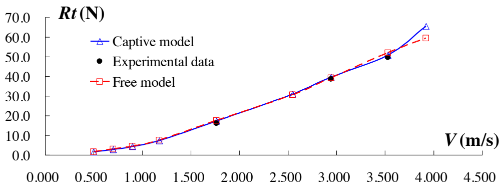

Fig.8. Comparison of the clam wanter resistance of the trimaran with T-foil.

R_t is the total clam water resistance of the trimaran with T-foil. It is shown in Fig. 8 that both the resistance of the captive model and the free model are close to the experimental data, except in the condition of V =3.924 m/s, in which the resistance of the captive model is larger than the free model clearly. The sinkage and trimming of the free model with T-foil are compared with the experimental data in Fig. 9.

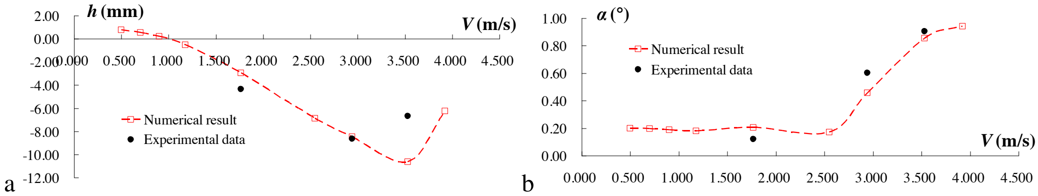

Fig.9. Comparisons of (a) sinkage; (b) trimming.

It is shown in Fig. 8 that the numerical results of sinkage and trimming agree with the test data, but the sinkage at the velocity equals to 3.531 m/s is larger than the experimental data, which is different from the trimaran without T-foil. The increment of the resistance and lift force of the main hull and outrigger are compared in Fig. 10.

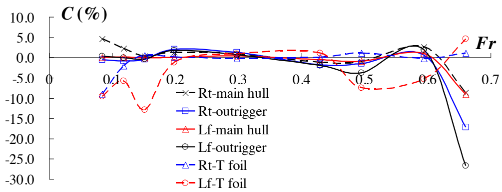

Fig.10 Comparisons of resistance and lift force increment rate

C is the increment rate of the resistance and lift force. Comparison of the resistance and lift force increment rate of the captive model and free model in Fig. 10 suggests that there is no obvious difference between them, and the changes of the components are not more than 10%, except the condition of V =3.924 m/s, at which the force acting on the outriggers is more susceptible by the gesture. For the trimaran with T-foil, the effect of the gesture is not remarkable. The wave patterns on the main hull at V =3.531 m/s (F_r ≈0.594) are shown and compared in Fig. 11.

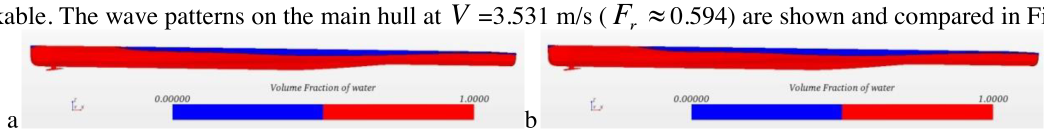

Fig.11. Comparisons of the wave patterns on (a) main hull (captive model); (b) main hull (free model).

It is shown in Fig. 11 that the difference of the wave patterns on the main hull in the conditions of captive and free model is not remarkable, but it is still necessary to take the effect of sinkage and trimming into account.

5. Conclusion

In the present paper, a trimaran in the conditions of free and restricted in 6 degrees of freedom with and without appendage is simulated, and the total clam water resistance, lift force, sinkage and trimming are calculated and compared with the experimental data. The analysis of the results allows the following conclusions:

(1) The scheme used in the present paper, which is composed by mesh generation method, turbulence model, and discretization scheme, is suitable for the calculation of the trimaran with and without T-foil. The agreement of the numerical results and test data reveals the efficiency of the proposed procedure in this study.

(2) For the trimaran without appendage, the comparison and analysis suggest that, it is necessary to take sinkage and trimming into account for the simulation, and the change of the gesture is caused by the lift force acting on the hull.

(3) For the trimaran with T-foil, the difference between the numerical results of captive modle and free model is not remarkable, but it does not mean the sinkage and trimming is not important, it is only suggestted that the effect of the gesture is not obvious for the trimaran with T-foil mentioned in the paper.

A further high precision method is needed to investigate the effect of sinkage and trimming on the viscous flow field around the hull, and different varieties of vessels should be included, in order to obtain some integrated rules.

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