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Research Article

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Viscous flow field analysis of sections of hybrid monohull with semi-submerged body under the bow

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ABSTRACT

The viscous effect of semi-submerged body fixing under the bow of the hybrid monohull makes it difficult to calculate the hydrodynamics of the ship, and the characters of viscous flow field of the sections have great influence on the form optimization of the hull aiming at the improvement of speedy and seakeeping performance. In this paper the hydrodynamic coefficients of the hull were calculated by means of RANS method. The influence of different turbulence models to the calculation results for hydrodynamic was discussed, and this result was compared with the one calculated by means of source/dipole mixed-distribution method and analyzed. Furthermore, the characters of viscous flow field of the sections for the different turbulence models was also discussed and the paper gave the calculation method applicable to the hydrodynamic coefficients of the hull adding the semi-submerged body by calculation. The research results were valuable to the optimization of hybrid monohulls.

Key words: Hydrodynamic; RANS; viscosity; turbulence model

INTRODUCTION

The viscous flow field analysis of ships has great influence on optimization of hull form and sailing performances of ships especially hybrid monohulls with seme-submerged body[1][2] (see figure 1). The seme-submerged body can product large viscous damping force to reduce longitudinal motions of ships in waves. The viscous force is too large to ignore it, so this makes it difficult to calculate the force accurately if the potential method is used only. RANS method is effective for viscous hydrodynamic calculation and flow field analysis. Therefore, in this paper the hydrodynamic coefficients of the hull was calculated with the viscous flow numerical calculation method and strived to improve the computational accuracy. In this paper a certain hybrid monohull was used as the research object, of which the parameters of main hull were as follows: the length of designed water line of the ship is 85m, the breadth of designed water line is 11m, the designed draft of the ship is 3.2m, and the displacement of the ship is about 1220t. And the parameters of the semi-submerged body were as follows: the length of the body is 16.8m, the maximum breadth of the body is 2.2m, the maximum thickness of the body is about 0.6m, and the total displacement of the body is about 30t.

The hydrodynamic coefficients of the hull were calculated with the 2-D method, and were compared with the 2-D source/dipole mixed-distribution method based on potential theory[3]. The calculation result of hydrodynamic coefficients revealed that, compared to the 2-D potential theory method, the 2-D RANS method can reflect the affect of the viscous effect of the semi-submerged body reasonably.

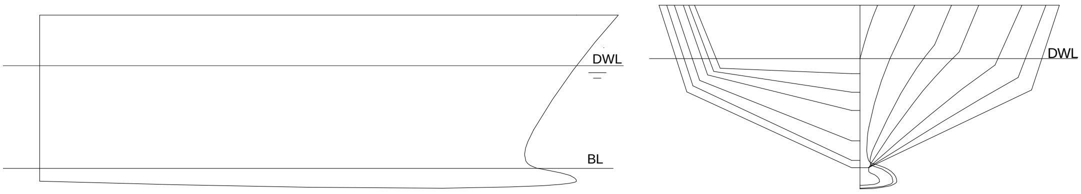

Fig.1 ： Sketch of the hybrid monohull installing semi-submerged body

Experimental procedures

Calculation Model：In this paper the RANS method was used for calculating the hydrodynamic coefficients of the hull with semi-submerged body, and currently the turbulence model used most extensively in the engineering was the two-equation model[4][5]. In this paper the RNG $k-\varepsilon$ model and SST $k-\omega$ model were adopted for calculation. Now we introduce briefly the two turbulence models in the following:

(1)RNG $k-\varepsilon$ model:The standard RNG $k-\varepsilon$ model is the most basic two-equation model, which means introducing the equation on the turbulence kinetic energy, k and dissipation rate,ε. The RNG $k-\varepsilon$ model is the modification of the standard $k-\varepsilon$ model. In the RNG $k-\varepsilon$ model, the small scale motion can be removed systematically from the controlling equation by means of the viscosity item after the big scale motion and amendment to reflect the effect on the small scale motion. The RNG $k-\varepsilon$ model can simulate the high strain rate and the larger curvature flow.

(2) SST $k-\omega$ model ：The SST $k-\omega$ model was developed by Menter, so that the $k-\varepsilon$ model could be used for the outer drainage zone close to the wall with the expectation of improving the application range and accuracy of the $k-\omega$ model. The SST $k-\omega$ model is divided into BSL model and SST model, where, SST model is the modification of BSL model. The advantage of SST model is that it blends the advantage of the standard $k-\omega$ and $k-\varepsilon$, in which, $k-\varepsilon$ model could be used for the area near the wall while $k-\omega$ model can be used for the area out of the boundary layer; and which contains the amended turbulence viscosity formula and considers the effect of turbulence shear stress. SST $k-\omega$ model can stimulate the magnitude of the separation point and separation zone caused by the pressure gradient more precisely.

Calculation of 2-D hydrodynamic coefficients：The viscous modification was conducted to the hydrodynamic coefficients of each transverse section of the hull with semi-submerged body at the bow in this paper, and the unsteady force produced from the heaving motion of each transverse section of the bow was calculated using RNG $k-\varepsilon$ model and SST $k-\omega$ model in calm water respectively. Then the above unsteady force was resolved to obtain the added mass and damping coefficient of each transverse section of the bow[6].

(1)Calculation setting：The transverse sections of stations 0.5, 1, 2 and 3 at the bow were chosen for calculating. The heaving frequency of each section was selected as 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.6, and 2.0 rad/s. To meet the linear assumption, the heaving motion amplitude of the transverse section is selected as 0.02m.

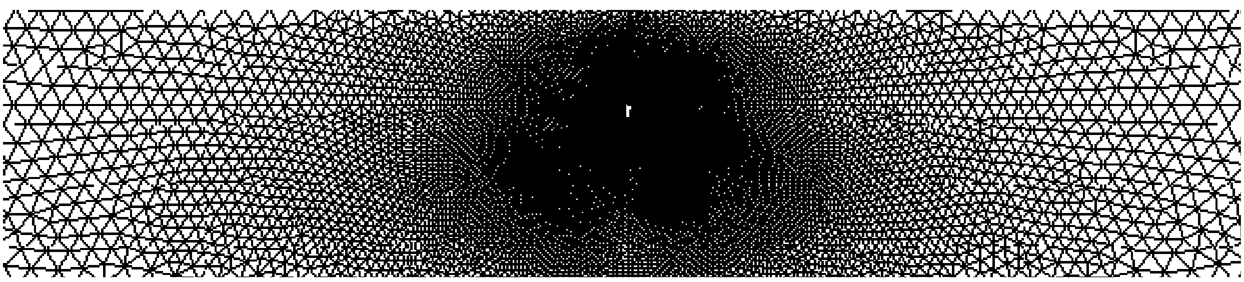

Fig.2： Calculation fluid zone and grids dividing of a section

(2)Calculation fluid zone: The breadth of the zone was selected as two times of the ship length in the left and right board in the width direction of the ship and as between 10 times of the ship draught under water and 2 times above the water at the vertical direction. The unstructured grids were used for the whole zone, and the grids closed to the hull were densed properly and bigger grids were used in the area far from the hull and near the wall. Ultimately, the number of grids of each transverse section was between 40 to 60 thousands. It was demonstrated that the grid number had less influence on the precision of the calculation result. The calculation fluid zone and the grid dividing can be seen in figure 2.

Initialization settings: the discrete way of calculation fluid zone was the finite volume method, which adopted VOF multiphase flow model. And the simulation of turbulence flow adopted the RNG $k-\varepsilon$ model and SST $k-\omega$ model. The heaving motion was simulated by means of dynamic mesh technique.

(3)Calculation result analysis：The unsteady force from the heaving motion of a certain transverse section is shown in Figure 3.

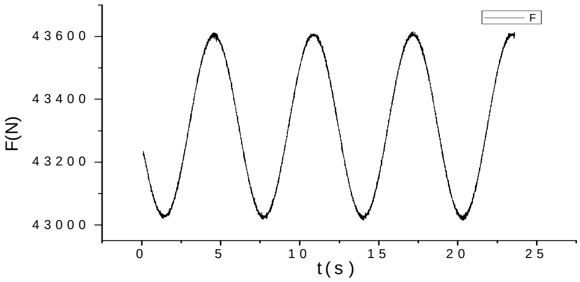

Fig.3 ：The unsteady force from the heaving motion of a certain transverse section

The computed unsteady force was transformed into regular cosine curves by fitting the rules, which was resolved to give the added mass λ_{33} and damping coefficients μ_{33}[7][8][9]:

$$\lambda_{33} = \frac{\rho gBA - F_a \sin\theta_0}{A\omega^2}, \quad \mu_{33} = -\frac{F_a \cos\theta_0}{A\omega} \tag{1}$$

Where, B is the width of waterline of transverse sections. A is the heaving amplitude, F_a is the heaving force amplitude, and θ_0 is the initial phase.

(4)Flow field analysis：In figure 4 to figure 7, the first figures and the second figures are the dynamic pressure distribution of RNG κ-ε model and SST κ-ω model within the 2-D flow field of each transverse sections at the certain moment after 15 seconds heaving motion at the circular frequency ω=1rad/s.

From figure 4 to figure 7 we can see the serious pressure grads near the semi-submerged body and the free liquid surface near the hull. It indicates that the flow field is turbulent.

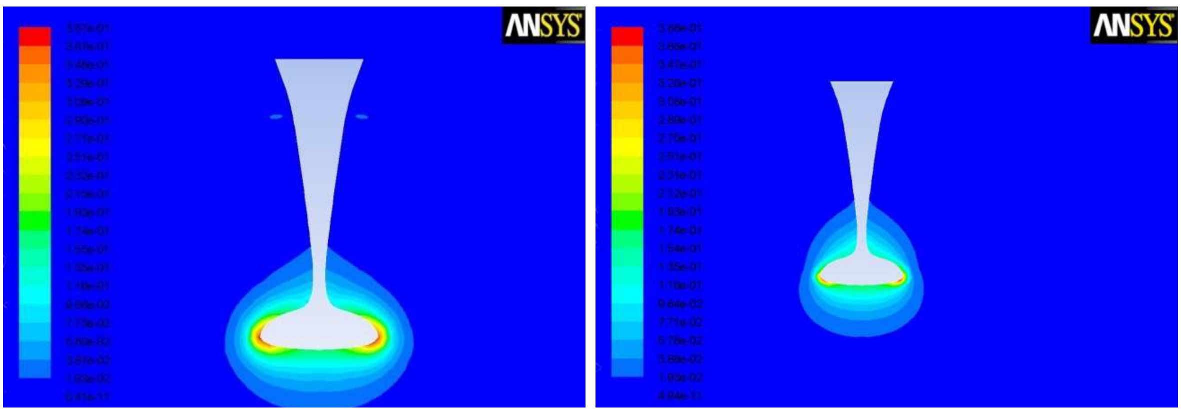

Fig.4 ：Dynamic pressure distribution of station 0.5

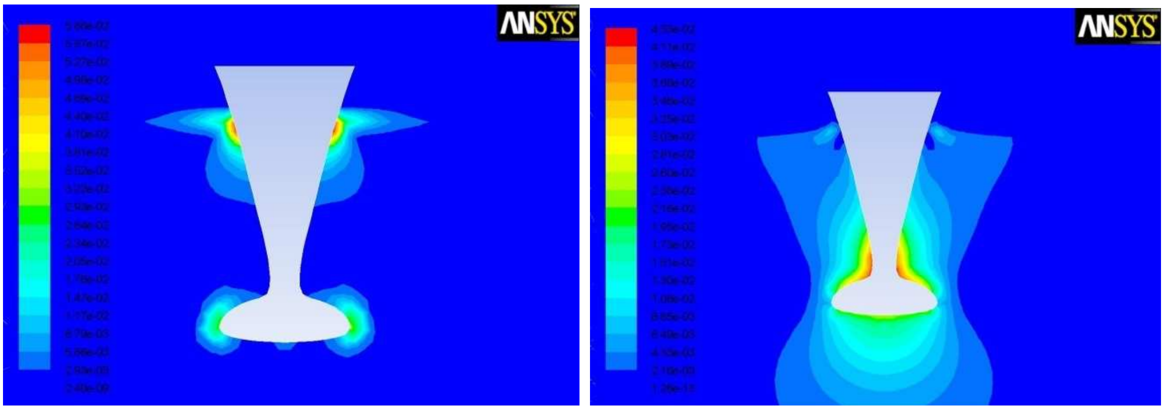

Fig.5 ：Dynamic pressure distribution of station 1

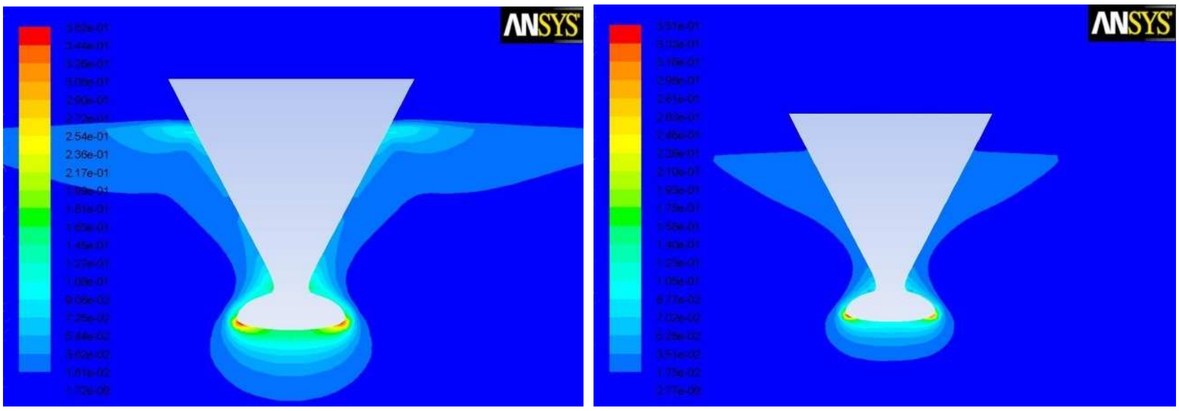

Fig.6 ：Dynamic pressure distribution of station 2

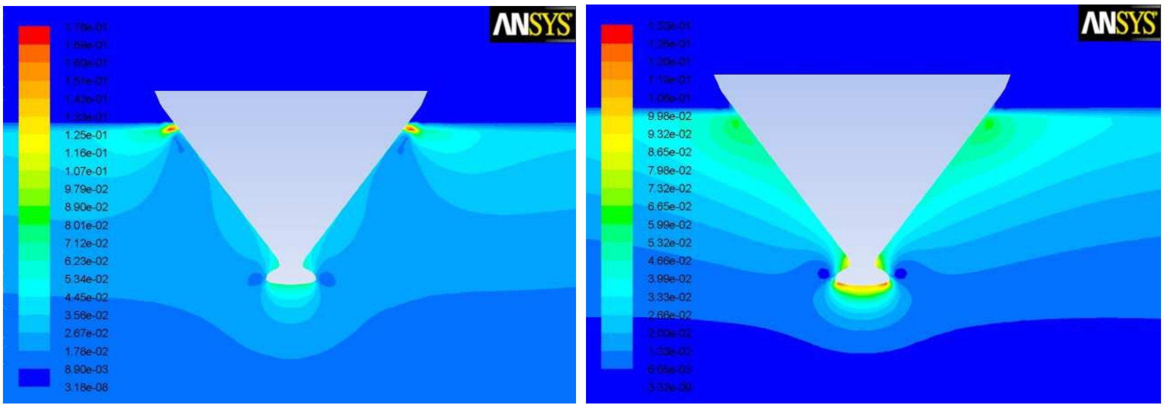

Fig.7： Dynamic pressure distribution of station 3

RESULTS AND DISCUSSION

Analysis of 2-D hydrodynamic coefficients calculation results: After fitting the unsteady force and solving by formula (1), the added mass and damping coefficient of each section was calculated like figure 8 to 15 show.

It can be seen from figure 8 to15 that for the section of the 0.5 station and 1 station, whatever it is the RNG κ-ε model or SST κ-ω model, the calculation results were greater than the result calculated by means of the potential method. Analyze combined with the dynamic pressure distribution of the transverse section revealed that the reason was that the profile curvature of the joint line in the connecting part of the semi submerged body changed very great; while the transverse section made heaving motion, the disturbance to the fore flow field of this kind of ship type was greater than that of the conventional one, and the variation of the flow field was complex and disordered and generated much viscous vortex. The calculated damping force by means of the method based on the potential theory was mainly the wave making damping, while the result of the RANS method contained the wave damping and viscous damping, so the hydrodynamic coefficients calculated with the turbulence model must be different of the results calculated with potential method.

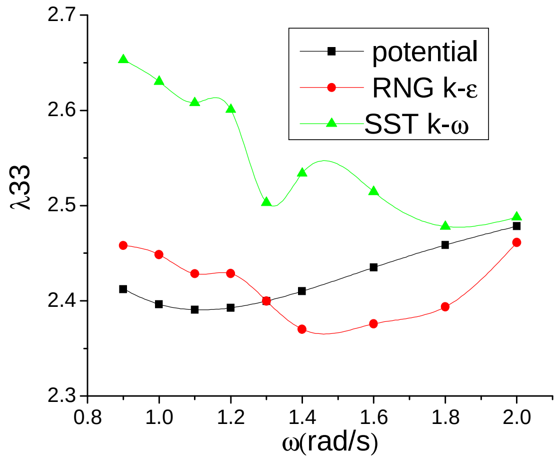

Fig.8 :Added mass of station 0.5

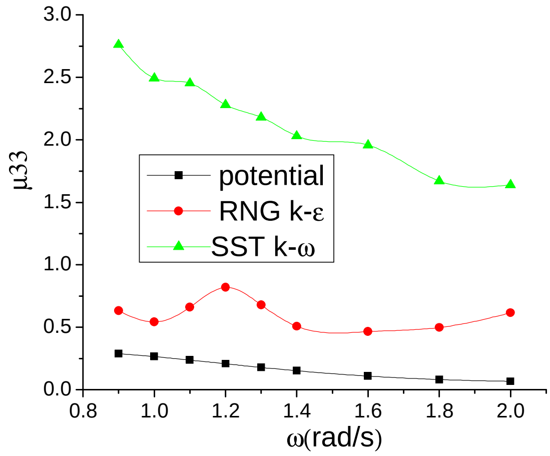

Fig.9: Damping coefficients of station 0.5

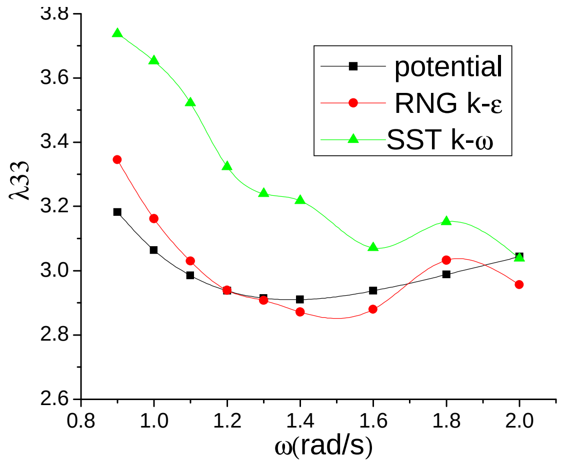

Fig.10 :Added mass of station 1

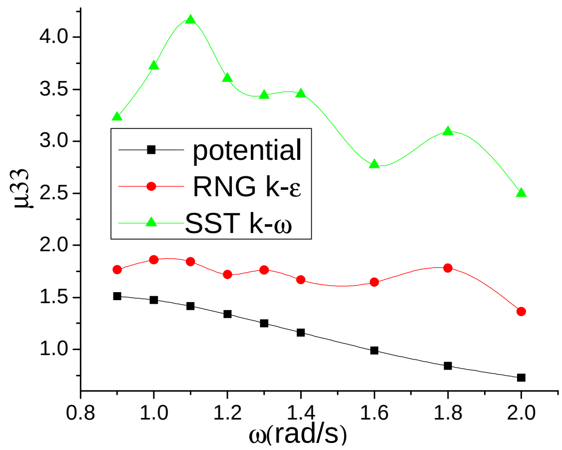

Fig.11 :Damping coefficients of station 1

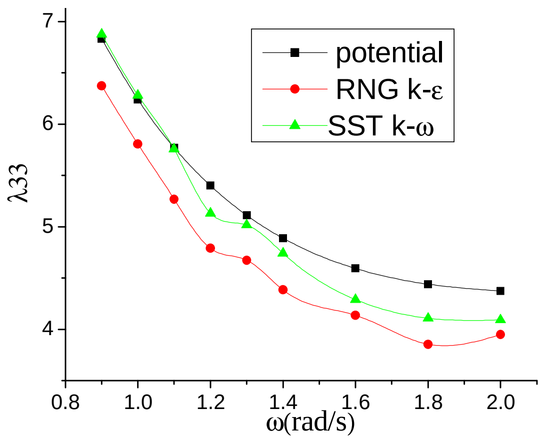

Fig.12 :Added mass of station 2

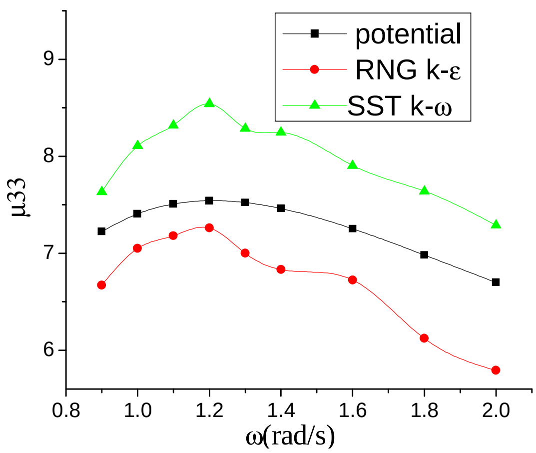

Fig.13 :Damping coefficients of station 2

In the transverse section at station 2 to 3, the results calculated by means of the RNG κ-εmodel were less than those calculated with potential theory, and it was demonstrated that the RNG*κ-ε* model can't fully reflect the viscous effect of the semi-submerged body, so that the calculation results were unreasonable. After analysis, we thought that it was because the calculation condition of empirical formula near to the wall in the selected RNG *κ-ε* model adapted to the turbulence flow with high Reynolds number. While in the flow field in which the lines is comparable smooth, the fluid had less disturbance, the inner laminar flow zone of the wall boundary layer was thicker, the flow was relatively stable, therefore in the area near the wall of the hull, RNG κ-ε model can't reflect the variety of flow field.

Compared to the calculation result of the damping coefficient, both results of added mass got by two turbulence model were close to the results of potential theory, while the calculation value got by the SSTκ-ω model was greater. Meanwhile, during the calculation process we found that the calculation time of the SSTκ-ω model was 1.5 times longer than that of the RNG κ-ε model when calculating the same 2-D sample.

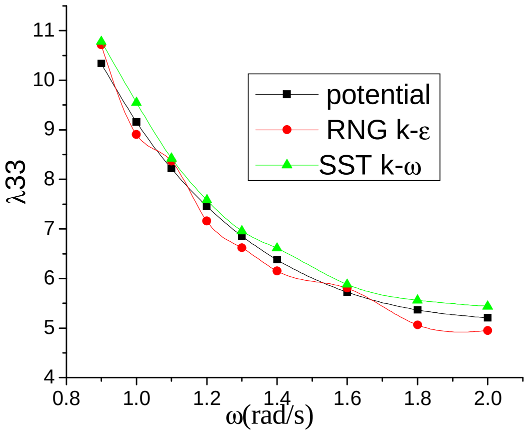

Fig.14: Added mass of station 3

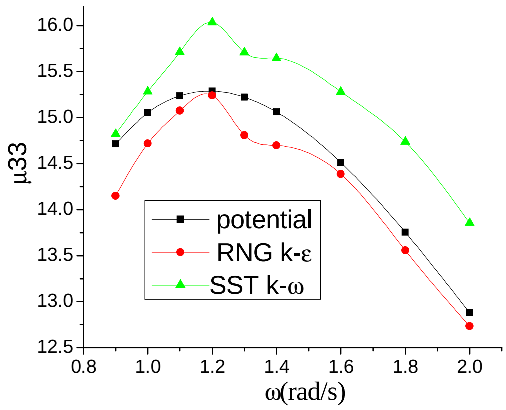

Fig.15 :Damping coefficients of station 3

CONCLUSION

Through the above research, we can get the following conclusions:

(1) From the viscous flow field analysis the viscous damping is obvious because of the presence of semi-submerged body, which produced obvious eddy flows and made the boundary layer thicker. Besides, the RANS method by means of two turbulence models including the RNG $k-\varepsilon$ and the SST $k-\omega$ model can calculate viscosity hydrodynamic and reflect the effect of semi-submerged body well.

(2) By analyzing the calculating results of two kinds of turbulence models and the comparison of the results of 2D potential method revealed that the SST $k-\omega$ model is better than the RNG $k-\varepsilon$ model for hybrid monohull hydrodynamic calculation and can reflect the viscous effect of the semi-submerged body better, but the efficiency is relatively lower.

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REFERENCES

[1] Cai Xingong, Li Jide, Wang Jianfang,Li Wei, Liu Ping. *Shipbuilding of China*,**2003**，44（3）：50-57
[2] Cai Xingong, Li Jide, Liu Yadong, Wang Jianfang. *Journal of Hydrodynamics*, **2003**,18(2):145-155
[3] Dai Yishan. Potential Flow Theory of Ship Motion in Waves in Frequency and Time Domain [M]. National Defense Industry Publication, Beijing, **1998**
[4] T.PERSSON,M. LIEFVENDAHL,R.E. BENSOW et al.LES. DES and RANS of High Reynolds Number. Wall Bounded Flows[A].*Numerical Towing Tank Symposium*; 20051002-04; Varna(BG)[C].**2005**.
[5] J.L. Lara,N，Garcia,I.J，Losada. *Coastal Engineering*, **2006**,Vol.53
[6] SUN Shu-zheng, LI Ji-de, ZHAO Xiao-dong. *Journal of Ship Mechanics*, **2009**，13（2）：177-183
[7] Li Jide, Zhang Heng. *Journal of Ship Mechanics*. Vol 12, No 2. **2008**.4:180-187
[8] WANG Xujie，SUN Shuzheng. *Journal of Harbin Engineering University*, **2012**，33（1）：15-19
[9] Gao Ni, Sun Shuzheng, Li Jide． *Journal of Ship Mechanics*．**2011**.9
[10] CHANG Huai-xin, LIU Ying-zhong, MIAO Guo-ping. *Journal of Ship Mechanics*.**2003**.6