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Numerical Study on the Performance of Resistance various Trim Tab’s Position and Size for High-Speed Small Boat

Kaicheng Yan, Jungkeun Oh, Dae-Won Seo*
Dept. of Naval Architecture and Ocean Engineering, Kunsan National University

트림 탭 위치 및 크기에 따른 고속 활주선 저항성능에 관한 수치적연구

옌카이청, 오정근, 서대원*
군산대학교 조선해양공학과

Abstract In general, appendage such as wedges, interceptor and trim tabs are mounted on the stern area to reduce resistance and improve operational stability of high-speed planning boat. The trim tab and interceptor can control the pitch motion by adjusting the trim of the boat. As a result, the wave resistance of the boat is reduced, and the fuel consumption can be reduced. In this study, we focus on the stern part of a high-speed boat with a length of 6.6 meters. We added wave plates with three specifications: lengths of 0.26m, 0.23m, and 0.2m, and widths of 0.34m, 0.3m, and 0.26m. We discuss the optimal position and size design of the adjusting wings when the angle of the wave plate is set at 5°, 7°, 10°, and 15° respectively. It is found that the resistance and motion of the planing boat changed significantly depending on the position of the trim tab. When the trim tab was installed at the stern at a distance of 50cm from the centerline, the resistance was relatively small and the pitch movement has been well adjusted. When the chord of the trim tab was 0.23m and the span was 76% of the chord, the resistance is the smallest and movement were got a good adjustment. The larger the installation angle of the trim tab, the smaller the pitch value, and the more stable the longitudinal movement of the planing boat.

요 약 일반적으로 웨지, 인터셉터, 트림 탭 등의 부가물은 고속 활주형선의 선미부에 설치되어 저항을 줄이고 운항 안정성을 향상시킨다. 트림 탭과 인터셉터는 트림을 조정하여 선박의 종방향 운동을 제어하는 역할은 한다. 이는 조파저항을 줄이고 연료 소비를 줄이는 데 도움이 된다. 본 연구에서는 길이 6.6m의 고속 보트의 선미 부분을 대상으로 하며, 길이가 각각 0.26m, 0.23m, 0.2m이며 너비가 0.34m, 0.3m, 0.26m인 세 가지 사양의 트림 탭의 성능을 살펴보았으며, 또한 트림 탭의 각도가 각각 5°, 7°, 10°, 15°일 때의 최적 각도에 대한 평가를 수행하였다. 트림 탭의 위치에 따라 활주선의 저항과 자세가 크게 달라지는 것을 알 수 있으며, 트림 탭을 중앙선에서 50cm 떨어진 선미에 설치 할 경우 저항이 상대적으로 작고 종방향 자세가 효과적으로 제어됨을 확인하였다. 트림 탭의 코드가 0.23m이고 스팬이 코드의 77%일 때, 선박의 저항은 가장 작았으며 운동도 효과적으로 제어되었다. 트림 탭의 설치 각도가 클수록 피치 값은 감소되어 선박의 종방향 운동이 감소되었다.

Keywords : Planning Boat, Trim Tab, Pitch Motions, Computational Fluid Dynamics, Ship Resistance

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*Corresponding Author : Dae-Won Seo(Kunsan National Univ.)
email: dwseo@kunsan.ac.kr
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1. Introduction

Speed performance is an important performance index of ships, and its quality directly determines ships' practicability and economic benefits, and the research on resistance, pitch, and sinkage is one of the most important contents in high-speed boat. The most notable feature of deep V-shaped high-speed planning boat is that all cross-sections are V-shaped. Compared with other ship types, the deep V-shaped high-speed planning boats have good seakeeping and planning stability and can maintain a high speed in waves. The V-shaped is widely used in the design of military ships, cruise ships, official ships, and high-speed ferries. It is worth noting that while the deep V-shaped ship obtains better seakeeping performance, the hydrostatic resistance performance decreases. To improve the comprehensive performance of this ship type, it is necessary to carry out ship type optimization and drag reduction technology research. Among the many ships' drag-reduction measures, the trim tab is one of the appendages that has been fully studied and proved to be effective. For displacement ships, the drag reduction effect of the trim tab is generally about 5%, and the maximum can reach about 15%.

To predict the delivered power requirements, running the trim, draft, and porpoising stability of prismatic planning hulls, the elemental hydrodynamic characteristics of prismatic planning surfaces are discussed, and empirical planning equations are given which describe the lift, drag, wetted area, center of pressure, and porpoising stability limits of planning surfaces as a function of speed, trim angle, deadrise angle, and loading by Daniel Savitsky [1] at Stevens Institute of Technology in 1964.

The Davidson Laboratory has conducted hydrodynamic studies on several fundamental planning hull phenomena. The formulae for the planning characteristics of a surface equipped with transom flaps are developed by Brown, P. W. [2] in 1971. The formulae include the effect of surface lift, wetted area, pressure distribution, wake shape, etc. Fridsma Gerard [3] published the results of a systematic investigation of the performance of planning craft in irregular head seas in 1971. Mercier John A. and Savitsky Daniel [4] defined the resistance of transom stern craft in the preplanning range in 1973. Daniel Savitsky and P. Ward Brown[5] published another paper in 1976. The preplanning resistance of transom-stern hulls, the effectiveness of trim control flaps, the effect of bottom warp on planning efficiency, the influence of reentrant transom forms, and the seakeeping of planning hulls were researched by them.

In 1989 the US Navy installed a stern deflector on the FFG25 and carried out a pilot study. The stern deflector had a chord length of 1.37m, a spread of 10.36m, and was installed at an angle of 10°. The test results showed that with the aft deflector, the drag performance of the ship improved significantly, the speed performance improved and the maximum speed increased by 0.3knot [6].

The US Navy has studied the dynamic performance of the Hurricane Patrol Boat PC1 with the addition of a stern deflector. In the model tests, the chord length of the tail deflector plate was taken to be approximately 0.5% to 1.5% of the interdrop length and the installation angle ranged from -5° to 15°. The test results show that the best hydrodynamic performance is achieved with a chord length of 1.4% of the interdrop length of the stern deflector. However, as the installation angle of the stern deflector plate for the optimum hull performance case did not meet the minimum drywall criteria, a standard installation angle of 3° was chosen. Although the installation angle chosen was not the optimum angle for the deflector performance, a power-saving of 4.5% was still achieved [7].

In 1995 the US Navy carried out shipboard trials of a PC13 class patrol boat fitted with a stern deflector. The stern deflector had a chord length of 0.73m, a spread of 5.48m, and was installed at an angle of 5°. The results showed a power saving of 7.7% and an increase in a speed of 0.9knot. There was a reduction in stern wave and spray. As with the FFG25, the results on the real boat far exceeded the predictions of the model tests, and the PC class patrol boats saved approximately US$10,000 per year in fuel consumption with the stern deflector installed [8].

The scholars then present a comprehensive analysis of the hydrodynamic performance of the aft deflector, based on the results of model tests on the CG47 and DD963 ships. The presence of the deflector alters the emerging waves aft of the ship and changes the distribution of velocity and pressure in the flow field around the ship. The stern deflector slows down the fluid velocity in the aft part of the ship, resulting in an increase in pressure, an increase in the lift in the aft region of the ship, a reduction in longitudinal inclination, and a small increase in the center of gravity, which contributes to the ship's sailing performance [9]. The Canadian Navy conducted a pre and post-test study of the Halifax-class frigate with a stern deflector, comparing eight different sizes of the stern deflector, including two chord lengths (1% and 1.5% of the interdrop length) and four mounting angles (4°, 7°, 10°, 13°, downwards relative to the horizontal). Experimental studies have shown that the tail deflector parameters that give the Halifax optimum drag performance are a chord length of 1.5% of the interdrop length, a spread of 7.6m, and a mounting angle of 4° downwards concerning the horizontal. The installation of this optimized stern deflector has reduced the annual fuel consumption of the frigate by approximately 1.08% compared to the period before the installation of the stern deflector [9].

For the Australian navigation boat "Aguisa", the researchers carried out ship model tests without a stern deflector and with six different stern deflectors, and the scale ratio of the ship model was 1:16. The results of the model test were converted to the real ship using the Froude method and the ITTC formula. After analyzing the whole test process and test data, the following conclusions are drawn in a considerable range of speed amplitude, the installation of the tail deflector has played a role in reducing the drag of the ship. And at low speed, the large installation angle of the tail plate is beneficial to the resistance performance, but as the speed increases, the stern deflector with a small installation angle will make the boat have better performance [9-12].

In 2005, Metcalf B J, Faul L, Bumiller E, et al [13] conducted experimental research for analyzing the U.S. Coast Guard planning hulls. They presented the trim angle and resistance of four models in various conditions including different displacements, various centers of gravity, etc.

In 2011, resistance measurement tests were performed on the boat with trim tab various ship speed [14]. As a result of conducting a model test while changing the angle between the trim tab and the bottom of the ship, the cord, and the span length, as the lifting force acting on the trim tab increases, the amount of levitation and the trim angle and resistance are reduced. Then three different planning hulls were introduced by them for improving performance and seakeeping in 2013. The third model has favorable resistance and seakeeping performance among the three model ships [15].

In 2014, A parametric study on the effects of trim tabs on the running trim and resistance of planning hulls was conducted by Parviz Ghadimi et al [16]. The effects of trim tab in two different practical situations were examined. The results for both high speedboats with an optimized deflection angle show that if the planning hull is constructed and difficulties occur with the trim angles, the best way to save the hull is to use either a fixed or a controllable trim tab. However, this approach may increase the resistance. Then the stern of a high-speed ship is generally designed by Parviz Ghadimi [17] In 2016, the results show that a transom stern, is beneficial for the sudden break-away of stern flow and the formation of rooster flow.

Amiadji [18] selected the trim tab geometry, then analyzed the resistance and trim of the ship using the CFD method in 2021. Through CFD simulation, the trim tab with an angle of 15° can reduce the value of the ship's resistance to 17.25% and the trim can be reduced to 46.72%. Then after the ship's propulsion power requirements calculation, it is shown that the trim tab with an angle of 15°, a reduction of 11.56% is obtained from 78.854 kW to 69.741 kW.

In 2021, Lee and Park [19] investigated the running attitude and resistance performance of the bare hull and trim plate hull of the model ship and the real ship are analyzed at several angles relative to the baseline, and the scale effect is compared. This shows that despite the presence of scale effects, the optimal running attitude can be determined from the trend.

The previous studies mainly considered the installation angle and size of the trim tab, and no research was carried out on the angle and size of the trim tab, and the installation position. Therefore, this paper uses the CFD method, based on the dynamic fluid body interaction (DFBI) theory, and takes a 6.6 m planning boat as the research object to study the position, angle, and speed of the planning board when adjusting the sailing attitude, to find the optimal value of the installation angle and position of the fine-tuning board.

2. Numerical Simulation

2.1 Target boat

Fig. 1 and Table 1 shows the 3D model of the target planning hull and principal dimensions respectively. Length of overall on the high-speed boat is 6.6m, Breadth is 1.83m. It is a fairly fast ship with a design speed of 25knots. Since this boat has two chine lines, it is designed to cut the wave when operating at high speed. The center of gravity is located at 2.5m from the stern and the angle of deadrise is 22.6°.

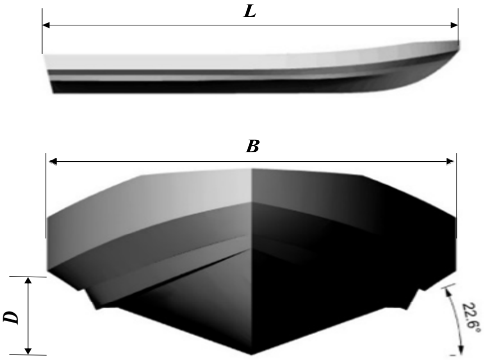


Fig. 1. Target planning boat

Table 1. Main dimensions of target planning boat

Item	Value
Length (m)	6.6
Breadth (m)	1.83
Draft (m)	0.46
LCG from the stern (m)	2.5
Deadrise angle (deg)	22.6
Mass (kg)	1215
Design speed (knot)	25

2.2 Governing Equations and calculation condition

A numerical study was carried out using STAR-CCM+, a general-purpose commercial software solution method employed was of finite-volume type and used control volumes of arbitrary polyhedral shape. The conservation equations in integral form for mass and momentum shown as (1), (2), together with an equation for volume fraction of liquid and two or more equations describing turbulence quantities, were solved using a segregated iterative solution method based on the SIMPLE algorithm. Details of the discretization and solution methods employed in this study can be found in the literature [20-22]. All surface and volume integrals were approximated using the midpoint rule; interpolation and gradient approximations were based on linear shape functions.

$$\frac{\partial u_i}{\partial x_i}=0 \tag{1}$$

$$\frac{\partial u_i}{\partial t}+\frac{\partial (u_i u_j)}{\partial x_j}=-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left\{(\nu+\nu_t)\frac{\partial u_i}{\partial x_j}\right\}+f_i, \tag{2}$$

where and are the velocity component and coordinate in the -direction; is the density; is the pressure; is the kinematic viscosity; is the eddy viscosity; and is the external force per unit mass.

Trimmed mesh method has the advantage since mesh size can be set relatively small for complex flow ranges or set large in cases of simple flow ranges through the configuration control of mesh density in accordance with each flow characteristic used[23].

The calculation of the spatial gradient of the physical property in a polyhedral grid made according to a trimmed mesh uses a least square method for second order accuracy. Moreover, to simulate the boundary layer flow around the ship surface more accurately, we used the prism layer technique to grid layers with 2.4 million grids as shown in Fig. 2.

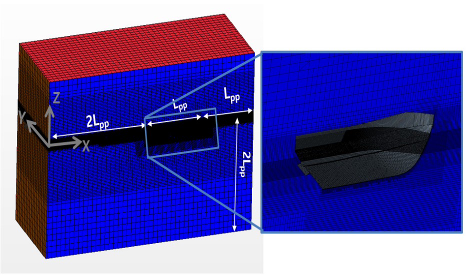


Fig. 2. Generated grid system

A large domain is required to capture the waves generated at the stern of a boat moving at high speed. Also, the computational domain must be large enough to ignore the effect of boundary conditions. The domain lengths in the x, y and z directions were set to -2 Lpp≤x 〈1 Lpp, 0≤y 〈1 Lpp and -2 Lpp≤z 〈1 Lpp, respectively (Table 2).

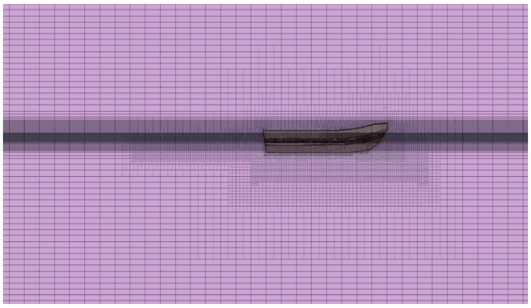
Table 2. Computational dommain and mesh information

Item	Value
Total grid No.	2,400,000 cells
Type of grid	Trimmed mesh
Domain size	-2≤X/Lpp〈1; 0≤Y/ Lpp 〈1.5; -2≤Z/ Lpp 〈1
Base size	0.15m
No. of Prism layer	3.0
Prism layer stretching	1.3
Prism layer thickness	0.004m
Surface size	Min.25%(0.0375m); Target 400%(0.6m)

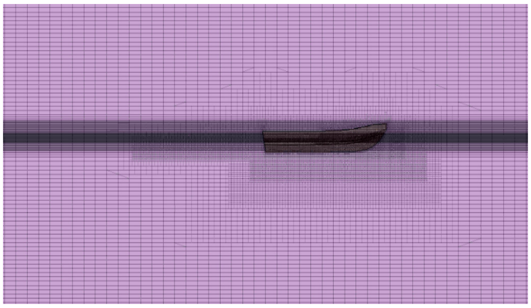
2.3 Influence of the grid distribution

Typically, a cut-cell grid with prismatic layers is used on the wet surface of the hull for drag analysis. The use of cut-cell grid cells means that the grid will be aligned with the calm free liquid surface. In the grid setup, the grid size of each region is based on the base size, so that the sparsity of the grid can be changed quickly. The finer the mesh, the higher the accuracy sought, and at the same time, more computational resources are required. When generating the grid, it is important to balance the grid size and the computation time. It is not necessary to put a dense grid over the entire computational domain, but a sufficient grid is required around the free surface and hull.

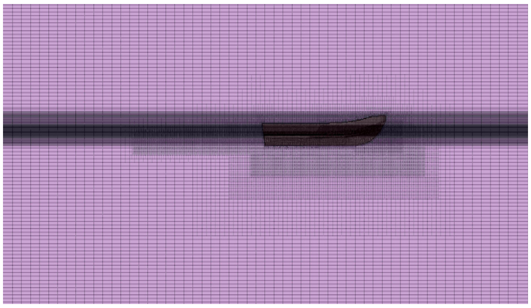
To choose a suitable grid for the calculation, three sizes of the grid were calculated and analyzed, the grid size increased in turn at a rate of $\sqrt{2}$ to generate three grids, the base size of the three grids was 0.21m, 0.15m and 0.11m respectively (Fig. 3).



(a) CASE 1 - Coarse mesh



(b) CASE 2 - Medium mesh



(c) CASE 3 - Fine mesh

Fig. 3. Generated mesh for grid dependency test

Table 3 shows the results of the ship's resistance and motion analysis according to the number of grids. When the number of grids is not sufficient (CASE 1-Coarse), the resistance of the ship is relatively small as 1445N. It can be seen that the resistance value, trim, and sinkage values converge as the grid number goes from medium to fine. In case of using many grids (CASE 3-Fine), the calculated value can be more accurate, but it takes a lot of time to calculate, so a medium grid system was selected in this study.

Table 3. Comparison of simulation results in varying mesh size

	CASE 1- Coarse	CASE 2- Medium	CASE 3- Fine
Base size	0.21m	0.15m	0.11m
Total mesh	108M	240M	439M
Resistance(N)	1445	1521	1536
Trim(deg)	4.760	4.840	4.886
Sinkage(m)	0.2887	0.2920	0.2919

2.4 Influence of the delta time

It is important to select an appropriate time step to calculate the resistance characteristics of a boat operating at high speed. If the time step is too large, the frictional resistance may not be calculated properly, and the total resistance of the vessel may be overestimated.

In order to choose a suitable time step for the analysis, the time steps of 0.01, 0.02, and 0.05 were selected for the bare boat at a speed of 15m/s. The resistance, trim, and sinkage were compared and analyzed by numerical calculation as shown in the Table 4.

It can be found from the Table 4 the difference between dt at 0.02 and 0.01 is not large enough to meet the needs of the calculation, but when choosing a time step of 0.05, the error is very large compared to 0.01 and 0.02. Finally, in order to save calculation time and more accurate result, the time step of 0.01 is chosen.

Table 4. Comparison of simulation on results in varying time step

dt(s)	Resistance (N)	Trim(deg)	Sinkage(m)	Mesh type
0.05	2150	8.8	0.75	CASE 2-Medium
0.02	1484	4.90	0.31	
0.01	1506	4.96	0.29	

2.5 Influence of the turbulence model

In this paper, three commonly used turbulence models: K-Epsilon model, K-Omega model, and Reynolds Stress Transport (RST) Models were simulated and analyzed respectively, and the results were compared at a bareboat speed of 15m/s and a time step of 0.01s as shown in Table 5. It can be seen that there is very little difference between each other from the calculation results shown in Table 5. Overall, the simulation of the drag performance and planing attitude of the planing ship is a little better using the RST turbulence model, which may predict the complex flow more accurately than the eddy viscosity model because the Reynolds stress transport equation itself considers the effects of turbulent anisotropy, streamline curvature, cyclonic rotation, and high strain rate. Therefore, the RST turbulence model was chosen.

Table 5. Comparison of simulation on results in varying time step

Turbulence	Resistance (N)	Trim (deg)	Sinkage (m)	Mesh type	Tiem step(s)
K-ε	1506	4.96	0.290	CASE 2-Medium	0.01
K-ω	1470	4.78	0.293		
RST	1506	4.89	0.294		

3. Influence of position and size of trim tab

The previous section simulated the direct motion of a bareboat glider in still water, showing that the numerical simulation method of STAR-CCM+ is feasible, and this section will analyze the planing boat with trim tab installed.

Planing boats operate at different speed ranges; however, different optimum trim angles exist for each operating speed. To improve the performance of planing boats at different motion speeds requires selecting different trim tab angles during the motion. In the selection of this trim tab, the most significant geometric parameters of a trim tab are chord length (chord), size through the aft beam (span), and trim tab angle (angle).

Proper position and sizing of trim tab is the key to getting optimal resistance performance. Improving the resistance performance of planning boat at different motion speeds requires selecting different angle of trim tab during the motion. In the selection of this trim tab, the most significant geometric parameters of a trim tab are chord length (chord), size through the aft beam (span), and angle of trim tab(α). The structure of the trim tab is illustrated in Fig. 4.

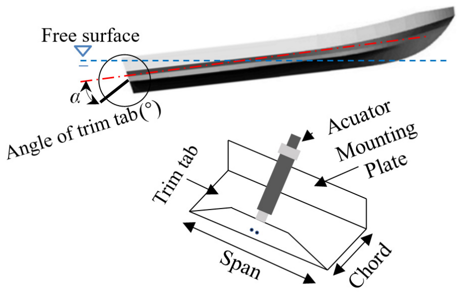


Fig. 4. Trim tab features

3.1 Influence of the trim tab's size

In order to select the appropriate size of the trim tab, this paper refers to the previous study [24] on the size of the stern trimming flap of high-speed craft and the user's Guide given by the American "Bennett marine" trim tab installation company. For the planing ship with a length of 6.6m studied in this paper, considering the space capacity of the stern, the trim tab with the shapes of the span of 30cm and chord of 23cm respectively are installed in the middle of the stern.To verify proper sizing, the trim tabs were scaled to the same proportions and the string lengths were set to 4%, 3.5%, and 3% of the length of the boat, respectively. The span was 77% of the string length.The three sizes of trim tabs selected are shown in the Table 6.

Table 6. Numerical simulation condition for various trim tab's size

	CASE 1-size	CASE 2-size	CASE 3-size
Chord(m)	0.2	0.23	0.26
Span(m)	0.26	0.3	0.34
Surface are(m2)	0.052	0.069	0.084
Chord/LOA	3%	3.5%	4%
Chord/ Span	77%		

The results show that the larger the surface area of the trim tab, the better the adjustment of the navigation attitude of the planing ship(Table 7). However, when the surface area of the trim tab is large, it will increase the resistance. When the surface area of the trim tab is small, it cannot provide enough surface area to use the water flow to provide more lift, nor can it adjust the navigation attitude well. Through comparative analysis, it is concluded that the size of the trim tab given by "Bennett marine" company (Span of 30cm and Chord of 23cm) meets the needs of the research model, and the ideal effect cannot be achieved if the size of the trim tab is too large or too small.

Table 7. Comparison of simulati on results in varying trim tab's size

	CASE 1-size	CASE 2-size	CASE 3-size
Resistance(N)	1642	1635	1662
Trim(deg)	5.48	5.33	5.28
Sinkage(m)	0.236	0.229	0.224

3.2 Influence of the trim tab position

To select the appropriate position of the trim tab, trim tabs, trim angle α=5°, are installed at three positions respectively: the stern, named outer (position A), middle (position B), and inner (position C), as shown in Fig. 5.

In order to select the appropriate position of the trim tab, 5-degree trim tabs are installed at three positions at the stern, the three positions are 0.3m, 0.5m, and 0.7m from the centerline of the ship, named outer(Position A), middle (Position B), and inner(Position C) respectively. The three installation positions are analyzed by numerical simulation at design speed.

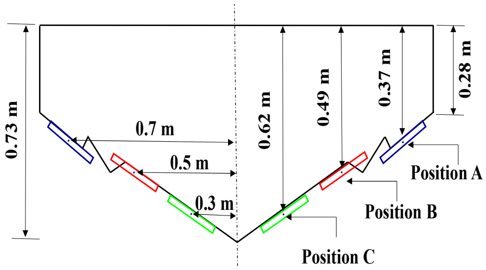


Fig. 5. Three positions of tab trim

The results of pitch, the position of Z direction (named as sinkage), resistance, pressure force and shear force are calculated and shown in Table 8. The results show that although the trim angle decreases gradually with the installation angle from inside to outside, the resistance is the smallest when installed in the middle position. Combined with the resistance and navigation attitude, installing the trim tab in the middle of the stern is more suitable. This is the same as the conclusion given by the installation company "Bennett marine", which proves the feasibility of installing in the middle of the stern. Hence, choose to install the trim tab at 0.5m from the centerline of the ship.

Table 8. The calculation results of the planning boat's differentpositions

Position	Resistance (N)	Pressure (N)	Shear (N)	Pitch (°)	Sinkage (m)
A	1667	315	1352	5.61	0.238
B	1635	328	1307	5.33	0.229
C	1775	378	1397	5.10	0.220

3.3 Influence of the trim angle and ship speed

Finally, installed the trim tab in position B, which installed at a distance of 50cm from the centerline. the span of the trim tab is 30cm, the chord is 3.5% of the length of the ship is 23cm, the thickness is 1cm.According to OMAR YAAKOB et al [24] when the angle of the trim tab is 15 degrees, it's the maximum angle that won't affect the wake height at the stern angle. Therefore, in this study, the angles of the wave suppressor plate are set at 5°, 7°, 10°, and 15° simulation of five different speeds (Fn from 0.62 to 1.9) in still water for each angle of the trim tab. Including the bare boat for a total of 25 cases of drag and planing attitude calculation analysis.

Froude number is an important parameter for ship resistance and motion characteristic, which is defined as

$$Fn = \frac{V}{\sqrt{gL_{PP}}} \tag{3}$$

Where V is the ship speed, g is gravity acceleration(9.8m/s^2).

Total resistance is expressed as the sum of normal force (R_P) and shear force (R_F). The total resistance coefficient (C_T), pressure resistance coefficient (C_P), and frictional resistance coefficient (C_F) are defined as

$$C_T = \frac{R_T}{\frac{1}{2}\rho V^2 S_0} \tag{4}$$

$$C_P = \frac{R_p}{\frac{1}{2}\rho V^2 S_0} \tag{5}$$

$$C_F = \frac{R_F}{\frac{1}{2}\rho V^2 S_0} \tag{6}$$

Where ρ is the water density, S_0 is wetted surface area under still water.

The calculation conditions are the same as in the previous section, and the resistance, trim, and sinkage of the planing boat after the installation of the trim tab are shown in Fig. 6-8.

Fig. 6 is the curve of the pitch motion(trim) changing with the speed under each installation angle. It can be seen from Fig. 6 that the change of speed and installation angle of the trim tab will obviously change the trim value. As the speed of the planning boat increases, the pitch shows a nonlinear trend of first increasing and then decreasing. Compared with the planning boat which installed trim tabs and without trim tabs, it is found that under different installation angles, the pitch values of planning boat with trim tabs are less than that of planning boat without trim tabs. The larger the installation angle of the trim tab, the smaller the pitch value, and the more stable the planning boat operation, as shown in Fig. 6. This is because, in the low-speed sailing stage, the flooded area of the hull is larger, and the planning boat runs relatively smoothly; as the speed increases, due to the lifting effect of the air on the planning boat, the front of the planning boat is raised, and the flooded area of the hull decreases, the pitch value of the planning boat reaches the maximum value at Fr.No.=1.24; with the further increase of the speed, the air buoyancy plays a major role in the planning boat, so the planning boat gradually returns to the stable operating condition, and the pitch gradually decreases.

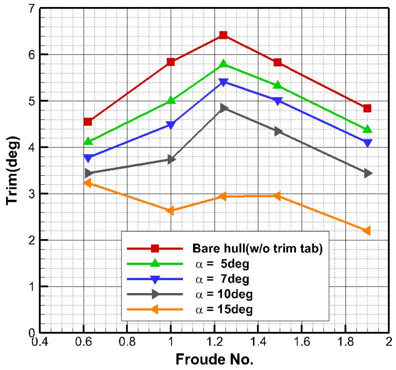


Fig. 6. Trim of boat in various trim tab angle and Froude number

Fig. 7 is the curve of the sinkage of the planing boat with the speed under different installation angles. Compared with the bare ship, the sinkage after installing the trim tab is reduced, but 15 degrees will cause a significant decrease in sinkage values.

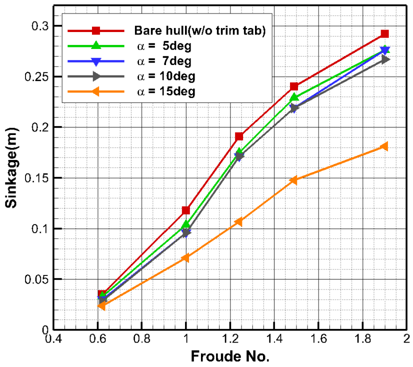


Fig. 7. Sinkage of boat in various trim tab angle and Froude number

Fig. 8-10 show the change curve of coefficient of pressure resistance, frictional resistance and total resistance according to ship speed and angle of trim tab. As previously known, it can be seen that the frictional resistance of the vessel is dominant when the Froud number is low (Fig. 9). However, as the Froude number increased, it was found that the pressure resistance increased significantly more than the change of the friction resistance.

In addition, it can be seen from the curve that with the change of speed, there is the best installation angle to reduce resistance. In general, the installation of a 5-degree trim tab has the effect of reducing resistance. When the angle of the trim tab is too large, it can be seen that the resistance increases with the increase of speed. The reasons for those phenomena are that the addition of trim tabs can cause an increase in pressure on the stern of the ship, especially in the area of adding trim tabs. This can be proven by obtaining the hydrodynamic pressure value from the ship simulation results.

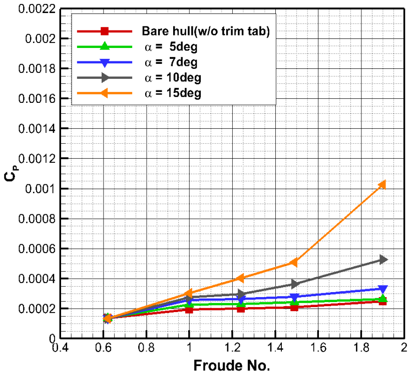


Fig. 8. Pressure resistance coefficient of boat in various trim tab angle and Froude number

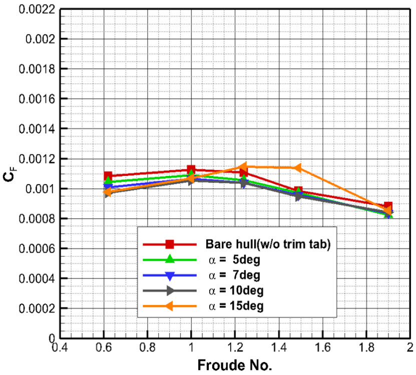


Fig. 9. Frictional resistance coefficient of boat in various trim tab angle and Froude number

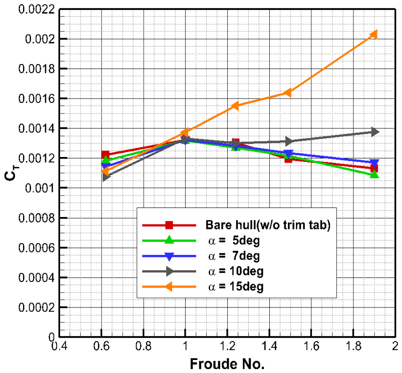
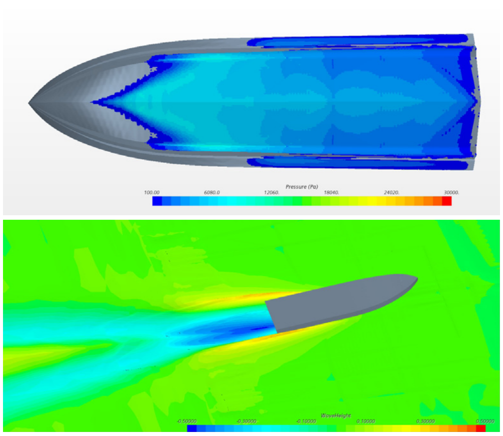
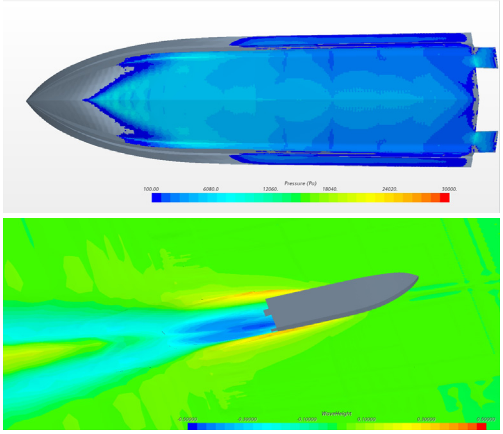


Fig. 10. Total resistance coefficient of boat in various trim tab angle and Froude number

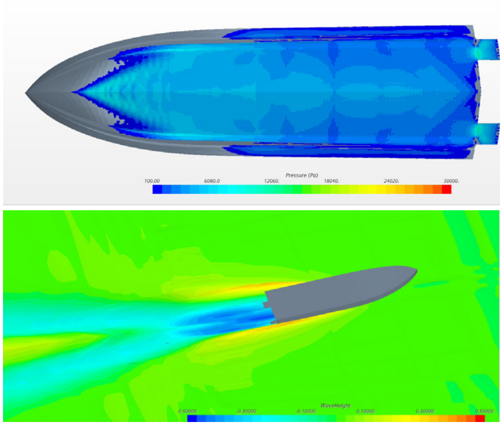
Fig. 11 show the pressure distribution and wave elevation on planing boat at various angle of trim tab. Under the condition of speed 12m/s, observing the bottom pressure distribution of the planing boat when it is planing stably, it can be seen that with the increase of the angle of the trim tab, the greater the pressure on the trim tab, the more obvious the effect on the trim of the planing boat. The change in wave elevation around the vessel was not significant. At the same time, the trim tab also changes the heave value of the planing boat, and the decrease of the trim value increases the wetted surface area. The influence of the trim tab on the navigation attitude can be directly reflected by the trim angle and the wetted surface area. It shows that the trim tab can effectively improve the navigation attitude.



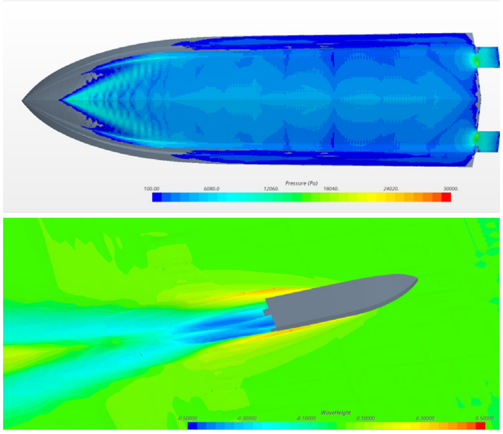
(a) Bare hull



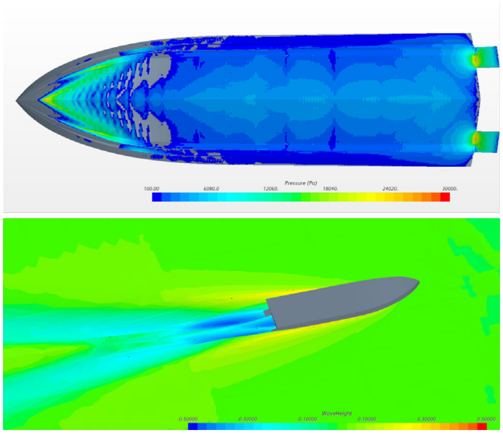
(b) α = 5°



(c) α = 7°



(d) α = 10°



(e) α = 15°

Fig. 11. Bottom pressure and wave elevation of planing boat at different trim tab angles at a speed of 12m/s

4. Conclusions

Based on the results of the analysis and simulations that have been carried out on a 6-meter planning boat regarding the impact of the trim tab installation, Froude number, and its angle variations, the following conclusions can be drawn as follow.

1. The influence of the trim tab on resistance and sailing attitude is closely related to its installation position and size. Choosing the right size and positioning, such as placing it in the middle of the stern at a distance of 50cm from the centerline, can effectively adjust sailing attitude and reduce resistance within a specific speed range.
2. Installing a trim tab sized at 0.23m x 0.3m on a planning boat resulted in notable impacts on resistance, pitch, and sinkage. Optimal conditions were observed at an angle of 5° and Fn=1.9 for the lowest resistance, 15° and Fn=1.9 for the lowest pitch, and high-speed conditions at Fn=1.9 and 15° for the lowest sinkage.
3. Despite increasing resistance at high speeds, larger trim tab angles were found to improve the stability of the planning boat, considering factors like pitch and sinkage motion. This contributes to enhanced operational stability during high-speed navigation.

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옌카이청(Kai-Cheng Yan) [정회원]

- 2019년 3월 : 군산대학교 조선해양공학과 (공학석사)
- 2021년 2월 ~ 현재 : 군산대학교 조선해양공학과 (공학박사)

〈관심분야〉
선박유체역학, 저항추진, 선박운동

오정근(Jung-keun Oh) [정회원]

- 1999년 2월 : 서울대학교 조선해양공학과 (공학석사)
- 2001년 2월 : 서울대학교 조선해양공학과 (공학박사)
- 2003년 3월 ~ 2007년 8월 : 서울대학교 수중음향특화연구센터 (책임연구원)
- 2007년 9월 ~ 2012년 8월 : 서울대학교 해양시스템공학연구소 (조교수)
- 2012년 8월 ~ 현재 : 군산대학교 조선해양공학과 교수

〈관심분야〉
실험유체역학, 유동가시화기법, 선박운동

서대원(Dae-Won Seo) [정회원]

- 2007년 2월 : 인하대학교 조선해양공학과 (공학석사)
- 2011년 2월 : 인하대학교 조선해양공학과 (공학박사)
- 2013년 3월 ~ 2020년 2월 : 한국선급 선박해양연구소 (책임연구원)
- 2020년 3월 ~ 현재 : 군산대학교 조선해양공학과 교수

〈관심분야〉
선박유체역학, 저항추진, 선박운동