Study on the shape parameters of bulbous bow of tuna longline fishing vessel

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Key words: longline fishing vessel; bulbous bow; CFD; resistance performance;

Abstract: The resistance performance of 49.5m tuna longline fishing vessel is simulated by using CFD software, the simulation results are in good agreements with experimental results, which verified the reliability of numerical calculation. Then change the bulbous bow three parameters of relative extend length, relative depth and maximum width ratio and build the different numerical models, their resistance performance are calculated by CFD method. Comparing and analyzing the calculation results, which show that in considering the general arrangement, driving safety and the strength of bulbous bow, add the bulbous bow extends length, relative depth and maximum width ratio can reduce the total resistance for this type of tuna longline fishing vessel.

Introduction

The resistance is one of the important factors that must be taken into account in ship design. Bulbous bow has been widely used in various military and civilian ships. The superposition of bulbous bow wave and ship front wave can form favorable interference, which can reduce the wave resistance effectively. Therefore, a suitable bulbous bow can improve speed to achieve better economic benefits. Recently, the application of bulbous bow is more and more widely in fishing vessel field. Using the traditional model test method, the domestic scholars for using bulbous bow to reduce the resistance on fishing vessel has got some results [1-4]. But the model test has the shortcomings of large cost, long cycle and can’t be reused. In recent years, with the continuous upgrading of computer hardware, computational fluid dynamic (CFD) has also been a rapid development. CFD has become an important auxiliary mean to optimize ship design and shorten the period of performance forecast, and it has been gradually applied into fishing vessel.

Numerical simulation and experimental verification

Numerical model and grid generation

The main parameters of tuna longline fishing vessel are given in Table 1. The establishment of numerical model is according to the size of ship model in towing tank, scale ratio is 1:12. The computational domain extends to 1*L* in front of the ship hull, 4*L* in behind and 1*L* to the side and bottom, *L* is the length overall. Because of the hull is symmetry, the hull half width is simulated to save the computation time, the model and computation domain are shown in Fig.1and Fig.2

Tab.1 Main parameters of hull

Length overall(m)	Length between perpendiculars (m)	Breadth(m)	Draught(m)	Block coefficient
49.5	43	8.2	3.8	0.693

Fig.1 The computational model of hull

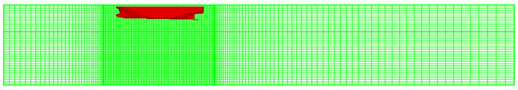

Fig.2 Grid of computational domain

Grid generation is a crucial step of numerical simulation. In order to get more accurate results, the computational domain is divided into three grid regions. The grids are refined near the hull and sparser far away which can keep a good grid transition, as shown in Fig 2. Due to the large curvature, the shape is very complicated of bow and tail. It is easy to generate a large wave, therefore, the grid are refined at bow and tail, as show in Fig.3.

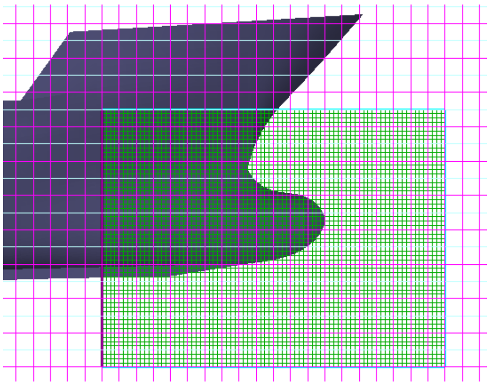

Fig.3 Grid refined of bow

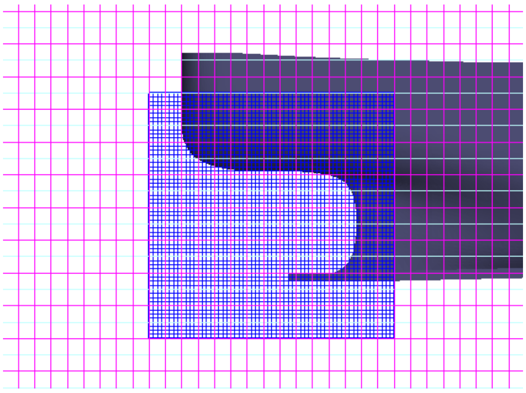

Fig.4 Grid refined of tail

Calculation results and verification

The resistance performance of hull in different speeds is simulated, numerical simulation results and experimental results are shown in Tab.2. V_s is the speed of actual ship, V_m is the speed of model in Tab.2. Put the numerical simulation results and experimental results draw into curve, as indicated in Fig.5.

Tab.2 Calculation results and experimental results

Vs (kn)	3.0	5.0	7.0	9.0	10.0	11.5	12.0	14.0
Vm (m/s)	0.4414	0.7357	1.03	1.3242	1.4714	1.6921	1.7657	2.0599
Experimental results(N)	1.6983	4.7599	9.2228	15.7623	19.9227	33.5199	41.2129	69.5918
Calculation results(N)	1.6128	4.5632	8.9443	15.2574	19.2327	32.4246	39.4814	66.3667
Deviation (%)	-5.03	-4.13	-3.02	-3.20	-3.47	-3.27	-4.20	-4.63

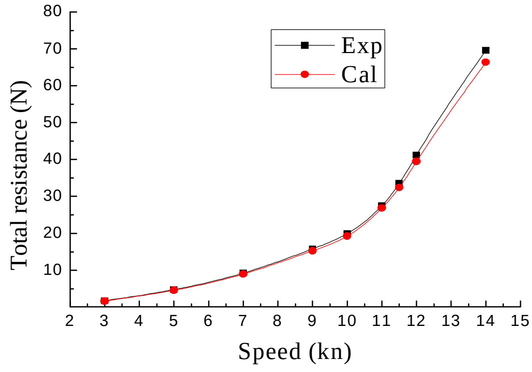

Fig.5 Comparison curve of resistance

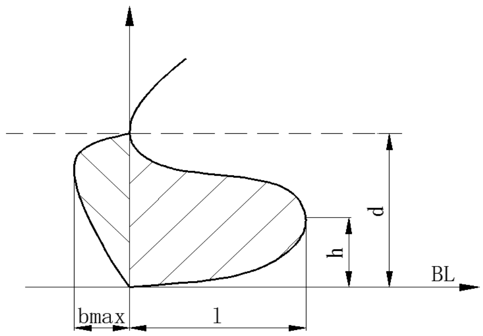

Fig.6 Shape parameter of bulbous bow

From tab.2 and fig.5 we can see, the total resistances of numerical calculation are consistent with experimental values, which shows that the establishment of numerical model, selection of turbulence model, setting of boundary condition and choice of solver are reasonable. Therefore, CFD technology has good feasibility in the resistance performance forecast of this type of longline fishing vessel.

Influence of bulbous bow parameters on the resistance performance

The shape parameter of bulbous bow is expressed by the following parameters, as Fig.6. Relative extend length *l/lpp*, relative depth *h/d* and maximum width ratio *bmax/B*. where, *l* is the distance from the front of bulbous bow to stem. *lpp* is the length between perpendiculars. *h* is the distance from the front of bulbous bow to basic line, *d* is draught. *bmax* is the maximum width of bulbous section in stem, *B* is breadth.

Influence of bulbous bow relative extend length on the resistance performance

Adopt the method of bulbous bow front whole move to realize the relative extend length changes of bulbous bow, which can obtain different bulbous bow length. This method did not change the bulbous bow in the direction of the captain of the linear scale and can ensure the relative height, maximum width of bulbous bow not to change. This paper take bulbous bow shorten 15%, increase 25% and increase 50% to study the influence of bulbous bow relative extends length on the resistance performance. The 3D model are presented in Fig7～10.

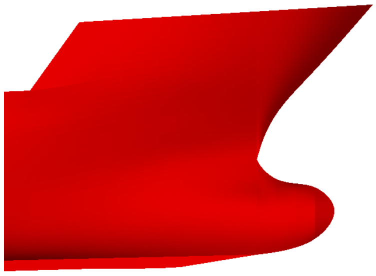

Fig.7 Original bulbous bow

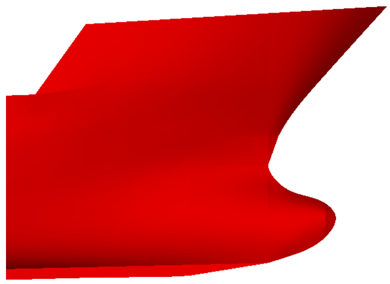

Fig.8 Relative length shorten 15%

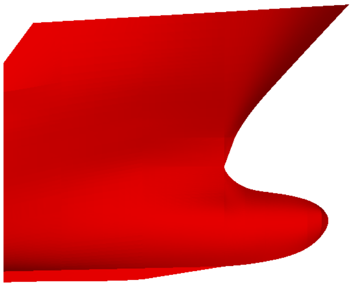

Fig.9 Relative length add 25%

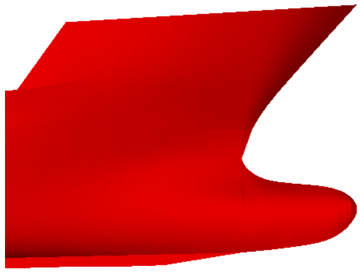

Fig.10 Relative length add 50%

Using numerical simulation method to calculate the hull resistance of three bulbous bow form in all kinds of speed. The calculation results as shown in Tab.3. *Vs* is the speed of actual ship, *Vm* is speed of ship model.

Tab.3 Numerical calculation results of different relative extend length

Vs(kn)	Vm(m/s)	Total resistance(N)			
		Original length	Shorten 15%	Add 25%	Add 50%
3.0	0.4441	1.6128	1.6564	1.5872	1.5764
5.0	0.7357	4.5632	4.6711	4.4817	4.4527
7.0	1.03	8.9443	9.2463	8.7824	8.7014
9.0	1.3242	15.2574	15.7682	14.9135	14.8201
10.0	1.4714	19.2327	20.0275	18.7836	18.5412
11.0	1.6185	26.8659	27.8533	26.2214	25.6896
11.5	1.6921	32.4246	33.4245	31.5270	30.9145
12.0	1.7657	39.4814	40.7817	38.0763	37.6078
14.0	2.0599	66.3667	68.4028	63.8245	63.0235

As shown in Tab.3, it has a big influence on the total resistance of the relative extend length of bulbous bow for this type of tuna longline vessel. The hull total resistance can reduced by 5.04% when the length add 50% while the total resistance may increase when the length shorten 15%. Therefore, increasing the length of bulbous bow can reduce the total resistance and with the increase of speed, the drag reduction effect more apparent.

Influence of bulbous bow relative depth on the resistance performance

In order to get bulbous bow of different relative depth, changing the distance from bulbous bow front point to the baseline in keeping the other parameters unchanged, then according to the trend of bulbous bow shape lines to determine the height of each body lines, finally, smoothing the shape lines of whole bulbous bow. The relative depth of origin bulbous bow is 0.58, the other two are 0.5 and 0.65. bulbous bow model are shown in Fig.11～13.

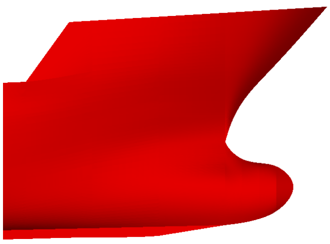

Fig.11 Relative depth 0.58

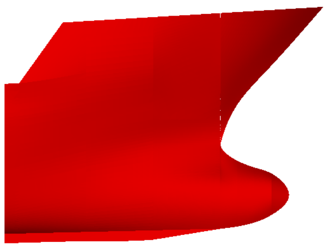

Fig.12 Relative depth 0.5

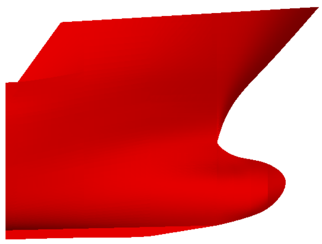

Fig.13 Relative depth 0.65

The resistance calculation results of different relative depth are shown in Tab.4, *Vs* is the speed of actual ship, *Vm* is speed of ship model.

Tab.4 Numerical calculation results of different relative depth

Vs(kn)	Vm(m/s)	Total resistance(N)		
		Relative depth0.58	Relative depth 0.5	Relative depth 0.65
3.0	0.4441	1.6128	1.6422	1.5942
5.0	0.7357	4.5632	4.6163	4.5247
7.0	1.03	8.9443	9.0576	8.8629
9.0	1.3242	15.2574	15.4117	15.0234
10.0	1.4714	19.2327	19.4324	19.0426
11.0	1.6185	26.8659	27.3218	26.7004
11.5	1.6921	32.4246	32.7846	31.9201
12.0	1.7657	39.4814	39.9094	39.0265
14.0	2.0599	66.3667	67.1571	65.3327

From the calculation results we can see that relative depth of bulbous bow has little influence on the resistance of longline fishing vessel. For this type of vessel, the total resistance will decreases with the increase of relative depth of bulbous bow. But due to the lots of space constraints in ship design, and considering the manufacturing process and strength of bulbous bow, the relative depth can't increase without limit. Here take 0.65 is relatively large, while the total resistance only reduced about 1% compared to the origin model. Therefore, for this type of vessel, select appropriate relative depth can reduce the total resistance of the hull, but the effect is not obvious.

Influence of bulbous bow maximum width ratio on the resistance performance

In order to get bulbous bow of different maximum width ratio, firstly, changing the maximum width of bulbous bow transverse section at stem in keeping the other parameters unchanged, then according to the trend of bulbous bow shape lines to determine the width of each body lines, finally, smoothing the shape lines of whole bulbous bow. The maximum width ratio of origin bulbous bow is 0.175, the other two are 0.155 and 0.206. bulbous bow model are shown in Fig.14～16.

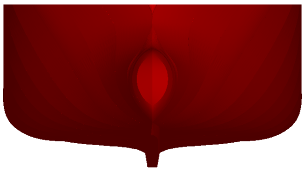
Fig.14 maximum width ratio 0.175

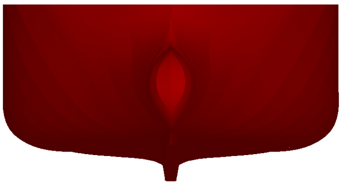
Fig.15 maximum width ratio 0.155

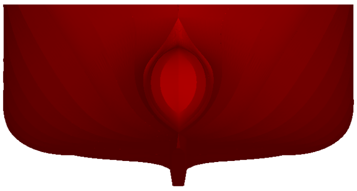
Fig.16 maximum width ratio 0.206

The resistance calculation results of different maximum width ratio are shown in Tab.5, *Vs* is the speed of actual ship, *Vm* is speed of ship model.

Tab.5 Numerical calculation results of different maximum width ratio

Vs(kn)	Vm(m/s)	Total resistance(N)		
		Maximum width ratio 0.175	Maximum width ratio 0.155	Maximum width ratio 0.206
3.0	0.4441	1.6128	1.6214	1.6016
5.0	0.7357	4.5632	4.6045	4.5292
7.0	1.03	8.9443	9.0116	8.8823
9.0	1.3242	15.2574	15.3753	15.1275
10.0	1.4714	19.2327	19.3641	19.0425
11.0	1.6185	26.8659	27.0637	26.6517
11.5	1.6921	32.4246	32.6108	32.2821
12.0	1.7657	39.4814	39.6725	39.2859
14.0	2.0599	66.3667	66.8038	66.0450

As shown in Tab.5, with the increase of maximum width ratio of bulbous bow, the total resistance will be gradually reduced for this type of longline fishing vessel. This article take the maximum width ratio of 0.206 is relatively large, but compare with the origin model, the total resistance reduced less than 1%, which express that the influence on the total resistance of maximum width ratio of bulbous bow is very small.

Conclusion

In this paper, the influence of the bulbous bow parameters on the total resistance are obtained. For this type of longline fishing vessel, adding the relative extend length of bulbous bow can reduce the total resistance, and with the increase of vessel speed, the effect more obvious. Increasing the relative depth and maximum width ratio can reduce the total resistance, but the effect is very small. Therefore, this type of vessel may be increase the three bulbous bow parameters of relative extend length, relative depth and maximum depth ratio, but also should be considering the ship general arrangement, driving safety, bulbous bow strength and cost to design the appropriate bulbous bow.

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