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A Study on the Effect of Different Types of Bulbous Bow on Resistance of a Fishing Boat Using Maxsurf

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Abstract:
Bulbous bows are used to reduce the resistance of fishing boats. The aim of this study is to determine the type of bulb which will be more effective in reducing total resistance on fishing boats. In this study, a conventional fishing boat hull without bulbous bow is taken and its resistance is found using MAXSURF software at different Froude numbers. Delta (Δ), Nabla (∇) and Elliptical (O) bulbs were added to the hull form and the corresponding resistance characteristics of each bulb was predicted. The results were compared to show the effect of bulbous bows on resistance of fishing boats.

Keywords: *Fishing boat, Hull shape optimization, Bulbous Bow, Hull resistance, Maxsurf*

I. INTRODUCTION

A bulbous bow extends outwards at the forward part of the hull below the waterline. This forward extension is generally two times the width of the base. They do not extend beyond the foremost tip of the bow. The position of the bulb is an important factor in deciding the phase difference of the waves created due to the bow and the bulb. The volume of a bulb is an important factor in determining the amplitude of the resultant wave due to the superposition of the bow wave and the bulb wave. There are three basic types of bulb geometry, namely, Delta (Δ), Circular-Elliptic (O) and Nabla (∇) sections. Energy efficiency is of great importance in the fishing industry because the fuel cost accounts for up to 30% of the total value of the catch [3]. Hence, it is essential to explore ways to reduce the fuel consumption. Resistance reduction due to bulbous bow was reported in the literature is about 10-20%.

II. VESSEL DIMENSIONS

The vessel which has been selected for this study is a conventional fishing boat whose hull form has been generated using Quick Start design in MAXSURF. Quick Start design allows us to quickly generate a basic design which is a good starting point for this study. The vessel has a design speed of 10 knots. The principal particulars of the vessel are given in Table 2.1.

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Table 2.1 Principal Particulars of the fishing boat

LOA	**20.00 m**
Breadth	**06.00 m**
Depth	**03.50 m**
Draft	**01.70 m**
C_B	**0.41**

Body Plan:

The vessel is having hard chine hull. It is also having a deadrise angle of 19 degrees. The 3D model of the vessel is shown in Fig.2.1. The body plan of the vessel is given in Fig 2.2

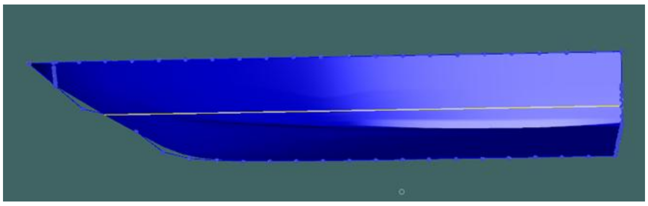

Fig 2.1. 3D model of the fishing boat

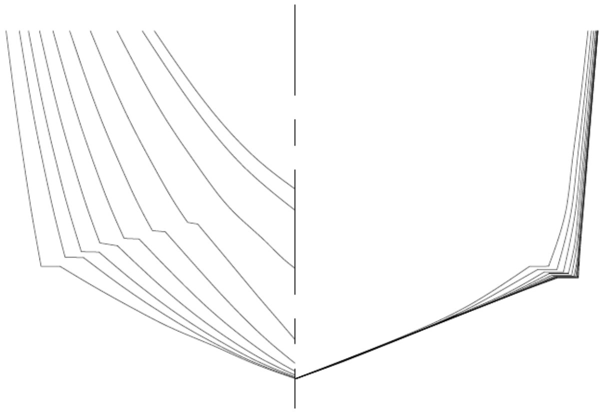

Fig 2.2. Body Plan of the fishing boat

Sectional Area Curve:

The sectional area curve of the vessel provides the data regarding the cross-sectional area for each unit length. The sectional area curve is shown in Fig. 2.3.

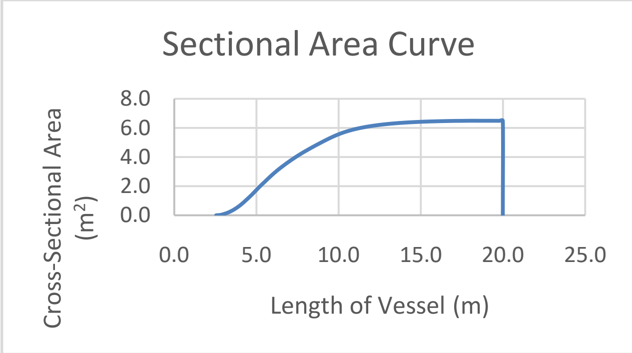

Fig. 2.3. The sectional area curve of the fishing boat

III. BULBOUS BOW

Bulbous bows have long been used in large ships to reduce fuel consumption. When larger vessels successfully used bulbous bows, smaller vessels started to explore the possibility of using bulbous bows. The desire for economy among the fishing fleets meant more attention was given to the optimization of bulbous bow for fishing boats [2]. The effectiveness of the bulbous bow tends to decrease for vessels below 60feet long [4]. Bulbous bow must be designed with precision by selecting specific bulb configurations to obtain maximum benefit. Bulbous bows are designed for a narrow range of speeds. Bulbous bows are generally useful when operating at Froude numbers ranging from 0.238 to 0.563.

Advantages of bulbous bow:

- Works as a protective "bumper" in case of a collision[8].
- Better course-keeping ability
- Bulbous bows can accommodate bow thrusters.
- Better seakeeping characteristics
- Advantageous when navigating through ice

The three basic types of bulb geometry, namely, Delta (Δ), Circular-Elliptic (O) and Nabla (∇) sections are given by Kracht,1978[1].

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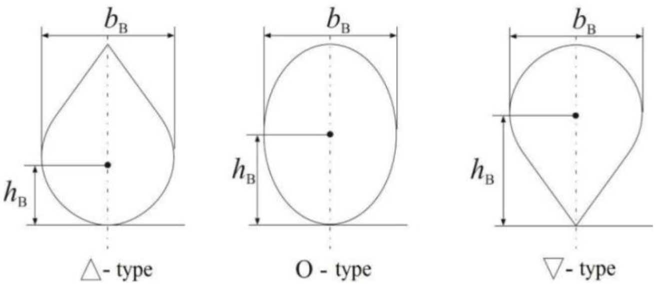

Fig 3.1 Types of bulbous bow[1]

Each of these profiles have their own advantages and disadvantages with respect to seakeeping and resistance characteristics. In this study, only the resistance aspect has been considered.

Linear and non-linear bulb parameters can be used to describe the shape of the bulbous bow.

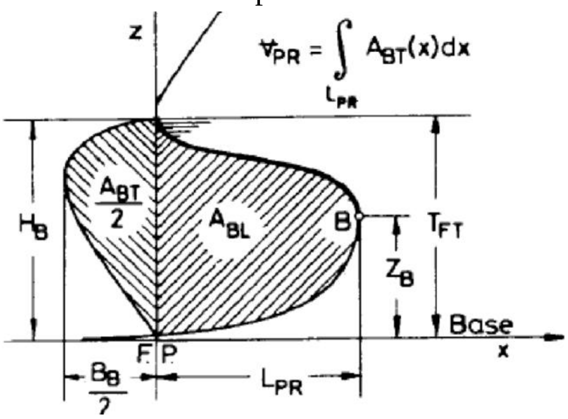

Fig 3.2 Bulb parameters[1]

Linear bulb parameters: $C_{BB} = B_b/B_{MS}$

$C_{LPR} = L_{PR}/L_{PP}$

$C_{ZB} = Z_B/ T_{FP}$

Non-linear bulb parameters: $C_{ABT} = A_{BT}/A_{MS}$

$C_{ABL} = A_{BL}/A_{MS}$

$C_{VPR} = V_{PR}/ V_{WL}$

Where, B_B is maximum breadth of bulb cross section,

B_{MS} is breadth of the ship,

L_{PR} is protruding length of the bulb,

L_{PP} is the length between perpendiculars,

Z_B is the height above baseline at the foremost point of the bulb,

T_{FP} is the draft at FP, A_{BT} is the cross-sectional area of the bulb,

A_{MS} is the cross-sectional area at midship,

A_{BL} is the area of the bulb in the longitudinal plane,

V_{PR} is the volume of the protruding part of the bulb and

V_{WL} is the volume of displacement of the ship.

The linear and non-linear parameters of each bulb chosen for this study is according to Kracht,1970[5]. These values have been summarized in Table3.1.

	DELTA	NABLA	ELLIPTICAL
C_{BB}	0.17	0.17	0.17
C_{LPR}	0.03	0.03	0.03
C_{ZB}	0.3	0.5	0.55
C_{ABT}	0.09	0.09	0.09
C_{ABL}	0.14	0.14	0.14
C_{VPR}	0.0025	0.0024	0.0027

Table 3.1 Linear and non-linear bulb parameters

Offset table:

The breadthwise and lengthwise offsets of each bulb is listed in Table 3.2. All values are in metres.

		0.0T	0.1T	0.2T	0.3T	0.4T	0.5T	0.6T	0.7T	0.8T	0.9T	1.0T
Delta	B	0	0.16	0.31	0.354	0.28	0.19	0.12	0.07	0.04	0.02	0
	L	0	0.53	0.67	0.70	0.65	0.55	0.38	0.22	0.09	0.02	0
Nabla	B	0	0.01	0.03	0.07	0.12	0.19	0.28	0.35	0.34	0.24	0
	L	0	0.16	0.33	0.48	0.61	0.71	0.78	0.83	0.81	0.62	0
Elliptical	B	0	0.21	0.28	0.32	0.34	0.35	0.34	0.32	0.28	0.21	0
	L	0	0.40	0.63	0.74	0.81	0.84	0.81	0.72	0.57	0.34	0

Table 3.2 Offset table of different bulbous bow

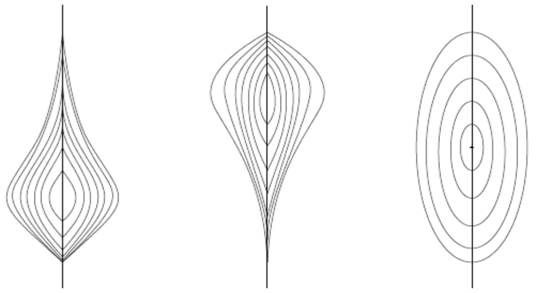

Fig 3.3 Cross sectional view of the bulbs

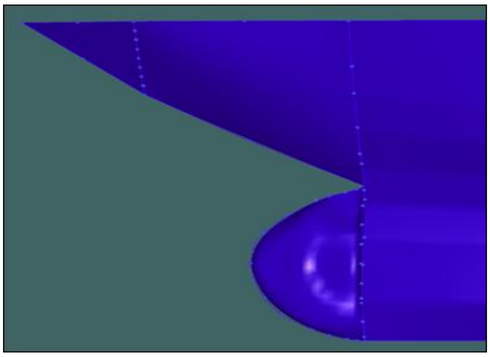

Fig 3.4 3-D model of Elliptical Bulb

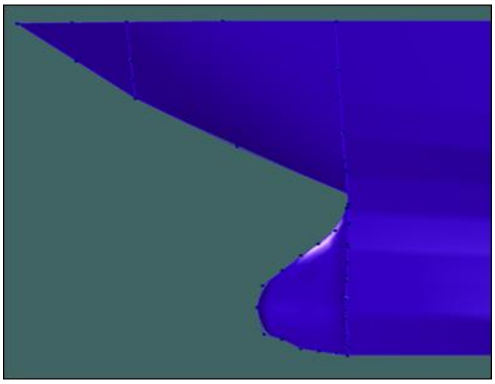

Fig 3.4 3-D model of Delta Bulb

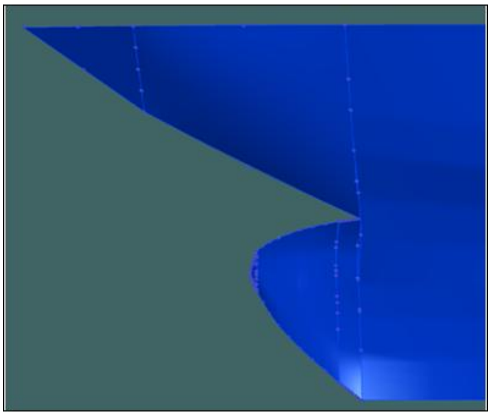

Fig 3.4 3-D model of Nabla Bulb

IV. RESISTANCE PREDICTION METHOD

When a ship tries to move through water, it experiences hydrodynamic forces. The resistance forces acting on the ship can be broadly classified into two types: frictional resistance and residuary resistance. The friction between the water and the hull surface causes frictional resistance. At the very low speeds, the residuary resistance is less significant. As the velocity increases, wave resistance forms a significant part of the total resistance. Viscous pressure resistance is created due to flow separation and is usually small when compared wave resistance.

Ships create both transverse and divergent waves. Divergent waves do not cause much resistance against the motion of the ship. However, transverse waves appear as crests and troughs along the length of the ship and make up the significant portion of wave making resistance.

Bulbous bows are helpful in reducing wave making resistance. The wave created by the bulb

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should be such that it cancels out the bow wave of the ship, thereby reducing the wave elevation of the resultant wave. This means that lesser energy is dissipated in the form of waves and hence power consumption is also lesser.

However bulbous bows increase the wetted surface area and hence contribute to an increase in frictional resistance. The reduction in wave making resistance must account for this increase in frictional resistance.

Total resistance is normally broken down into a Froude number dependent component – wave resistance (residuary resistance) and a Reynolds number dependent component – viscous resistance (friction resistance).

Total resistance = Wave + Viscous resistance or

Total resistance = Frictional resistance + residuary resistance

Typically, the friction resistance is predicted using the ITTC'57 ship-model correlation line or some similar formulation.

The viscous resistance includes a form effect applied to the friction resistance thus:

Viscous resistance = (1 + k) Friction resistance

where (1 + k) is the form factor.

Resistance of a ship is calculated in the absence of waves. In real life, the presence of waves will increase the resistance acting on the ship. This is known as added resistance. Hence, a sea margin of 15- 30% is added to the total resistance.

In general, there are three main methods forpredicting the resistance of a ship:

1. Experimental methods
2. Empirical methods
3. Numerical methods

Resistance of ships can be found using model tests. The model is made by following scaling laws. Several regression-based methods can be used to predict the resistance of the hull form. Computational fluid dynamics (CFD) softwarecan also be used to predict the resistance acting on the hull in a fast and efficient manner.

At high Froude numbers, there are non-linearities in wave pattern, spray formation and wave breaking effects [3]. These effects are neglected by practical flow solvers which are based on potential flow theory. MAXSURF uses potential flow theory and hence does not account for viscous effects of water.

V. RESISTANCE PREDICTION USIING MAXSURF

The maxsurf resistance module helps the user to predict the bare hull resistance of the vessel. Once the hull is imported to the software, using the resistance prediction algorithms for ananalysis the results are obtained for various speeds. The maxsurf resistance module is much compliance with a wide range of monohull, catamaran and trimaran. The algorithms are used for calculating the resistance for planning vessel, yachts and displacement hulls. There are number of regression-based methods and an analytical knowns slender body. For the analytical method the Maxsurf uses panel method which is based on potential flow theory, which states that the flow is considered as ideal, having properties such as irrotational, non-viscous. Hence the resistance based on analytical method (slender body) will not consider the resistance due to the viscous force (frictional resistance). The"Maxsurf resistance" also can calculate the components of resistance in coefficient forms.

The regression method opted to find the bare hull resistance is Holtrop Mennen. This method is used to find the resistance of displacement hulls such as Tankers, Bulk Carriers, Containers, Fishing Vessel, Tugs, Frigates. The total resistance calculated using Holtrop Mennen method can be broken down into Frictional Resistance, Residuary Resistance, Wave-Making Resistance, Resistance due to Correlation Allowance, Appendage Resistance, Air Resistance. In this method, the wave resistance considers the transom and bulb effect also[7].

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VI. RESULTS AND DISCUSSIONS

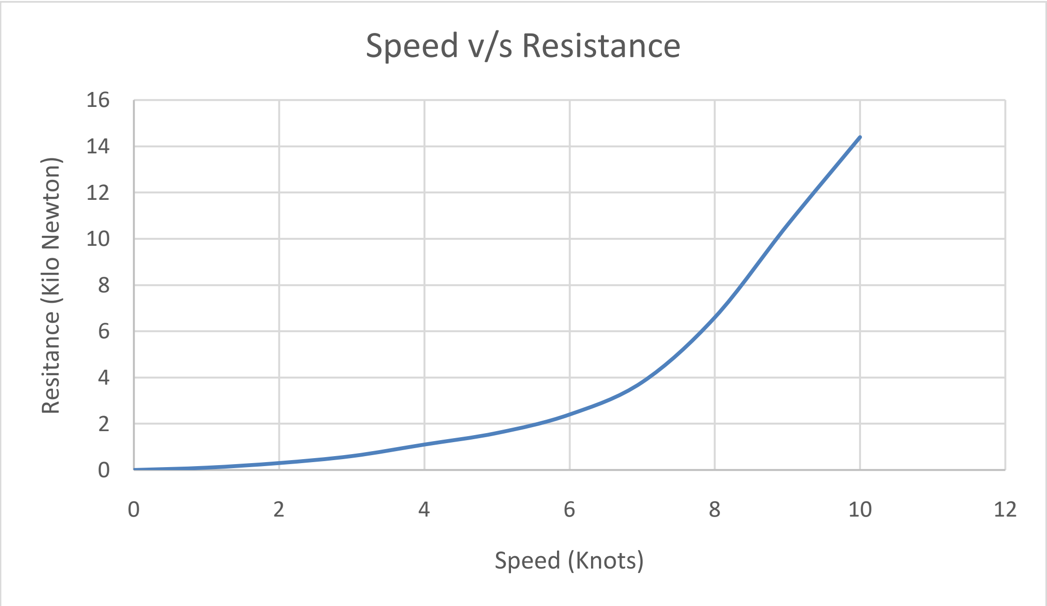
The resistance is calculated for bare hull, Fishing boat without bulb, with Delta, Nabla, Elliptical bulbs using Holtrop Mennen method. The resistance is found for various Froude numbers. The results obtained for Delta, Nabla and Elliptical bulbs have been compared with each other and with the bare-hull resistance without bulb.

6.1 FISHING BOAT WITHOUT BULB

The resistance of the fishing boat without bulb was predicted using Maxsurf resistance module. The resistance at various speeds is given in the Table.6.1.1 and the Graph 6.1.1.

Froude Number (Fn)	Velocity (V_s) (knots)	Resistance (R_T) (kN)
0	0	0
0.039	1	0.1
0.079	2	0.3
0.118	3	0.6
0.157	4	1.1
0.197	5	1.6
0.236	6	2.4
0.275	7	3.8
0.315	8	6.6
0.354	9	10.6
0.393	10	14.4

Table 6.1.1 Total Resistance at different Froude Number for Hull without bulb



Graph 6.1.1 Speed v/s Total Resistance for fishing boat without bulb

6.2FISHING BOAT WITH DELTA BULB

The resistance of the fishing boat with Delta bulb was predicted using Maxsurf resistance module. The resistance at various speeds is given in the Table.6.2.1 and the Graph 6.2.1

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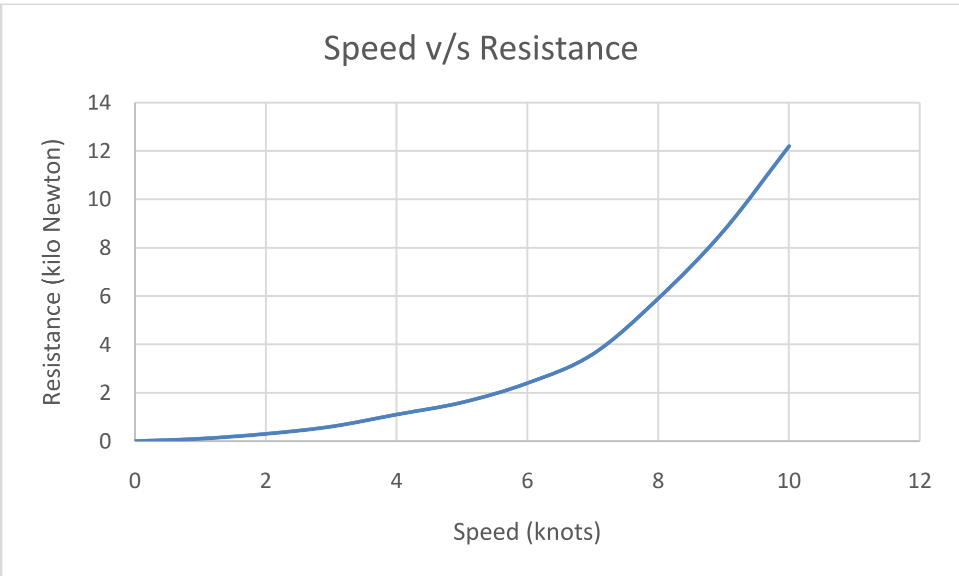
Froude Number (Fn)	Velocity (V_s) (knots)	Resistance (R_T) (kN)
0	0	0
0.039	1	0.1
0.079	2	0.3
0.118	3	0.6
0.157	4	1.1
0.197	5	1.6
0.236	6	2.4
0.275	7	3.6
0.315	8	5.9
0.354	9	8.7
0.393	10	12.2

Table 6.2.1 Total Resistance at different Froude Number for Hull with delta bulb



Graph 6.2.1 Speed v/s Total Resistance for fishing boat with delta bulb

6.3 FISHING BOAT WITH NABLA BULB

The resistance of the fishing boat with Nablabulb was predicted using Maxsurf resistance module. The resistance at various speeds is given in the Table.6.3.1 and the Graph 6.3.1.

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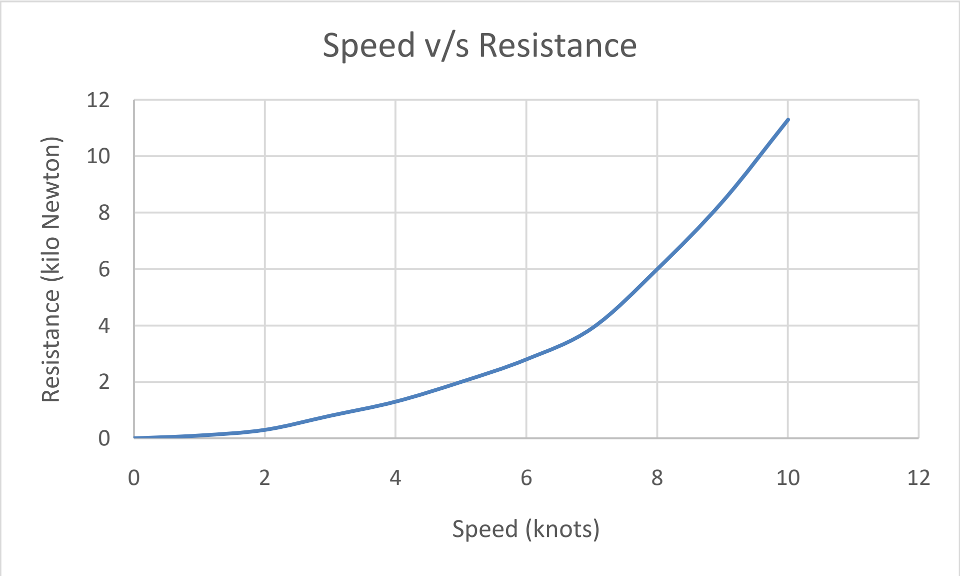
Froude Number (Fn)	Velocity (V_s)	Resistance (R_T)
	(knots)	(kN)
0	0	0
0.039	1	0.1
0.079	2	0.3
0.118	3	0.8
0.157	4	1.3
0.197	5	2.0
0.236	6	2.8
0.275	7	3.9
0.315	8	6.0
0.354	9	8.4
0.393	10	11.3

Table 6.2.1 Total Resistance at different Froude Number for Hull with Nabla Bulb



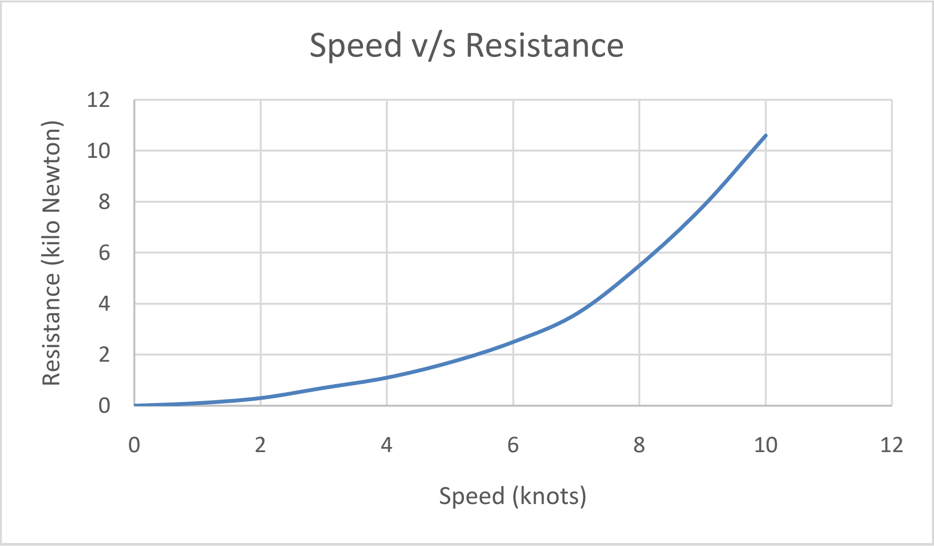
Graph 6.3.1 Speed v/s Total Resistance for fishing boat with Nabla bulb

6.4 FISHING BOAT WITH ELLIPTICAL BULB

The resistance of the fishing boat with Elliptical bulb was predicted using Maxsurf resistance module. The resistance at various speeds is given in the Table.6.4.1 and the Graph 6.4.1.

Froude Number (Fn)	Velocity (V_s) (knots)	Resistance (R_T) (kN)
0	0	0
0.039	1	0.1
0.079	2	0.3
0.118	3	0.7
0.157	4	1.1
0.197	5	1.7
0.236	6	2.5
0.275	7	3.6
0.315	8	5.5
0.354	9	7.8
0.393	10	10.6

Table 6.4.1 Total Resistance at different Froude Number for Hull with Elliptical Bulb



Graph 6.4.1 Speed v/s Total Resistance for fishing boat with Elliptical bulb

6.5 COMPARISON OF RESULTS

The resistance of all the hulls were compared with each other to determine the most efficient bulb for this fishing boat. It can be inferred from the graph that there is a significant decrease in total resistance of bare hull with bulb for Froude numbers greater than 0.33.

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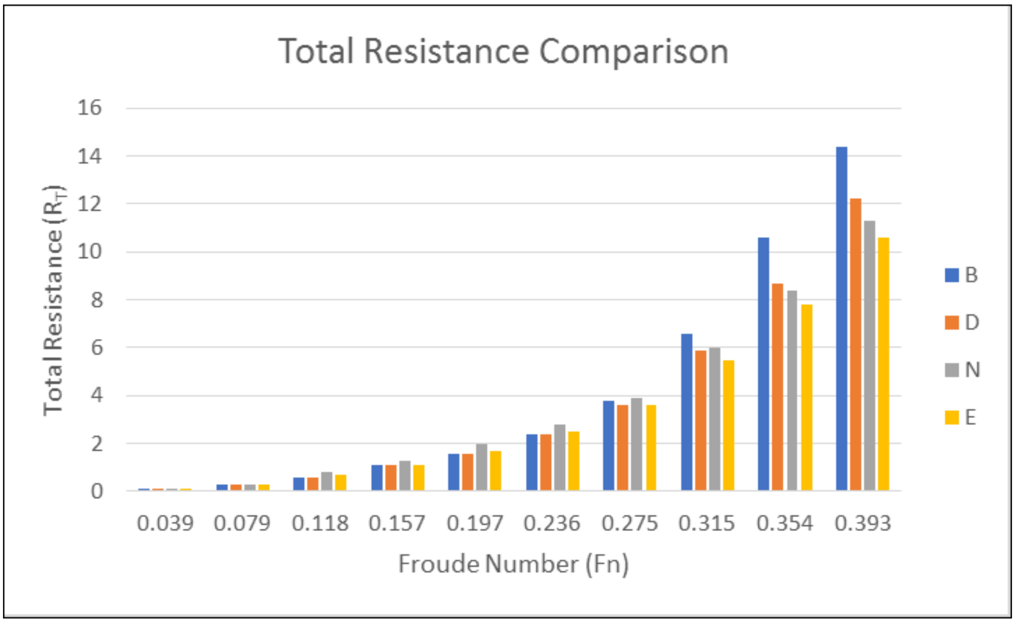

Table 6.5.1 Comparison of Total resistance with and without bulbous bow

B – Without Bulb; D – With Delta Bulb; N – With Nabla Bulb; E – With Elliptical Bulb

Hull model with Elliptical bulb is having the least total resistance when compared to hull forms with other bulbs.

$$\text{Percentage Reduction in Total Resistance} = \frac{R_T\,(\text{without bulb}) - R_T\,(\text{with bulb})}{R_T\,(\text{without bulb})} * 100$$

The percentage of reduction in R_T with Elliptical bulbatFr no .393= [(14.4 – 10.6)/14.4] *100 =26.38 %

The percentage of reduction in R_T with Nabla bulb at Fr no .393 = [(14.4 – 11.3)/14.4] *100 = 21.52 %

The percentage of reduction in R_T with Delta bulb at Fr no .393 = [(14.4 – 12.2)/14.4] *100 = 15.27 %

It is observed that forFr no 0.275 both elliptical and delta is more efficient than hull without hull and with Nabla bulb. After Fr no. 0.227 the hull with Elliptical bulb is providing the least resistance. From Fr no 0.039 to 0.275 the hull with Nabla bulb offers more resistance than other hull forms with other bulb forms and without bulb.

VII. CONCLUSION

Therefore, bulbous bows can be used to provide a significant reduction in fuel consumption. Bulbous bows can be used by fishing boats to comply with strict Energy Efficient Design Index (EEDI) regulations by International Maritime Organisation (IMO) which may be implemented in near future. Thus, bulbous bows can be considered as an energy saving option for fishing boats.

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