Influence of thrust fins on hydrodynamic performance of pod propeller

Zhenqiu Yao, Wenyu Liu, Zhirong Xu, Hongjie Ling

Departments of Naval Architecture and Ocean Engineering, University of Jiangsu Science & Technology, 212003, China
Email: 415162430@qq.com
TEL: 15380230713

Abstract: Based on the viscous flow theory, the influence of the arrangement and geometrical changes of the thrust fins on the hydrodynamic performance of the pod propeller is studied by using the sliding grid technology and the commercial fluid calculation software FINE/marine. The results show that the extension of the thrust fin can slightly increase the resistance performance and propulsion efficiency of the pod propeller while significantly reducing the lateral force of the pod. Changing the circumferential position of the thrust fin can change the magnitude and even the direction of the total lateral force of the nacelle without affecting the resistance of the pod. The thruster is the most efficient when the circumferential angle of the thrust fin is 60 degrees. When the initial angle of attack of the fin is in the range of -4 to 8, the angle of attack is larger, the efficiency of the thruster is higher, the total lateral force is smaller, and the cabin resistance is smaller. However, after the angle of attack is greater than 4 degrees, the cabin resistance is no longer reduced.

1. Introduction

The concept of the pod propeller was first proposed by the Finnish Kvaerner Masa shipyard and ABB(Asea Brown Boveri Ltd) in 1987[1]. It is the world's first electrically driven propeller propulsion system installed on the hull of a ship[2]. The pod propeller is mainly composed of brackets, cabins and propellers. The propeller breaks through the design of the traditional propeller propulsion mode. Its propeller is directly connected to the drive motor and placed together in a 360-degree full-rotation nacelle. Through the bracket and the hull, it forms a separate propulsion module. The modular design enables the pod propeller to be installed before the ship is basically completed or tested, and can also be installed, disassembled or repaired underwater. In addition, the pod propeller has the advantages of high reliability, low noise, low vibration, low exhaust gas emissions and no oil leakage, which meets the current requirements for energy saving and emission reduction of ships[3].

For the study of the hydrodynamic performance of the pod propeller, the theoretical calculation methods are mainly divided into two types, one is the lift surface method and the surface element method based on the potential flow theory, and the other is the calculation method based on the viscous flow theory, that is, solving the RANS equation. Yang et al[4] used the panel method to analyze the interaction between the propeller and the nacelle, and studied the influence of the pod on the blade load distribution; Using the same method, Guo[5] studied the influence of fin position and fin installation angle on pod propeller. Hu et al[6] used the viscous flow theory to solve the influence of the geometrical changes of the tail fins on the hydrodynamic performance of the nacelle by solving the RANS equation. The results...
show that the caudal fin can significantly absorb the rotational energy in the wake field of the propeller, but the absorption effect of the single and double caudal fins is not much different; the change of the angle of attack of the fin has little effect on the overall hydrodynamics; the variation of the fin length can be obvious Improve the total load on the fins.

In this paper, Solidworks is used to establish the model of the specified pod propeller, and the performance of the open water is predicted by Fine/Marine. The reliability of the algorithm is verified by comparison with the experimental data. Then, thrust fins are installed on both sides of a pod propeller cage to study the effects of thrust fin extension, circumferential position and initial angle of attack on the hydrodynamic performance of the pod propeller.

2. Numerical calculation method

2.1 Control equation

In this paper, water is an incompressible fluid, and energy exchange is not considered, so only the continuity equation and the momentum conservation equation need to be considered:

\[
\frac{\partial}{\partial t} \int_V \rho dV + \int_V \rho \left( \nabla \cdot \mathbf{u} \right) dV = 0
\]

\[
-\frac{\partial}{\partial t} \int_V \rho \mathbf{u} dV + \int_S \rho \mathbf{u} (\mathbf{u} - \mathbf{U}) \cdot \mathbf{n} dS = \int_V \left( \tau_{ij} I_{ij} - \rho g \right) dV
\]

Where \( t \) is the time; \( \rho \) is the density; \( \mathbf{V} \) is the control body; \( S \) is the area of the control body; \( \mathbf{U} \) is the speed vector; \( \mathbf{U} \) is the control the velocity of the body surface in the vector direction; \( \mathbf{n} \) is the control external normal vector; \( U_i \) is the average velocity component in the direction of the \( x_i \) coordinate axis; \( \tau_{ij} \) is the viscous stress tensor; \( I_{ij} \) is the direction vector; \( P \) is the pressure; \( g \) is the gravity vector.

2.2 Turbulence model

In this study, the shear pressure transmission k-\( \omega \) (SST-Menter) model is used. The transport equation of the turbulent energy \( k \) and the turbulent dissipation rate \( \omega \) is:

\[
\frac{\partial}{\partial t} \left( \rho U_j k \right) + \frac{\partial}{\partial x_j} \left( \rho U_j U_k \frac{\partial k}{\partial x_j} \right) = \tau_{ij} S_{ij} - \beta^* \rho \omega k
\]

\[
\frac{\partial}{\partial t} \left( \rho U_j \omega \right) + \frac{\partial}{\partial x_j} \left( \rho U_j (\mu + \sigma_\omega \mu_t) \frac{\partial \omega}{\partial x_j} \right) = P_{\omega \omega} - \beta \rho \omega^2 + 2(1-F_1) \rho \sigma_\omega \frac{\partial k}{\partial x_j} \frac{\partial \omega}{\partial x_j}
\]

Where \( U_j \) is the average velocity component in the \( x_j \)-axis direction; \( \mathbf{M} \) is the dynamic viscosity; \( \mathbf{M}_t \) is the turbulent eddy viscosity; \( T_{ij} \) is the Reynolds stress tensor; \( S_{ij} \) is the average strain rate tensor; \( P_{\omega \omega} \) is the the derivation of \( \omega \); \( F_i \) is the auxiliary mixing function; \( \beta, \beta^*, \sigma_k, \sigma_\omega \) are the turbulence model constants.

2.3 Sliding grid technology

Sliding grid technology divides the grid model that needs to be calculated into several regions, allowing relative sliding of the grid between interfaces. It does not require that the mesh nodes on both sides of the interface overlap each other, but the flux on both sides of the interface must be calculated to transfer the data. In FINE/Marine, the adjacent grid cells on both sides of the interface are determined in each time step. By searching and matching the most matching grid units on both sides of the interface, the flux is directly used as the adjacent grid. Calculate, no specific interpolation method is used.

2.4 Computational domain and meshing

In this paper, the sliding grid technique is used to simulate the rotation of the propeller. When calculating the grid, two calculation domains should be established, one is the rotating inner domain containing the
propeller, and the other is the fixed outer domain containing the pod, as shown in Figure 1. Show. The surface shared by the two domains is set as an interface for realizing the transmission of flow field data such as pressure and velocity between the two domains.

The Galilean coordinate system is used to define each direction in the calculation domain. The propeller advance direction is the positive direction of the X-axis, the port side of the nacelle is the positive direction of the Y-axis, and the opposite direction of gravity is the positive direction of the Z-axis. The origin of the coordinates is located on the blade surface and the paddle. The intersection of the axis centerlines.

The inner domain of the rotation is a cylinder coaxial with the propeller, with a diameter of 1.2D (D is the diameter of the propeller) and a length of 0.25D; the fixed outer domain is a rectangular parallelepiped, the length is 13D, the width is 5D, the height is 4D, the entrance boundary is 3D from the blade surface, and the exit boundary is 11D from the blade surface. The left and right boundaries are 2.7D from the center axis of the propeller, and the upper and lower boundaries are 1.7D and 2.7D from the center axis of the propeller, respectively. In order to obtain the key flow field information, the leading edge, the edge and the blade tip of the blade are encrypted by local encryption, and the pod and the bracket area are also encrypted, as shown in Fig. 2.

Since the free surface is not considered, the single-phase flow model is used; the turbulence model is k-ω (SST-Menter); For the momentum equation and the turbulence equation, the AVLSMART format is used for discretization; The boundary conditions between the propeller and the nacelle are set to the boundary with a wall function. The conditions for calculating the boundary of the entrance and exit of the domain and the boundary conditions on the left and right sides of the propeller are defined as the velocity far-field condition, and the velocity is zero; the bottom and top boundary conditions are set to the specified pressure condition.

2.5 Numerical method verification
This verification uses a pod propeller tested jointly by the Memorial University of Newfoundland and the National Oceanic Technology Institute of Canada. The 3D model is shown in Figure 3. The main scale parameters are shown in Tables 1-2. Using the above numerical method, the hydrodynamic performance of the pod propeller with the advancement coefficient of 0.2, 0.4, 0.6, and 0.8 is predicted.
In the table, $K_T$, $10K_Q$, $K_T$, and $\eta$ represent the propeller thrust coefficient, 10 times the propeller torque coefficient, the total thrust coefficient of the pod thruster, and the thruster efficiency respectively; Exp indicates the test data, and Num indicates the numerical simulation data. The prediction result is close to the test as shown in Fig. 4, and the maximum error is only 3.63% and 2.06%, the overall thrust coefficient error of the thruster is also less than 5.5%.

![Figure 3. Model of POD thruster.](image)

**Table 1. Main dimensions of propeller model.**

| Main scale | Parameters                  |
|------------|-----------------------------|
| Diameter   | 270mm                       |
| Number of blades | 4                           |
| Design speed coefficient | 0.8                      |
| Hub diameter ratio | 0.26                    |
| Rotating speed | 15rps                      |
| Blade profile thickness distribution | NACA 66 (DTMB Modified) |
| Blade length distribution | P4119 (DTMB Modified) |
| Propeller disk ratio | 0.60                      |
| Pitch      | 1                           |

**Table 2. Main dimensions of pod model.**

| Main scale | Parameters |
|------------|------------|
| Diameter   | 139mm      |
| Length of pod | 410mm    |
| Height of pod | 300mm    |
| Length of Bracket | 225mm |
| Width of bracket | 60mm    |
| Length of front cone | 85mm  |
| Front cone angle | 15°     |
| Back cone length | 110mm  |
| Rear cone angle | 20°     |
| Bracket distance | 100mm   |
### Table 3. Calculation table of open water performance of podded thruster.

| J  | Exp\_KTP | Num\_KTP | error | Exp\_KT | Num\_KT | error | Exp\_10KQ | Num\_10KQ | error |
|----|-----------|-----------|--------|----------|---------|--------|-----------|-----------|--------|
| 0.2| 0.421     | 0.420     | -0.25% | 0.408    | 0.386   | -5.50% | 0.601     | 0.608     | 1.24%  |
| 0.4| 0.344     | 0.341     | -0.82% | 0.330    | 0.312   | -5.36% | 0.520     | 0.509     | -2.06% |
| 0.6| 0.255     | 0.251     | -1.50% | 0.228    | 0.222   | -2.62% | 0.410     | 0.413     | 0.80%  |
| 0.8| 0.162     | 0.156     | -3.63% | 0.122    | 0.128   | 4.84%  | 0.298     | 0.297     | -0.26% |

![Figure 4. Curve of open water performance of POD thruster.](image)

### 3. Influence of variation of thrust fin parameters on hydrodynamic performance

#### 3.1 Change of geometric parameters of thrust fins and calculation results

This paper mainly studies the three parameter changes of the fin: the extension of the fin, the circumferential position of the fin and the initial angle of attack of the fin, as defined in Figure 5. They are numbered according to their respective parameter characteristics. For example, FIN\_1\_60\_m2 indicates that the thrust fin has a length of 375 mm, the radial maximum position of the thrust fin is about 0.7 times the propeller radius, and the circumferential angle between the fin and the longitudinal section of the nacelle is 60 degrees. The angle between the initial angle of attack of the fin and the X-axis (propeller forward direction) is -2 degrees, the front edge of the right fin is turned downward, and the upward rotation of the leading edge of the left fin indicates that the angle of attack is reduced. The model of the finned pod propeller is shown in Figure 6; the specific geometric parameters of the thrust fin are shown in Table 4.
Figure 5. Definition of thrust fin length, circumferential position and initial attack angle.

Figure 6. Model of POD thruster with thrust fin.

Table 4. Thrust fin parameter changes

| Number      | Fin length(mm) | Circumferential position(°) | Initial angle of attack(°) |
|-------------|----------------|-----------------------------|---------------------------|
| FIN_1_60    | 175            | 60                          | 0                         |
| FIN_2_60    | 375            | 60                          | 0                         |
| FIN_3_60    | 575            | 60                          | 0                         |
| FIN_4_60    | 875            | 60                          | 0                         |
| FIN_2_45    | 375            | 45                          | 0                         |
| FIN_2_90    | 375            | 90                          | 0                         |
| FIN_1_60_8  | 175            | 60                          | +8                        |
| FIN_1_60_6  | 175            | 60                          | +6                        |
| FIN_1_60_4  | 175            | 60                          | +4                        |
| FIN_1_60_2  | 175            | 60                          | +2                        |
| FIN_1_60_m2 | 175            | 60                          | -2                        |
| FIN_1_60_m4 | 175            | 60                          | -4                        |

Under the design conditions, the hydrodynamic calculation results of the pod propeller after the geometric parameters of the thrust fins are changed are shown in Tables 5-7. Propeller thrust coefficient and torque coefficient represent the thrust and torque along the X-axis generated on the blade and hub; the total thrust coefficient represents the resultant force of the propeller, the cabin, the bracket and the thrust fin, and the efficiency of the pod thruster is the total thrust coefficient and The propeller torque coefficient is calculated; the drag coefficient of the pod propeller indicates that it is stressed in the X-axis direction, and the lateral force coefficient indicates the force in the Y-axis direction.

$F_x$ represents the force on the x axis, body, strut, thrust fin and total respectively represent cabin,
bracket and thrust fin and the whole pod.

Table 5. Propeller thrust, torque, total thrust coefficient and efficiency.

| FIN_1_60 | 0.1266 | 0.2117 | 0.1176 | 0.6192 |
| FIN_2_60 | 0.1269 | 0.2120 | 0.1185 | 0.6231 |
| FIN_3_60 | 0.1270 | 0.2125 | 0.1190 | 0.6245 |
| FIN_4_60 | 0.1274 | 0.2127 | 0.1196 | 0.6271 |
| FIN_2_45 | 0.1269 | 0.2121 | 0.1184 | 0.6224 |
| FIN_2_90 | 0.1270 | 0.2122 | 0.1181 | 0.6204 |
| FIN_1_60_8 | 0.1268 | 0.2116 | 0.1181 | 0.6221 |
| FIN_1_60_6 | 0.1268 | 0.2118 | 0.1180 | 0.6211 |
| FIN_1_60_4 | 0.1267 | 0.2118 | 0.1181 | 0.6214 |
| FIN_1_60_2 | 0.1268 | 0.2118 | 0.1179 | 0.6202 |
| FIN_1_60_m2 | 0.1267 | 0.2118 | 0.1174 | 0.6179 |
| FIN_1_60_m4 | 0.1267 | 0.2118 | 0.1171 | 0.6164 |

Table 6. Resistance coefficient of each parts of POD.

| FIN_1_60 | -0.0036 | -0.0053 | -0.0001 | -0.0090 |
| FIN_2_60 | -0.0026 | -0.0052 | -0.0005 | -0.0083 |
| FIN_3_60 | -0.0021 | -0.0052 | -0.0006 | -0.0079 |
| FIN_4_60 | -0.0018 | -0.0052 | -0.0006 | -0.0077 |
| FIN_2_45 | -0.0027 | -0.0053 | -0.0004 | -0.0085 |
| FIN_2_90 | -0.0032 | -0.0052 | -0.0005 | -0.0089 |
| FIN_1_60_8 | -0.0029 | -0.0053 | -0.0005 | -0.0087 |
| FIN_1_60_6 | -0.0030 | -0.0054 | -0.0004 | -0.0087 |
| FIN_1_60_4 | -0.0031 | -0.0053 | -0.0002 | -0.0087 |
| FIN_1_60_2 | -0.0034 | -0.0053 | -0.0002 | -0.0089 |
| FIN_1_60_m2 | -0.0039 | -0.0053 | -0.0001 | -0.0093 |
| FIN_1_60_m4 | -0.0041 | -0.0053 | -0.0002 | -0.0096 |

Table 7. Transverse forces coefficient of each parts of the POD.

| FIN_1_60 | 0.0039 | 0.0033 | -0.0007 | 0.0065 |
| FIN_2_60 | 0.0015 | 0.0029 | -0.0029 | 0.0014 |
| FIN_3_60 | 0.0002 | 0.0022 | -0.0055 | -0.0031 |
| FIN_4_60 | -0.0011 | 0.0016 | -0.0088 | -0.0083 |
| FIN_2_45 | 0.0006 | 0.0027 | -0.0047 | -0.0015 |
| FIN_2_90 | 0.0059 | 0.0028 | 0.0007 | 0.0094 |
| FIN_1_60_8 | 0.0011 | 0.0026 | -0.0021 | 0.0016 |
| FIN_1_60_6 | 0.0018 | 0.0028 | -0.0016 | 0.0029 |
| FIN_1_60_4 | 0.0030 | 0.0030 | -0.0013 | 0.0047 |
| FIN_1_60_2 | 0.0035 | 0.0032 | -0.0009 | 0.0057 |
| FIN_1_60_m2 | 0.0043 | 0.0034 | -0.0004 | 0.0073 |
| FIN_1_60_m4 | 0.0049 | 0.0035 | -0.0002 | 0.0082 |

3.2 Influence of thrust fin extension on hydrodynamic performance
It can be seen from the data in Table 5 that the influence of the variation of the thrust fin on the thrust
and torque of the propeller is not particularly obvious. However, the efficiency of the pod propeller increased with the increase in the length of the booth, up by 1.28%.

Figure 7 shows the curve of the drag coefficient of each part of the pod propeller as a function of the spread length. It can be seen that the resistance of the thrust fin increases with the increase of the length of the extension, but the resistance increases less when the length exceeds 575 mm; the resistance of the cabin decreases with the increase of the length of the stent, and the resistance of the bracket is basically unchanged, thereby making the suspension The total resistance of the cabin also decreases with the increase of the length of the exhibition. However, after the thrust fin extension is more than 575mm, that is, the radial maximum position of the thrust fin is greater than 0.8 times the propeller radius, the total resistance coefficient decreases and the total resistance of the pod decreases. It has dropped by almost 14%.

It can be seen from Fig. 8 that the influence of the change of the extension on the lateral force is very significant. As the extension of the thrust fin increases, the lateral force of the thrust fin increases continuously, which is basically linear with the extension; the cabin and the bracket The lateral force gradually decreases, but the variation is small, in which the lateral force of the bracket is always along the positive direction of the Y-axis, and the lateral force of the cabin is almost reduced to zero when the thrust fin is 575 mm, further with the extension. Increase, the lateral force changes from the positive direction along the Y axis to the negative direction along the Y axis; the change trend of the total lateral force of the nacelle is basically the same as that of the cabin. When the extension is about 435mm, the total lateral force drops to zero.

It can be seen that changing the extension of the thrust fin can significantly reduce the lateral force of the pod and even change the direction of the overall lateral force while slightly increasing the drag performance and propulsion efficiency of the pod propeller. When the initial angle of attack is 0° and the circumferential angle is 60°, the larger the length, the higher the efficiency of the thruster, and the smaller the resistance, the total lateral force can be reduced to zero at a length of 435mm.
3.3 Influence of circumferential position of thrust fins on hydrodynamic performance

As can be seen from the data in Tables 5 and 6, the effect of the circumferential position of the thrust fin on the propeller thrust, torque, and resistance of the various parts of the nacelle is not particularly noticeable. However, the efficiency of the propeller is highest at the angle of 60 degrees, and is increased by 0.11% and 0.44% from 45 degrees and 90 degrees, respectively.

As can be seen from Fig. 9, the change in the circumferential position of the thrust fin has a significant influence on the lateral force of the cabin and the thrust fin. As the number of clamping angles increases, the lateral force of the cabin increases in the positive direction of the Y-axis; the lateral force of the bracket is almost constant; the lateral force of the thrust fins is decreasing, from the negative direction of the Y-axis to the positive direction; changes so that the total lateral force of the nacelle increases from the negative direction of the Y-axis in the positive direction of the Y-axis, and the total lateral force drops to zero at an angle of about 54 degrees.

It can be seen that by changing the circumferential position of the thrust fins, the magnitude and even the direction of the total lateral force of the nacelle can be changed without affecting the resistance of the nacelle propeller. When the initial angle of attack is 0 degrees and the extension is 375 mm, the thruster is the most efficient when the circumferential angle of the thrust fin is 60 degrees, and the total lateral force can be reduced to zero when the angle is 54 degrees.
3.4 Influence of initial angle of attack of thrust fin on hydrodynamic performance

The data in Tables 5-7 show that the change of the initial angle of attack of the thrust fin has a significant influence on the total lateral force of the nacelle and the efficiency of the pod propeller, that is, with the initial angle of attack. As the direction increases, the total lateral force gradually decreases, and the propulsion efficiency gradually increases. Before the +4 degree angle of attack, the total resistance of the pod decreases with increasing angle. After +4 degrees, the total resistance of the angle of attack increases. When the initial angle of attack is +8 degrees, the total drag coefficient of the pod is reduced by 3.33% compared with 0 degree, the total lateral force coefficient is reduced by 75.38%, and the efficiency is increased by 0.47%.

Figure 10 shows the resistance coefficient of each component of the nacelle as a function of the initial angle of attack of the thrust fin. It can be seen that as the initial angle of attack increases, the resistance of the stent hardly changes much; the resistance of the thrust fin itself is increasing, and its effect on the flow of the fluid around the cabin is more obvious, so that the pressure distribution on the surface of the cabin changes, and the resistance of the cabin gradually decreases. The reduction in cabin resistance is the main reason for the reduction in total drag of the pod. However, after the initial angle of attack is greater than 4 degrees, the thrust fin resistance increases and the cabin resistance decreases, causing the total resistance of the pod to be basically the same between the initial angle of attack of 4 to 8 degrees.

Figure 11 is a graph showing the lateral force coefficient of each component of the nacelle as a function of the initial angle of attack of the thrust fin. As can be seen from the figure, the thrust fin always produces a lateral force opposite to the bracket and the cabin. As the initial angle of attack increases, the lateral force of the thrust fin continues to increase, and the lateral force of the cabin decreases, while the lateral direction of the bracket The force is almost constant, resulting in a continuous reduction in the total lateral force of the pod.

It can be seen that by appropriately increasing the initial angle of attack of the thrust fin, the overall lateral force of the nacelle can be improved while reducing the total resistance of the nacelle and improving the efficiency of the propeller. When the exhibition length is 175mm and the circumferential angle is 60°, the larger the initial angle of attack, the smaller the total lateral force of the nacelle, the smaller the total resistance and the higher the efficiency.

![Figure 10. Resistance coefficient curves of each parts of POD with thrust fin attack angle.](image-url)
CONCLUSION

Based on the viscous flow theory, the hydrodynamic performance of the propeller with thrust fins is calculated. The influence of the geometric parameters of the fin on the hydrodynamic performance of the pod propeller is studied. The following conclusions are obtained:

1. Changing the length of the thrust fins can significantly reduce the overall lateral force of the pod while slightly increasing the drag performance and propulsion efficiency of the pod propeller. The larger the thrust fin is, the higher the propulsion efficiency is, the smaller the cabin resistance is. However, after the extension length is greater than 575mm, that is, the radial maximum position of the thrust fin is greater than 0.8 times the propeller radius, the cabin resistance does not change much; As the length of the extension increases, the force increases from the negative direction of the Y-axis to the positive direction of the Y-axis.

2. Changing the circumferential position of the thrust fin can change the magnitude and even the direction of the total lateral force of the nacelle without affecting the resistance of the nacelle propeller. The thruster is the most efficient when the circumferential angle of the thrust fin is 60 degrees.

3. Appropriate increase of the initial angle of attack of the thrust fin can reduce the cabin resistance and improve the efficiency of the propeller while improving the lateral force of the nacelle. The initial angle of attack of the thrust fin is in the range of -4 to +8. The greater the angle of attack, the higher the thruster efficiency, the smaller the total lateral force, and the smaller the cabin resistance, but the cabin resistance after the angle of attack is greater than +4 degrees. No longer reduced.

REFERENCES

[1] Zhang,Q.W. (2007) Prospect and utilization of the podded CRP propulsion system. J.Ship and ocean engineering.36(2):57-59.

[2] Pakaste,R,Laukia,K,Willhelmson.M. (1999) Experience with Azipod propulsion systems on board marine vessels.J.ABB Reviews,12-18.

[3] Ji,L.M,Wang.Q.Z. (2002) 21st Century Azipod Pod Electric Propulsion System. J.Ship engineering.2:61-64.

[4] Yang,C.J.,Qian,Z.F.,Ma.C.(2003)Influence of Pod on the Propeller Performance.J.Journal of Shang Hai Jiao Tong University.37(8):1229-1233.

[5] Guo,C.Y.,Sun.Y.,Zhao.D.G. (2013) Influence of thrust fins with different installation angles performance of podded propulsor.J.Huazhong University of Science &Technology(Natural Science Edition).41(12):106-111.

[6] Hu.F.L.,Zhang.Z.R. (2013) Study on the Influence of the Change of Fin in the Propeller of Hydrofoil on Hydrodynamic Performance.In:National Hydrodynamics Conference.Zhe Jiang.656-664.