

The CFD Numerical Simulation of H-Boat

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Abstract. Using commercial software CFD (Computational Fluid Dynamics) analysis of fluid to simulate the H-Boat. Based on the numerical methods, use the VOF (volume of fluid) method to simulate the free surface, and use RNG (Renormalization-group) $k-\varepsilon$ model to close RANS (Reynolds Average Navier-Stokes) equations to get solving. Obtained the ship resistance and waveform graphs of different speeds, compare the drag coefficient obtained by numerical simulation and drag coefficients obtained by the empirical formula, verify the effectiveness of FLUENT fluid analysis in simulation of ship resistance.

Introduction

Since the 21st century, the competition between countries is extending from land to the vast sea, struggle over maritime rights among many coastal countries becomes more sharply. And with the development of national economy, energy supply becomes increasingly nervous, environmental protection requirement becomes increasingly strict, the problem of marine energy consumption is becoming more and more attention [1]. Therefore, countries around the world develop new ship form positively, make the ship meet the requirements of high speed and low consumption. H-boat [2] is a new type of ship, belong to the catamaran, can reach sliding status under a certain speed, reduce the resistance of the ship.

The Design of H-boat Hull Bottom

The three-dimensional model of H-boat is built by rhino software and optimized by MAXSURF software. The basic dimensions are shown in table 1 below.

Table 1. Basic parameters of yacht

Long	Breadth	Depth	Draft	Displacement
13.75[m]	4.7[m]	1.544[m]	0.78[m]	13.0[t]

H-boat including the main hull、 the two wide sheetbody, middle small slots and the two narrow slot on either side, and the knuckle line. The entrance of slot on the bottom is big, the closer to the stern is smaller, so conducive to force air into the bottom. Three-dimensional shape as shown in figure 1.

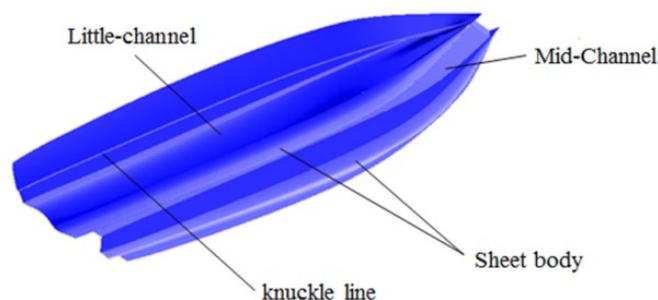


Fig.1 The structure of the bottom of H-boat.

The Numerical Simulation of H-boat

The Partition of The Grid Basin. Import the model into Gambit, meshing, set the scale ratio. H yacht hull is symmetry, consider the analysis time and the performance of the computer, only half of the model is selected to simulate analysis. Import the model and create fluid domain, establish large external basin, use the external domain to reduce the hull volume through minus operation, generate fluid domain. Merging the areas that are not needed and small surface is easy to generate high quality grids. Divide the entrance surface into two parts, the upper is air, the lower is water, interface is the waterplane. Basic basin range (figure 2) is divided according to the length of the ship, the entrance of the water is located in the double length of the ship in the whole basin, the water outlet is located in three times length of the ship in the whole basin, the top is located in the half length of the ship, the bottom of the basin is at the 1.5 times length of the ship under the model.

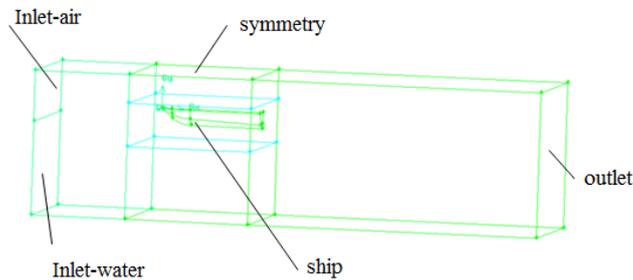


Fig.2 Computational domain of the H-boat.

Definition of Boundary Conditions. Define air velocity inlet, named inlet-air, it is the area above the cutting line of first part of drainage area, there is only air flows into this boundary, flow velocity equals the speed of the ship. Adopt the VELOCITY - INLET type.

Define water velocity inlet, named inlet-water, it is the area below the cutting line of first part of drainage area, there is only water flows into this boundary, flow velocity equals the speed of the ship. Adopt the VELOCITY - INLET type.

Free flow boundary, named outlet, for the unknown flow condition, often adopt the OUTFLOW types.

Define the plane of symmetry, named symmetry, it is symmetry plane of interface at hull longitudinal, there is no mass and momentum exchange inside and outside boundary in this setting, advantageous to the convergence of calculation. Adopt the SYMMETRY type.

Define the hull surface for solid wall, named wall, adopt the WALL type, the rest of the surface will be default for WALL type.

Turbulence Model. This article use the RNG $k - \varepsilon$ turbulence model, through the modification on turbulent viscosity, considering the effect of rotation in flowing and vortex flow^[3, 4].

Result and Analysis

The Friction Drag Coefficient Analysis. Based on the smooth plate frictional resistance coefficient formula, can get more forms of friction resistance. There is famous Schoenherr formula, Prandtl-Schlichting formula and ship model conversion 1957ITTC formula. Schoenherr formula was achieved in 1932 when Schoenherr applied the law of logarithmic velocity distribution, and according to the plate towing test results. When the Reynolds number is from 106 to 109, using simple formula:

$$C_f = \frac{0.4631}{(\lg R_e)^{2.6}} \quad (1)$$

Prandtl - Schlichting applied the above methods, analyzed the approximate formula:

$$C_f = \frac{0.455}{(\lg R_e)^{2.58}} \quad (2)$$

In the 1950 s, an international conference of ship, through calculating the experiment result of the approximate shape model resistance, think that Schoenherr formula can get smaller value than usual at low Reynolds number, then proposed 1957ITTC formula^[5] after the meeting:

$$C_f = \frac{0.075}{(\lg R_e - 2)^2} \quad (3)$$

Using different calculation methods to get the frictional resistance coefficient of boat in different speed, the results are presented in table 2, through the friction coefficient values to analyze the difference between them.

Table 2. Friction resistance coefficient comparison

v [m/s]	Re [10 ⁻⁶]	FLUENT [10 ⁻³]	Schoenherr [10 ⁻³]	Prandtl [10 ⁻³]	1957ITTC [10 ⁻³]
1	1.165	4.933	4.664	4.456	4.357
2	2.330	3.733	3.616	3.835	3.932
3	3.495	3.722	3.504	3.574	3.633
4	4.660	3.456	3.335	3.404	3.441
5	5.825	3.221	3.213	3.279	3.302

Transform the values in table 2 into a graph, it can be clearly observed all kinds of drag coefficient and the direction of the trend. As shown in figure 3.

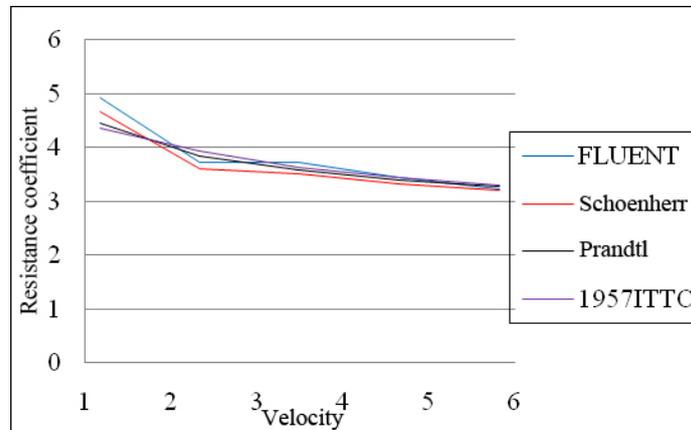


Fig.3 Different resistance coefficient.

It can be observed from above that the viscous resistance coefficient gained by the fluid simulation software and the values gained by using various formula is basically similar, and the value is falling as the Reynolds number rise.

Resistance Value Analysis. Table 3 is total resistance value obtained by numerical simulation of fluid in different speed.

Table 3.Total resistance

Velocity[m/s]	1	2	3	4	5	6
Resistance[N]	18.73	37.42	70.5	89.91	85.32	110.31

Give some conversion to the total resistance value obtained by numerical simulation of fluid in table 3 to get resistance value of real ship. Through analysis and calculation, it is known that since yacht start to the speed slowly growth, resistance increase unceasingly, when the speed reached 27.8 Kn, mean the speed is 14.3 m/s, the ship resistance get largest, then resistance begin slowly decrease. After reaching the maximum, the yacht raise its hull under the action of dynamic lift on the glide surface, wet area is reduced, the water resistance of the hull is lower. When speed is 9.28 Kn, mean 4.7 m/s, the volume Froude number $F_{rV}=1$; Under the speed of 4.7 m/s, the hull is in the displacement type; In the speed of 4.8 m/s to 14.3 m/s, the Froude number is $1 < F_{rV} < 3$, the hull is in a transitional type; when $F_{rV} > 3$, mean that the speed is between 14.3 m/s and 18 m/s, the hull is in the glide type, the most hull is out of the water.

Oscillogram Analysis

The ship can produce waves when driving, the size of the waves is different from the stem to stern, and the size of the waves under different speed is different, too. Stern wave will follow the movement direction of the ship and continuously expand the scope. Wave produced by the hull called ship wave, can be divided into the fore and aft transverse wave and the scattered wave. Usually two shear wave of bow and stern mix in the stern of the ship, make up compound shear wave. Ship in figure 4 to figure 8 is the tail waveform figure when speed is 1 m/s, 2 m/s, 3 m/s, 4 m/s, 5 m/s respectively.

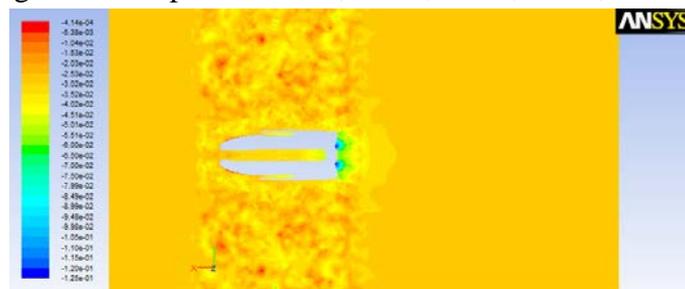


Fig.4 Waveform Graph of 1m/s.

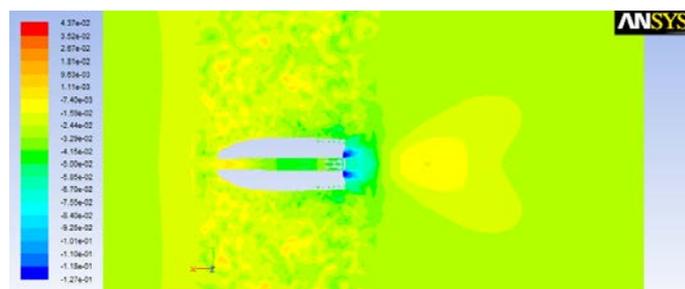


Fig.5 Waveform Graph of 2m/s.

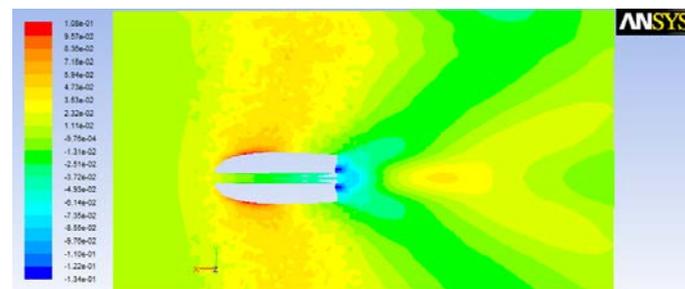


Fig.6 Waveform Graph of 3m/s.

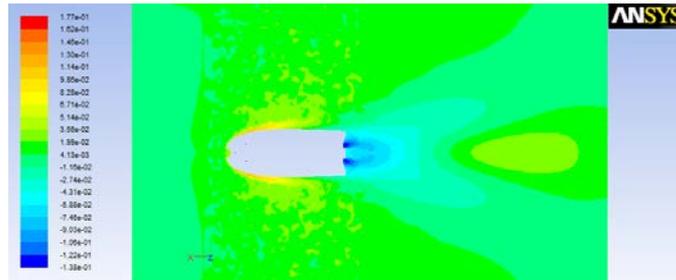


Fig.7 Waveform Graph of 4m/s.

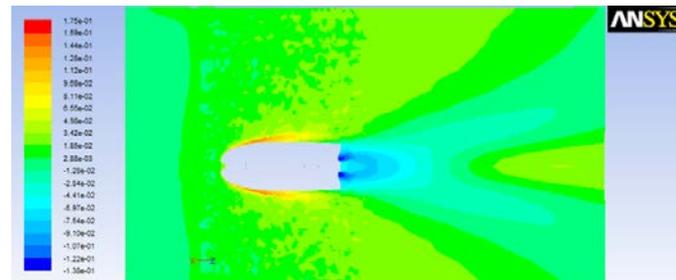


Fig.8 Waveform Graph of 5m/s.

As can be seen by the above: there does not exist the shallow water effect in navigation (When divide basin, the distance between model basin and the ship bottom is larger), the bigger speed, the wavelength of ship wave longer. For low speed ship, the proportion of the wave-making resistance in total resistance is almost can be ignored, but for the high speed ship, the ratio of wave-making resistance will account for a lot. The size of wave-making is related to the type and speed, when the speed is in the 4 m/s and 5 m/s, the scattered wave at the back of the hull is reduced, the reason is that the dynamic lift of the bottom air will lift the hull up, reduce the contact with water, so as to reduce the wave drag. With the increase of speed, the stem wave became largest at 3 m/s, the corresponding wave value is larger relative to other speed.

For the H-boat with narrow slot, fully immersed in water at low speeds, be in a state of gliding at high speeds, the top of the slot way is at the condition filled with air, come into being a air lubrication layer. Under the effect of air lubrication, the hull can reduce the cushion and vibration, decrease the function of stern wave.

Conclusion

1、 The results showed that a state of gliding could be gotten in high speed condition, which could reduce the ship resistance and improve the running speed effectively.

2、 Comparison between the drag coefficient which obtained by numerical simulation and obtained by the empirical formula, the results showed that the simulations of ship resistance were correct and effective.

3、 From the perspective of the waveform figure of the hull, the basin should be widened and extended.

The numerical simulation of the ship resistance has wide practical value. Using the CFD simulation of ship resistance is beneficial to speed up the ship design and ship form optimization, can effectively improve the efficiency of research and development and reduce the cost. The resistance analysis of the H new high-speed yacht both has the theoretical guiding significance and engineering practicability, and provides an efficient method for the new ship form optimization improvement.

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