

PAPER • OPEN ACCESS

Effect of Aspect Ratio and The Maximum Relative Camber on Hydrodynamic Performance of A Vertical Double-Curved Otter Board

To cite this article: X Rao *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **237** 032115

View the [article online](#) for updates and enhancements.

Effect of Aspect Ratio and The Maximum Relative Camber on Hydrodynamic Performance of A Vertical Double-Curved Otter Board

X RAO^{1,2}, H L HUANG^{1,2*}, L Z LI^{1,2}, S Chen^{1,2} and J L Yang^{1,2}

¹Key Laboratory of Oceanic and Polar Fisheries, Ministry of Agriculture; East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200090

²Engineering Technology Research Center of Marine Fishing, Chinese Academy of Fishery Sciences, Shanghai 200090, China

Corresponding author's e-mail address: ecshhl@163.com

Abstract. As an important accessory of Antarctic krill fishing gear, otter board has the effect of providing net horizontal expansion. To study the effects of aspect ratio and maximum relative camber on the hydrodynamic performance of Antarctic krill otter board, provide theoretical basis for the design and optimization of the otter board, the hydrodynamic performance parameters were analysed by flume model experiments. The results show: with the increase of aspect ratio, C_{lmax} and K_{max} show an upward trend; when the maximum relative camber is less than or equal to 10%, the value of α_0 fluctuates around 20°. When the maximum relative camber is greater than 10%, α_0 decreases gradually in the range of 32.5° to 22.5°; $K_{\alpha 0}$ increases firstly and then decreases. With the increase of maximum relative camber, C_{lmax} shows an upward trend; K_{max} shows a downward trend; when the aspect ratio is less than or equal to 2.0, α_0 shows an upward trend in the range of 20° to 32.5°, and when the aspect ratio is greater than 2.0, the value shows a fluctuating trend around 20°. $K_{\alpha 0}$ fluctuates and there is no obvious principle.

1. Introduction

At present, the scale of commercial development of Antarctic krill fishing in China is expanding day by day, but the basic research of Antarctic krill fishing gear still has a gap compared with developed countries^[1]. As an important accessory, otter board has the effect of providing net horizontal expansion. Hydrodynamic performance of the otter board directly affects net horizontal expansion, affects further the catching and fishing efficiency^[2-3].

It is assumed to be significant to study on hydrodynamic performance of the otter board from both economic and environmental reasons. It is also an important development direction of the fishery engineering in our country now and future.

To study the hydrodynamic performance of otter board, the method of model test or numerical simulation is commonly used^[4-7]. In the early stage of study in China, experiment was mainly completed in wind tunnel^[2]. Recently, experiment has been gradually carried out in flume.

Matsuda carried out flume experiment on V type otter board, the relationship between lift drag ratio and attack angle was obtained, the attack angle of the maximum lift drag ratio was confirmed, and the



trend of lift-drag ratio inside normal operation was analyzed^[8]. The overall evaluation of hydrodynamic performance of V-type otter board was summarized.

To analyze the hydrodynamic performance of low aspect ratio vertical cambered otter board under different angle of attack, the drag and lift coefficient of model otter board was measured and calculated through flume experiment. The results showed the trend of coefficient versus angle of attack. By comparing the hydrodynamic performance of different types of otter boards, provide a reference basis for the rational use and further development of the new types of otter board^[9].

In the research of otter board, there are two key points: hydrodynamic performance of certain otter board type and hydrodynamic influence of certain structural parameters, such as aspect ratio^[10-12], camber or curvature^[10-12], the number and structure of slots. In this paper, a vertical double-curved otter board was selected, flume experiments were carried out, and the effects of aspect ratio and maximum relative camber on the hydrodynamic performance were analyzed. The design direction of high performance otter board was discussed.

2. Material and Method

2.1. Flume experiment setup

The experiment was conducted in the recirculation water tank of the East China Sea Fisheries Research Institute. The scale of the experimental section is 180cm * 50cm * 50cm and the maximum flow velocity is 2.5m/s. The otter board model located in the middle section of the flume, and connected with the three-component force sensor. The sensor was fixed on the rotary table of the machine tool. By adjusting the rotary table, the angle of attack angle could be changed. The experiment setup is shown in Fig1. The measuring instrument is LSM-B-500NSA1-P three component force sensor manufactured by the Japan electric power company. The measuring range is 500N, and the measuring data are recorded by computer.

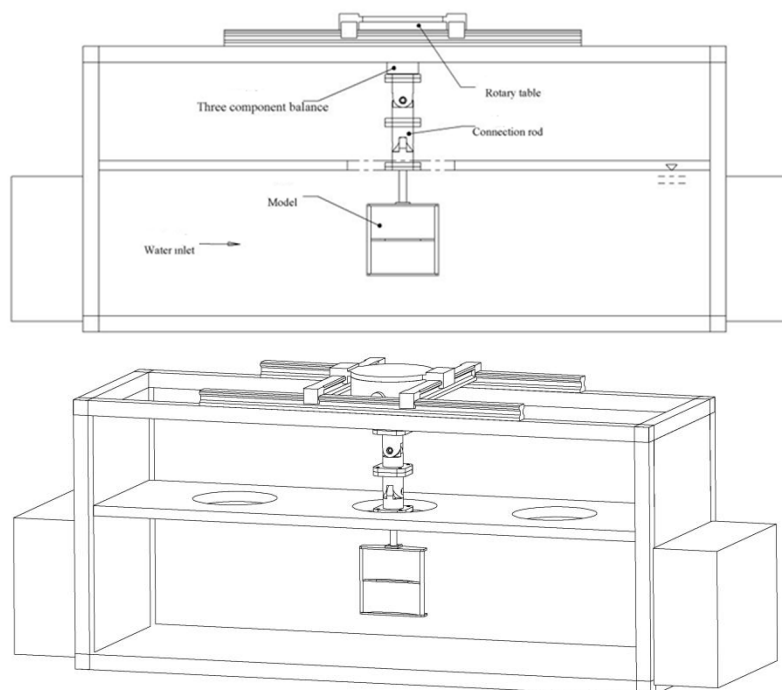


Figure 1. Flume experiment setup

2.2. Otter board model

According to the similarity principle of fluid mechanics, the Reynolds similarity rule is adopted, the Reynolds number of the otter board model equals to the object. The model is made of stainless steel with a thickness of 3mm. The cross-section sketch map is outlined in Fig3, the chord length is 20cm. The model is in scale of 1:20.

The structural parameters selected in this paper are aspect ratio and maximum relative camber, then 20 models were made. The aspect ratio (λ) is the ratio of the wing span l to the wing chord length b . The maximum camber f_{max} is the maximum distance between the arc and the wing chord, and the maximum relative camber f is defined as the percentage of the maximum camber and the length of the wing chord.

2.3. Experimental conditions

The experimental velocity range is 60cm/s-100cm/s. In the experiment, when the flow velocity is greater than a certain value, the hydrodynamic coefficients basically keep almost stable called automatic model region. The hydrodynamic coefficients discussed in this paper are measured and taken the average value in the region. The attack angle is set up between 15 and 40 degrees every 2.5 degrees, and between 0 and 15 degrees and 40 to 60 degrees every 5 degrees.



Figure 2. Sketch map of otter board model

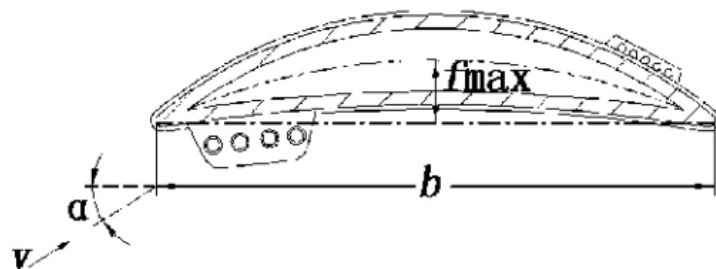


Figure 3. The cross-section sketch map of otter board model

3. Otter board hydrodynamic properties results

The measured steady-state hydrodynamic force coefficients (lift, drag and lift to drag ratio) are shown as below, according to equation (1)–(3)^[2].

Where ρ_w is the water density, A_m is the plan-form area, U_m is the flow velocity.

$$C_L = \frac{f_x}{0.5 \rho_w A_m U_m^2} \quad (1)$$

$$C_D = \frac{f_y}{0.5 \rho_w A_m U_m^2} \quad (2)$$

$$K = \frac{C_L}{C_D} \quad (3)$$

3.1. Flume experiment results of certain maximum relative camber and varying aspect ratio

The experimental results of the model with the maximum relative camber fixed at 8% and aspect ratio from 1.6 to 2.4 are selected and processed according to equation (1)– (3).

Fig. 4-6 shows that: with the increase of the attack angle, C_D increases sharply until the peak value, when λ is 1.6, 1.8, 2.0, 2.2 and 2.4, C_{Dmax} approaches 1.704, 1.385, 1.460, 1.558, 1.713 respectively. C_L increases to the peak value then decreases, when λ is 1.6, 1.8, 2.0, 2.2 and 2.4, C_{Lmax} approaches 1.189, 1.132, 1.207, 1.229, 1.242 respectively. K increases slightly between 0 and 5 degrees, then decreases sharply, when λ is 1.6, 1.8, 2.0, 2.2 and 2.4, K approaches 3.481, 4.119, 5.194, 5.015, 5.525 respectively.

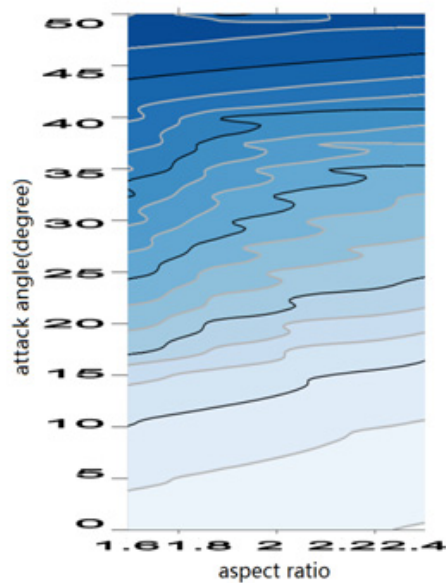


Figure 4. Measured drag force coefficient C_D for varying attack angle and aspect ratio

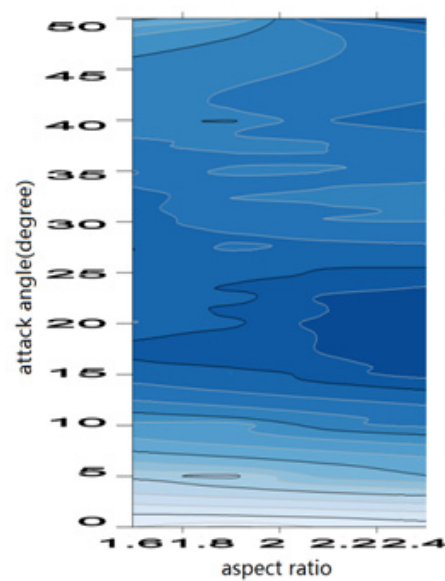


Figure 5. Measured drag force coefficient C_L for varying attack angle and aspect ratio

With the increase of aspect ratio, C_D shows a downward trend, then gradually stays stable finally rise again. When the attack angle is in 0° - 15° , aspect ratio has less influence on C_L , and C_L increases with the increase of aspect ratio between 15° - 30° and 35° - 50° . When the attack angle is in 0° - 20° , K increases obviously with the increase of aspect ratio, but when the attack angle is in 20° - 50° , the increase trend is slow.

3.2. Flume experiment results of certain aspect ratio and varying maximum relative camber

The experimental results of the model with the aspect ratio as 1.6, and maximum relative camber from 8% to 14% are selected and processed according to equation (1)– (3). Fig. 7-9 shows that: with the increase of the attack angle, C_D also increases sharply until the peak value, when f is 8%, 10%, 12% and 14%, C_{Dmax} approaches 1.704, 1.612, 1.454, 1.431 respectively. C_L increases to the peak value then decreases, when f is 8%, 10%, 12% and 14%, C_{Lmax} approaches 1.189, 1.332, 1.337, 1.504 respectively. K increases slightly between 0 and 5 degrees, then decreases sharply, when f is 8%, 10%, 12% and 14%, K approaches 3.481, 3.690, 2.613, 2.671 respectively. With the increase of maximum relative camber, C_D increases when attack angle is in 0° - 20° , and decreases gradually after 20° . C_L fluctuates when attack

angle is in 0° - 15° , C_L increases after 15° . K decreases sharply when the attack angle is in 0° - 15° , and then decreases sharply after 15° .

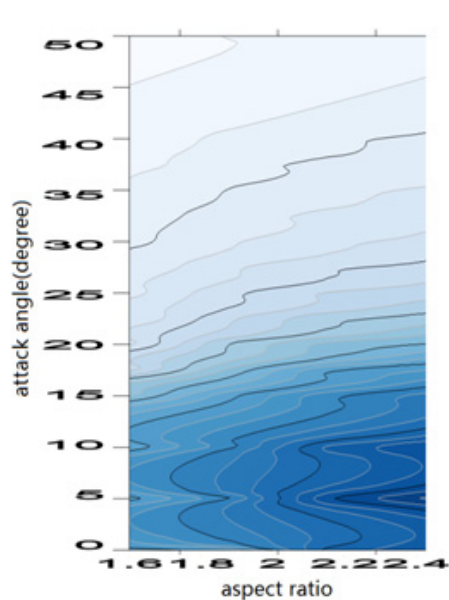


Figure 6. Measured drag to lift ratio K for varying attack angle and aspect ratio

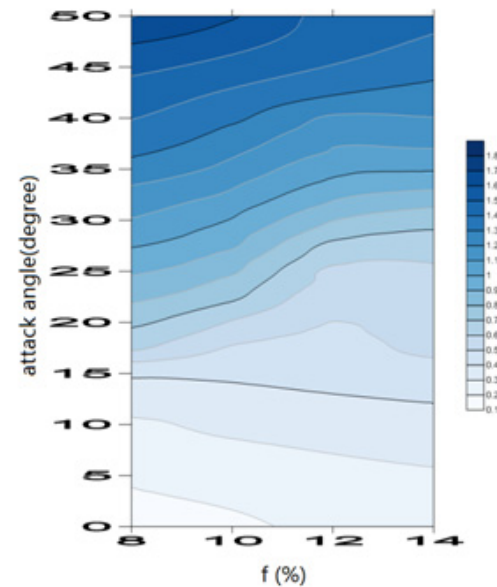


Figure 7. Measured drag force coefficient C_D for varying attack angle and maximum relative camber

3.3. Hydrodynamic performance of otter board with varying aspect ratio and maximum relative camber

The main parameters were chosen which can represent the hydrodynamic performance of the otter board: the maximum lift coefficient C_{lmax} , the maximum lift to drag ratio K_{max} , the critical attack angle α_0 , the corresponding lift-drag ratio at the critical attack angle K_{α_0} , to study the influence of aspect ratio and the maximum relative camber on the main parameters.

The results are summarized as Fig. 10-13. It shows that: with the increase of aspect ratio, C_{lmax} shows an upward trend. In the case of smaller maximum relative camber, the upward trend is gentle, while in the case of larger maximum relative camber, the upward trend is more intense. K_{max} also increases with the increase of aspect ratio. when the maximum relative camber is small, the upward trend is more intense, and when the maximum relative camber gets larger, the upward trend is slower. When the maximum relative camber is less than or equal to 10%, the value of α_0 fluctuates around 20° . When the maximum relative camber is greater than 10%, α_0 decreases with the increase of aspect ratio, and decreases gradually in the range of 32.5° to 22.5° . With the increase of aspect ratio, K_{α_0} increases firstly and then decreases. when the aspect ratio is around 2.0, K_{α_0} reaches peak value.

With the increase of maximum relative camber, C_{lmax} shows an upward trend, the upward trend fluctuates but generally stable. K_{max} also decreases with the increase of maximum relative camber. When the aspect ratio is smaller, the trend of decline is slower, and when the aspect ratio is larger, the trend of decline is more intense. When the aspect ratio is less than or equal to 2.0, α_0 shows an upward trend in the range of 20° to 32.5° , and when the aspect ratio is greater than 2.0, the value shows a fluctuating trend around 20° . K_{α_0} fluctuates with the increase of aspect ratio, and there is no obvious principle.

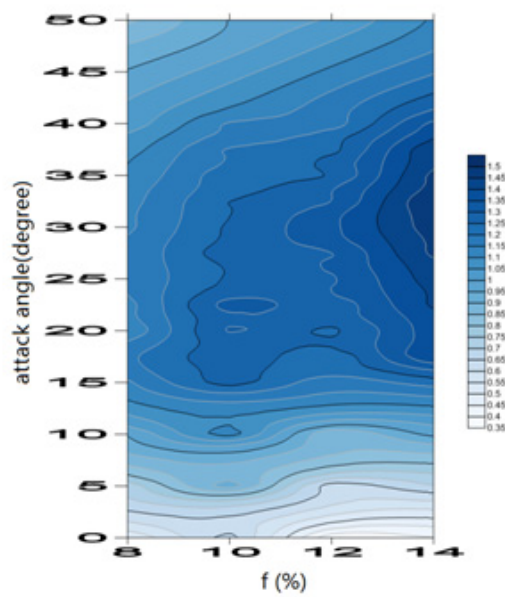


Figure 8. Measured drag force coefficient C_L for varying attack angle and maximum relative camber

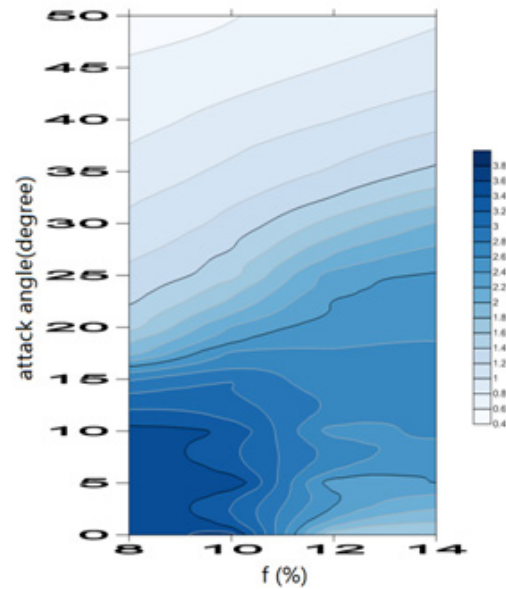


Figure 9. Measured drag to lift ratio K for varying attack angle and maximum relative camber

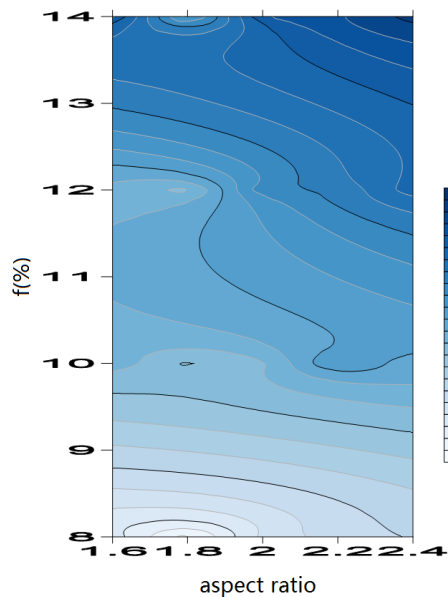


Figure 10. Measured maximum lift force coefficient C_{Lmax} for varying maximum relative camber and aspect ratio

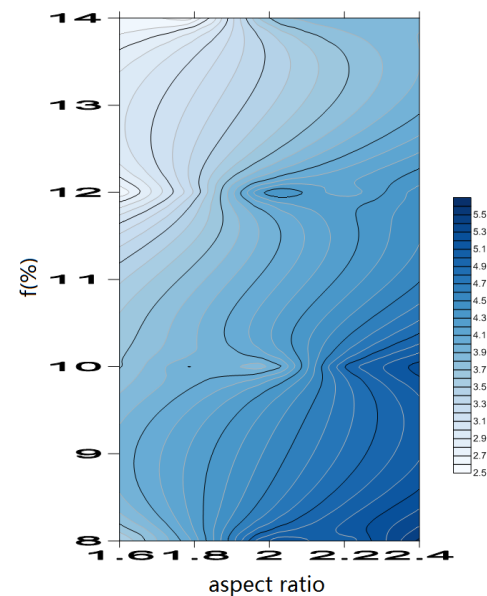


Figure 11. Measured maximum drag to lift ratio K_{max} for varying maximum relative camber and aspect ratio

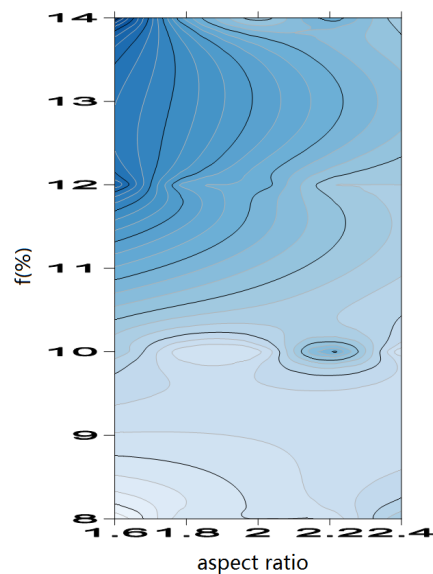


Figure 12. Measured drag force coefficient α_0 for varying maximum relative camber and aspect ratio

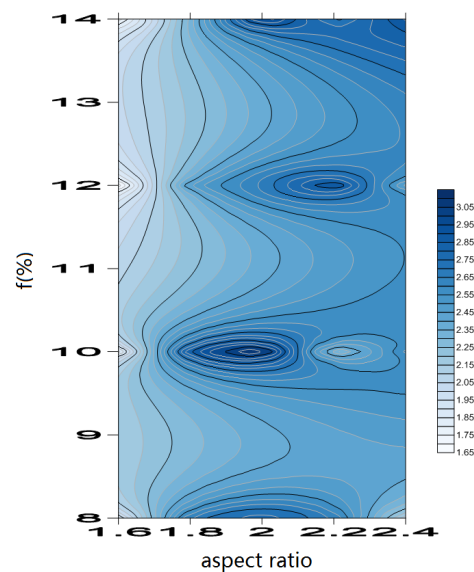


Figure 13. Measured drag to lift ratio $K_{\alpha 0}$ for varying maximum relative camber and aspect ratio

4. Conclusion

In this paper, the selected otter board is used in the Antarctic krill fishing. Large aspect ratio would make the center of gravity move upward even have unstable production operations, so the selected range of aspect ratio is 1.6-2.4, which does not cover the situation of larger aspect ratio. Therefore, the obtained rules will not be overall, and more accurate rules and formula will be obtained if more experimental data are gained.

Although the maximum relative camber and aspect ratio have positive effects on the maximum lift coefficient, the maximum lift to drag ratio does not increase with the increase of maximum relative camber. This is because when the maximum relative camber is too large, the flow is easy to be separated, which leads to the increase of vortex, then the drag force increases rapidly, and the lift to drag ratio decreases. In this study, when the aspect ratio is 2.0 and the maximum relative camber is 12%, both C_{lmax} and K_{max} reach their peak values, and the drag coefficient is also low.,

ACKNOWLEDGMENT

Authors wishing to acknowledge the assistance from Project NO.2014T01 supported by special research fund for the national non-profit institutes(East China Sea Fisheries Research Institute); Natural Science Foundation of China project Youth fund (31402351) ;

References

- [1] Xu, B.S., Zhang, X. ,Wang, M.Y. (2010)A review on the trawl otter board evolution. Journal of Fujian Fisheries,3(1):86-90.
- [2] Guo, G.X., Liu,T.Y., Huang, X.H.et al.(2008)Theory research and practice of the hydrodynamic of otterboard. Guangdong Science and Technology Press,Guangzhou.pp.160-211.
- [3] Zhang X.,Wang M. Y.,Xu B. S.(2004) A primary study on type, structure and performance of trawl otter board. Journal of Fishery Sciences of China,11(z1) :107-113.

- [4] Takajashi, Y.,Fujimori, Y.,Hu, F. X. et al.(2015)Design of trawl otter boards using computational fluid dynamics. *Fisheries Research*,161: 400-407.
- [5] Parkh, H.(2007)A method for estimating the gear shape of a mid-water trawl.*Ocean Engineering*,34(3-4): 470-478.
- [6] Prat,J., Antonijuan, J., Folch, A. et al. (2008) A simplified model of the interaction of the trawl warps, the otter boards and netting drag. *Fisheries Research*, 94(1) : 109-117.
- [7] Sun, X. F.,Yin, Y. , Jin, Y. C. et al.(2011)The modeling of single-boat,mid-water trawl systems for fishing simulation. *Fisheries Research*, 109(1) :7 -15.
- [8] Matsuda, E., Hu, F., Ishizawa, S.(1998)Hydrodynamic characteristics of vertical V type otter board.*Bulletin of the Japanese Society of Scientific Fisheries*, 56(11):1815- 1820.
- [9] Liu, J.,Huang, H.L.(2013)Hydrodynamic characteristics of low aspect ratio vertical cambered otter board.*Journal of Fisheries of China* ,37(11):1742-1749.
- [10] Fukuda, K., Matsuda, K., Hu, F. X. et al.(1997) Amodel experiment on hydrodynamic characteristics of biplane-type otter board.*The Japanese Society of Fisheries Science*,63(2):207 - 212.
- [11] Fukuda, K.,Hu, F. X.,Tokai, T. et al.(1999)Effects ofaspect and camber ratios on hydrodynamic characteristics of biplane-type otter board.*The Japanese Society of Fisheries Science*, 65(5) : 860 - 865.
- [12] Fukuda, K.,Hu, F. X.,Tokai, T. et al.(2000) Effect of aspect ratio on lift and drag coefficients of cambered plates . *The Japanese Society of Fisheries Science*,66(1):97-103.