

Development of Catamaran Fishing Vessel

D. Setyawan¹, I K. A. P. Utama¹, Murdijanto¹, A. Sugiarto¹, and A. Jamaluddin²

Abstract—Multihull due to a couple of advantages has been the topic of extensive research work in naval architecture. In this study, a series of investigation of fishing vessel to save fuel energy was carried out at ITS. Two types of ship models, monohull (round bilge and hard chine) and catamaran, a boat with two hulls (symmetrical and asymmetrical) were developed. Four models were produced physically and numerically, tested (towing tank) and simulated numerically (CFD code). The results of the two approaches indicated that the catamaran mode might have drag (resistance) smaller than those of monohull at the same displacement. A layout of catamaran fishing vessel, proposed here, indicates the freedom of setting the deck equipments for fishing vessel.

Keywords—monohull, catamaran, resistance, energy saving

I. INTRODUCTION

In the last three decades, there has been a significant increase on the use of multihull vessels for various applications such as ferries, fishing vessels, sporting craft, and oceanographic research vessel [12]. The principle advantages of these vessels compared to monohull are more attractive layout accommodation, better transverse stability, and in certain case lower total resistance as well as the size of main engine [4, 10]. Various types of vessel are further developed to satisfy the design criteria. Among others, the concept of catamaran is preferred and becoming more popular [10]. Pal and Doctors [8] developed a preliminary design method to provide accurate solution of catamaran passenger vessel operated in the river.

The calculation of power required by the catamarans needs an investigation into the resistance characteristics entirely in order to obtain the most by ship design [7, 10]. The resistance of catamaran can provide complex phenomena to ship designers particularly with the appearance of interaction between the semihull of catamaran. Therefore, it has been a basic need to obtain the breakdown and understanding of correct ship resistance components in order to obtain accurate calculation based on scaling transformation from model to the real ship.

A systematic investigation has been made by Insel and Molland [4] showing that there is a certain separation between 2 demihulls causing very small interaction or in practice it can be said that there is no interaction [4]. The small interaction occurs at separation to length ratio (S/L) of 0.4 and 0.5 and this provides an idea that a catamaran with similar displacement comparable to monohull could have smaller or equal resistance and hence power of main engine.

The most widely used estimation of catamaran resistance is the method proposed by Insel and Molland [4]. In this case, catamaran hull consists of 2 isolated demihulls and creates wave and viscous resistance interference and formulated as follows:

$$C_T = (1 + \phi k) \sigma C_F + \tau C_W \quad (1)$$

where C_T is total resistance coefficient, C_F is frictional resistance coefficient, from ITTC-1957 correlation line ($C_F = 0.075 / \log(R_N - 2)^2$), C_W is wave resistance coefficient of isolated demihull, $(1+k)$ is form factor value of isolated demihull, ϕ is used to estimate the change of pressure around demihull, and σ represents additional velocity between demihulls and calculated from the summation of local frictional resistance around wetted surface area.

In fact, the factors of ϕ and σ are difficult to measure hence for the practical purposes, the two factors can be combined to form viscous resistance interference factor (β) where $(1 + \phi k) \sigma = (1 + \beta k)$ hence:

$$C_T = (1 + \beta k) C_F + \tau C_W \quad (2)$$

where for monohull or demihull at isolation the value of both β and τ is one. This study performs a series of experimental tank test and CFD simulation to determine the resistance characteristics of monohull form (round bilge and hard chine) and catamaran form (symmetrical and asymmetrical). The resistance results of these hull forms were compared to know whether the power efficiency of catamaran could be gained for the development of catamaran fishing vessels. This power efficiency will in turn, save the use of fuel energy. Furthermore, the computed resistance is compared to experimental tests for better understanding of the capability of CFD code in predicting the total resistance.

II. METHOD

The investigation was carried out both experimentally and numerically. The experimental work was conducted using towing tank and 4 ship modes were applied, namely monohulls (hard-chine and round-bilge) and catamarans (symmetric and asymmetric) and tested at various space to length (S/L) ratios. The demihulls were usually positioned abreast of each other, with a distance between the centre lines S (Fig. 1a and 1b). The asymmetrical demihull was arranged such that the hull width is a half of the symmetrical hull with the flat sides facing inwards.

The displacement for both symmetrical and asymmetrical demihull was kept constant; consequently each hull had a different draught (T) and Wetted Surface Area (WSA). The numerical work was carried out using commercial design software (Maxsurf and Ansys CFX). The models were tested at speed equal to the speed of real vessel at open sea from about 5 to 10 knots and the Froude numbers were about 0.24 to 0.48 or from low speed to medium speed condition. In the case of catamaran model, separation between the hulls (S/L) was taken as 0.2, 0.3 and 0.4 [4,12].

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Principal particulars of the four vessels are given in Tables 1 to 4. Physical models of the monohull and catamaran are shown in Fig. 2 to 5. The models are made from Fibreglass Reinforced Plastics (FRP) in order to obtain appropriate displacement as scaled from full ship mode in accordance with froude law of similarity.

III. RESULT AND DISCUSSION

Weibull statistical distribution function has been Traditional methods to predict resistance on real hulls are based on towing tank models running at corresponding Froude numbers and then scaling results taking into account a friction line for the respective Reynolds number. Advantages of these methods are the knowledge and experience acquired through the years that make results reasonably trustworthy. The disadvantages are the asso-iated cost and the limitation on the availability of physical tanks and models for every single design.

This has been one of the motivations of attempting to predict hull behaviors using computational tools, for this specific case, resistance. Although computations started in earlier 60's solving the simplified boundary layers Equations [16], followed by methods based on potential flow theories and those to solve Reynolds Navier-Stoke Equations in the last two decades [3], experimental data are still required to validate computational results.

A. Experimental Investigation

In the resistance tests the ship model is towed by carriage and the total longitudinal force acting on the model is measured by load transducer for various speeds. Turbulence stimulators are present at the bow of the ship model to stimulate transition from a laminar into a turbulent boundary layer. During the measuring run the ship model is free to heave and pitch.

In the extrapolation of the resistance test results Froude's hypothesis and similarity law are employed. In general, the resistance is scaled-up according to:

$$R_s = (R_m - R_{Fm}(1+k))\lambda^3 \frac{\rho_s}{\rho_m} + R_{FS}(1+k) + R_{allowance} = (R_m - F_D)\lambda^3 \frac{\rho_s}{\rho_m} = (R_m - F_D)\lambda^3 \frac{\rho_s}{\rho_m} \quad (3)$$

where,

$$F_D = 0.5\rho_m V^2 m S_m (1+k)(C_{Fm} - C_{Fs}) \frac{\rho_m}{\rho_s} R_{allowance} / \lambda^3$$

or

$$F_D = 0.5\rho_m V^2 m S_m \{(1+k)(C_{Fm} - C_{Fs}) \frac{\rho_m}{\rho_s} C_A\} \quad (4)$$

and $R_{allowance}$ is the resistance component supposed to allow for hull roughness, appendages on the ship but not present in the model experiment, still air drag of the ship or another additional resistance component acting on the ship but not on the model. C_A is the incremental resistance coefficient for model-ship correlation, and λ is the model scale factor.

Results of the experimental work are tabulated in Tables 5 to 8, which describe the correlation of resistance or drag against speed or Froude Number of ship. Results of CFD analysis are shown in Table 9 in which in the case of catamaran, S/L was taken 0.2.

B. CFD Analysis

The CFD code of ANSYS - CFX adopts a false time step or pseudo-time step to solve equations as a means of under relaxation. The under relaxation is necessary to

stabilize some iterative processes of obtaining steady state solutions [15]. Smaller physical time steps are more robust than larger ones [2]. Nonetheless, convergence will require more PU time. The grid quality is a fundamental for the convergence and accuracy of CFD [9]. Setting of CFD and its boundary condition are shown in Fig. 6. The ship hull was set as wall or solid body and the entrance and exit flows were set as inlet and outlet or mass flow, respectively. The separation to length (S/L) ratio was taken as 0.2 only. Three dimensional CFD model of the four hulls is shown in Fig. 7 to10.

C. Layout Development

The wider space area for fishing activities on main deck is the main concern for the commercial fishing industry now. The space area on main deck for catamaran is mostly related to the separation length ratio (S/L). Therefore this ratio need to be investigated and discussed into the resistance performance to estimate the ship speed and power required.

The large deck space is a key feature of catamaran fishing vessel, which provides an incredible amount of spaces for accommodation, bridge, engine room and massive fish storage.

Layout development of catamaran and monohull types of vessel are presented in Fig. 11 and 12. The layout shows the arrangement of fish holds and area for crew activities on the main deck.

D. Discussions

Monohull and catamaran models have been tested and simulated at Froude numbers up to 0.5. A comparison of the hard chine and round bilge forms as well as symmetrical and asymmetrical catamarans were made to evaluate the resistance (drag) characteristics. In general, the resistance results of experimental work show higher than that of CFD calculation.

Table 5 to 6 and Fig. 13 show the resistances of monohulls both hard chine and round bilge forms. The results of the resistance test analyses concerning the hard chine with dead rise of 18 deg, and round bilge form with dead rise of 12 deg, indicated that the total resistance of hard chine form is lower than that of and round bilge form for $Fr > 0.3$, where the formation of wave breaking started.

This reduction in resistance allows less horsepower to be used for a given speed, thereby increasing range and reducing engine rpm. Conversely, the round bilge form give a good resistance performance at lower speed (or lower Froude numbers).

Hard chine forms having a so called V-hull configuration have been exceptionally popular due to their desirable riding and handling characteristics, particularly in rough water. In the "V-hull" design, the hull has a continuous surface from bow to stern with a ridge down the central portion thereof, forming a "V" shape when viewed from the stern.

The deadrise of such a boat, that is, the angle between the hull surface and a horizontal plane. While the round bilges, traditional hull shape is the displacement hull, which is supported by buoyancy. However, due to the large surface area in contact with the water, the speed of such craft is limited.

Fig. 14 shows the resistance comparison of experiment and CFD simulation for symmetrical and asymmetrical

catamaran with clearance ratio $S/L = 0.2$. It is found that the resistance for asymmetrical catamaran is higher than that for symmetrical one. In addition, the experimental results are higher than CFD results. The higher the Froude numbers are, the higher the result differences will be. At lower Froude numbers, both experiment and CFD results show a good agreement.

Furthermore, Table 7 to 8 and Fig. 15 to 16 apparently indicate that the resistance is affected by the change of hull clearance (S/L) for both symmetrical and asymmetrical catamarans. The interaction effects due to clearance on the symmetrical catamaran are quite stronger, while these effects are less strong on the asymmetrical catamaran.

This interaction effects can be divided into two parts. The first, body interference: flow around a demihull is asymmetric due to the influence of other demihull or the pressure field is not symmetric relative to the centre line of the demihull. This has following overcomes the perturbation velocity around the demihull increases, especially on the inside, tunnel side, of the hull due to the venture effect. This velocity augmentation causes an increase in the skin friction resistance and modifies the form factor. Experiments of Miyazawa indicate an increase in perturbation velocity of up to 10% in the x direction compared with that of the demihull in isolation [6].

In addition, the difference wave heights at the stern inside and outside of the demihull can cause vortices and spray at the stern resulting in an induced drag component. The second effect is wave interference as a result of two hulls running side by side.

The interaction between the waves of the demihulls may occur divergent waves from other demihull become complicated [5]. Wave making of the demihulls may change by changing the hull clearance ratio (S/L).

In general, the resistance of the asymmetrical catamaran is higher than that of the symmetrical catamaran; especially being much higher at higher Froude numbers. It is also shown that the smaller the clearance (S/L), the higher the resistance and the critical Froude number becomes. This is attributed to the more intensive wave and viscous interaction between the hulls of catamaran [1]. CFD showed nearly the same results. This, in general, is in a good agreement with Utama, and Insel and Molland [7, 12, 13].

The small interactions occur at clearance ratio (S/L) of 0.4 and 0.5 [4, 11] and this provides an idea that a catamaran with similar displacement to comparable monohull could have smaller resistance and power of main engine. As a result, predictions on resistance are good way to know how the energy is spent.

Considering the resistance performance and large deck area for catamaran hull, it is a potentially good to apply for fishing vessel. The layout arrangement of catamaran demonstrated the wider space area for fishing activities on the main deck and freedom of fishermen or ship crews to install several types of equipments [14]. Furthermore, the capacity of cargo hold for catamaran vessel is larger than that of monohull fishing vessel. Fig. 11 and 12 show the general arrangement of catamaran and monohull fishing vessel.

IV. CONCLUSIONS

In this work, physical and numerical models are used for investigating both monohull and catamaran fishing vessels.

Vessel of monohull with hard chine ran faster than round bilge for the same main engine (horse) power at higher Froude number (over 0.3). The catamaran most probably offer total resistance (engine power) lowers than or equal to those monohull. Wider deck area of catamaran fishing vessel could provide the freedom of setting the deck equipments, etc.

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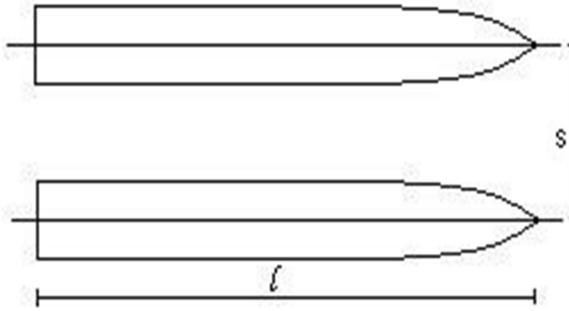


Fig. 1a. Symmetrical catamaran

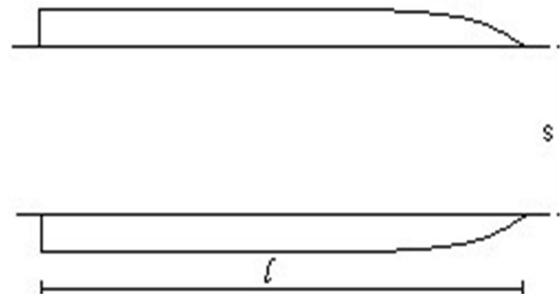


Fig. 1b. Asymmetrical catamaran

TABLE 1.
PARTICULAR OF HARD-CHINE MONOHULL

LOA = 12.9 m	LBP = 11.8 m	B = 3.0 m
H = 1.5 m	T = 0.6 m	$V_s = 8.0$ knots

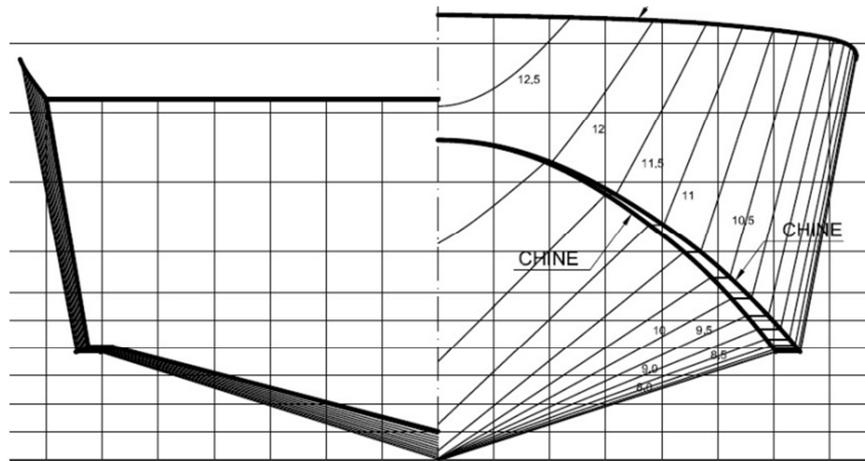


Fig. 2. Hard-chine monohull

TABLE 2.
PARTICULAR OF ROUND-BILGE MONOHULL

LOA = 12.9 m	LBP = 11.8 m	B = 3.0 m
H = 1.5 m	T = 0.6 m	$V_s = 8.0$ knots

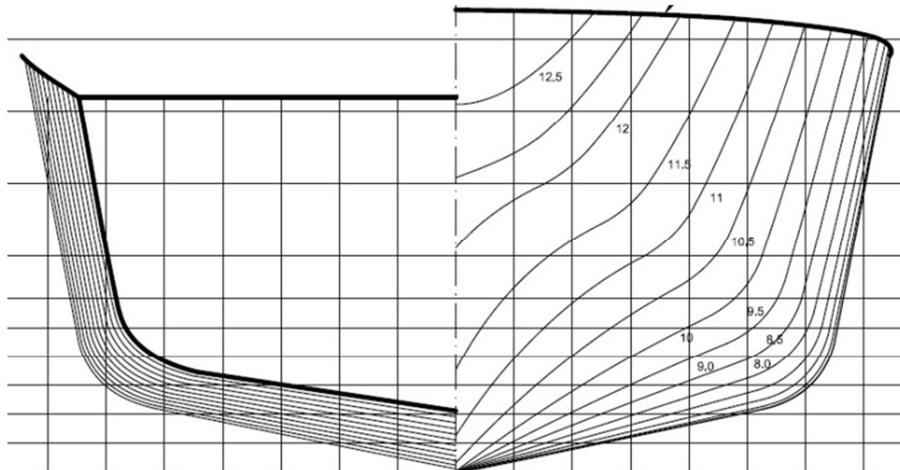


Fig. 3. Round-bilge monohull

TABLE 3.
PARTICULAR OF SYMMETRICAL CATAMARAN

LOA = 12.9 m	LBP = 11.85 m	B = 4.0 m
H = 1.5 m	T = 0.7 m	$V_s = 8.0$ knots

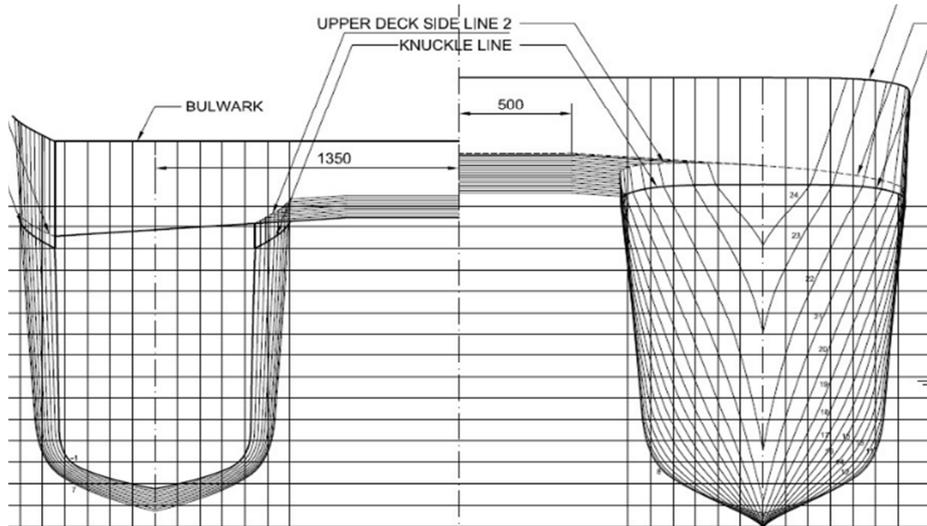


Fig. 4. Symmetrical catamaran

TABLE 4.
PARTICULAR OF ASYMMETRICAL CATAMARAN

LOA = 12.9 m	LBP = 11.8 m	B = 3.0 m
H = 1.5 m	T = 1.1 m	V _s = 8.0 knots

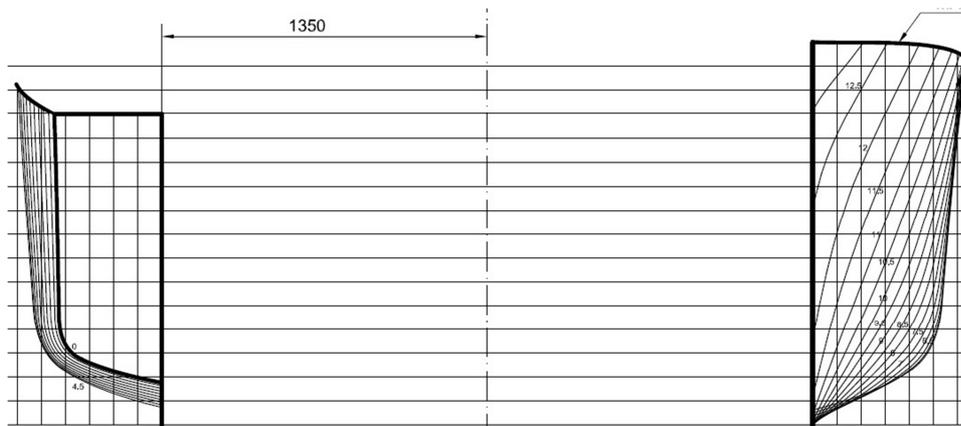


Fig. 5. Asymmetrical catamaran methodology

TABLE 5.
RESISTANCE OF HARD-CHINE MONOHULL

Run Number	Speed (knots)	Froude Number	Resistance (kN)
1	5	0.239	0.64
2	6	0.287	1.13
3	7	0.335	2.28
4	8	0.382	2.97
5	9	0.430	5.24
6	10	0.478	8.37

TABLE 6.
RESISTANCE OF ROUND-BILGE MONOHULL

Run Number	Speed (knots)	Froude Number	Resistance (kN)
1	5	0.239	0.84
2	6	0.287	1.28
3	7	0.335	1.93
4	8	0.382	2.52
5	9	0.430	4.01
6	10	0.478	5.79

TABLE 7.
RESISTANCE OF SYMMETRICAL CATAMARAN

Run Number	Speed (knots)	Froude Number	Resistance (kN)		
			S/L=0.2	S/L=0.3	S/L=0.4
1	5	0.239	1.11	1.12	1.12
2	6	0.287	1.59	1.59	1.59
3	7	0.335	2.30	2.28	2.26
4	8	0.382	2.96	2.94	2.92
5	9	0.430	4.06	4.00	3.95
6	10	0.478	5.50	5.37	5.28

TABLE 8.
RESISTANCE OF ASYMMETRICAL CATAMARAN

Run Number	Speed (knots)	Froude Number	Resistance (kN)		
			S/L=0.2	S/L=0.3	S/L=0.4
1	5	0.239	1.43	1.45	1.47
2	6	0.287	2.05	2.07	2.08
3	7	0.335	2.94	2.94	2.94
4	8	0.382	3.87	3.87	3.87
5	9	0.430	4.92	4.92	4.90
6	10	0.478	6.12	6.11	6.09

TABLE 9.
RESISTANCE RESULTS OF CFD ANALYSIS

Speed (knots)	Froude Number	Resistance (kN)			
		Hard-chine	Round-bilge	Symmetric Catamaran	Asymmetric Catamaran
5	0.239	0.55	0.45	1.19	1.47
6	0.287	0.85	0.65	1.82	2.09
7	0.335	1.21	0.99	2.59	3.49
8	0.382	1.63	1.34	4.20	5.65
9	0.430	2.97	3.34	8.11	9.20
10	0.478	4.46	5.66	10.26	12.88

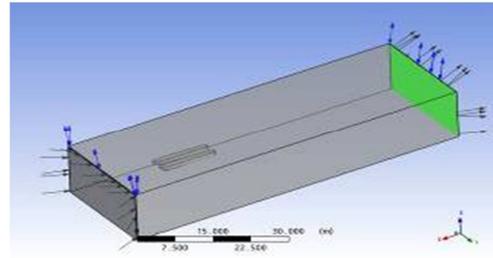


Fig. 6. Setting of CFD boundary condition



Fig. 7. 3-D CFD model of hard chine

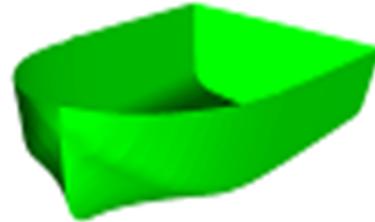


Fig. 8. 3-D CFD model of round-bilge

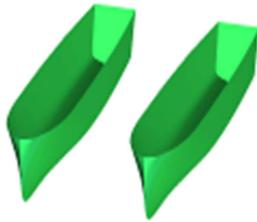


Fig. 9. 3-D CFD model of symmetric catamaran

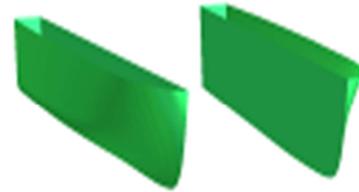


Fig. 10. 3-D CFD model of asymmetric catamaran

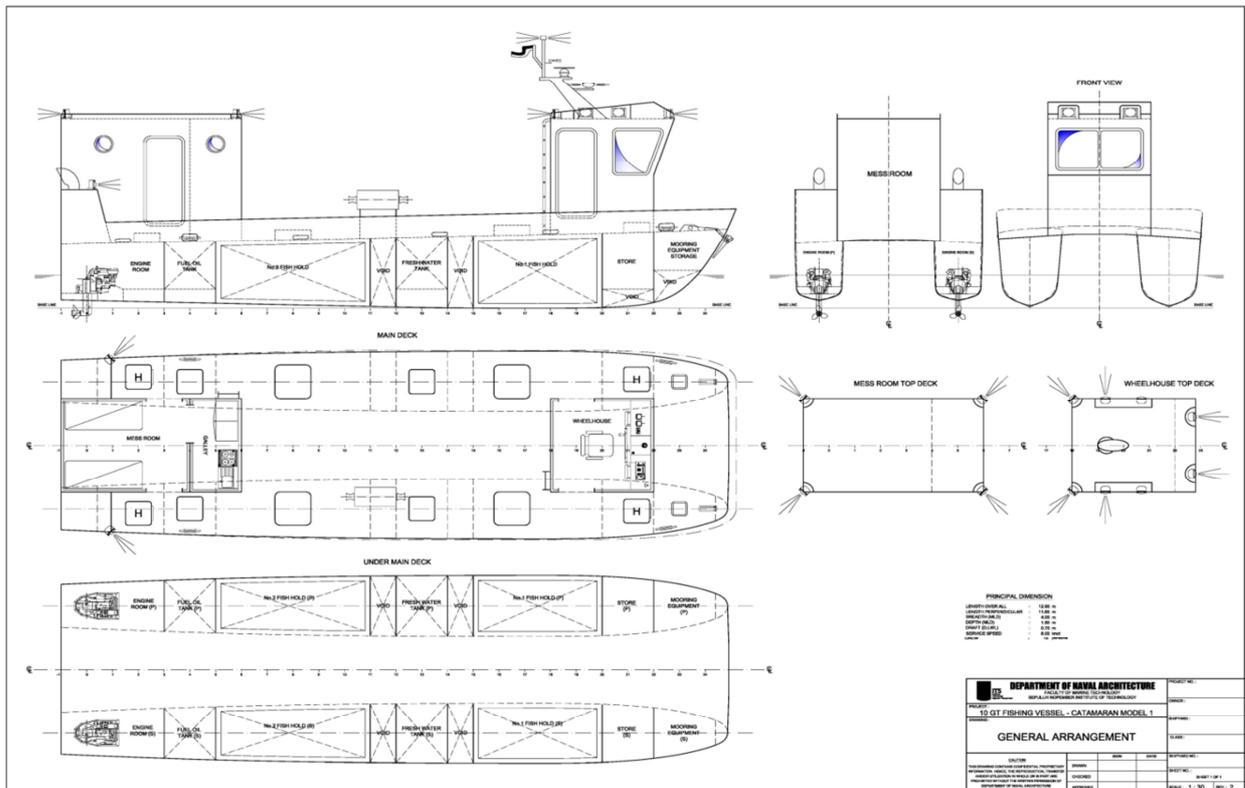


Fig. 11. General arrangement of catamaran fishing vessel

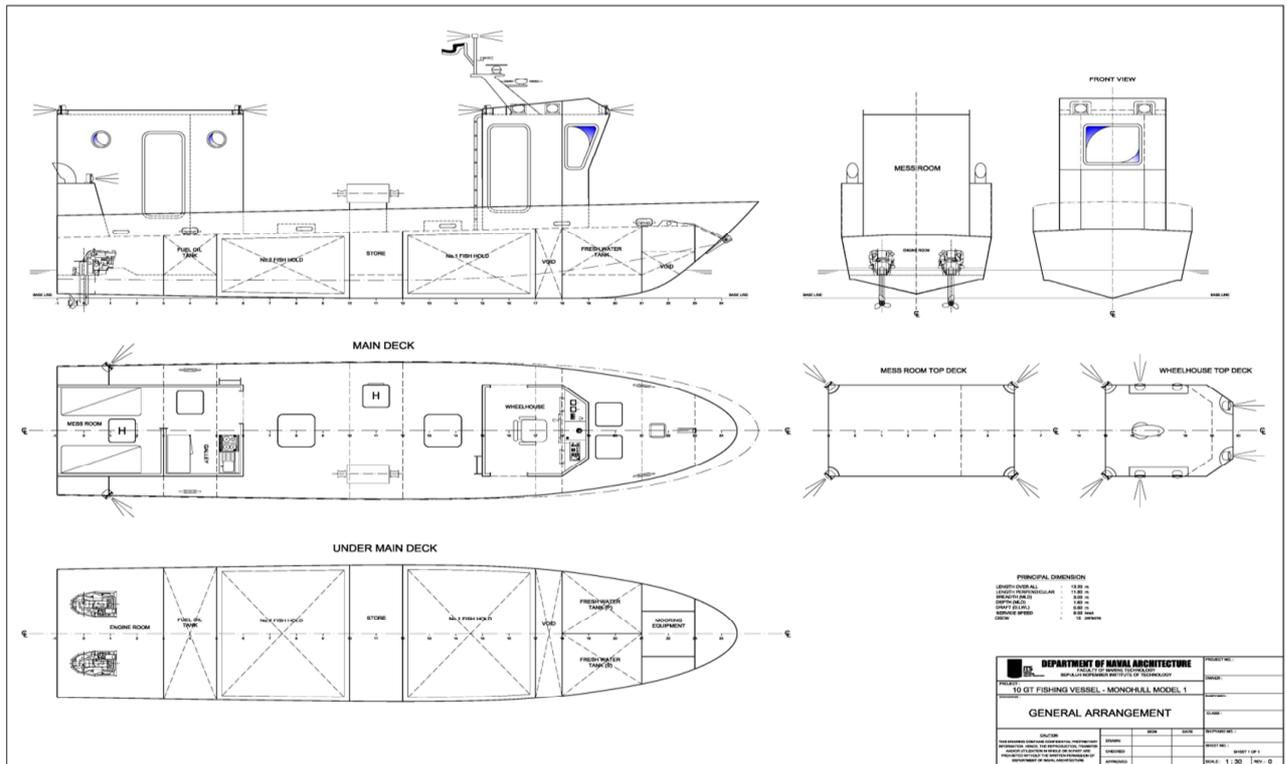


Fig. 12. General arrangement of monohull fishing vessel

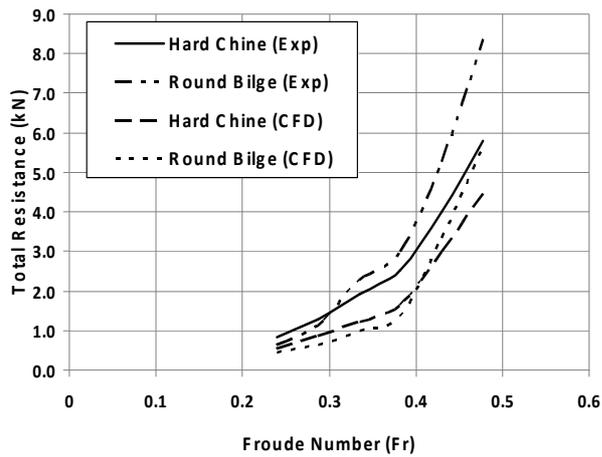


Fig. 13. Resistance of hard-chine and round-bilge monohull

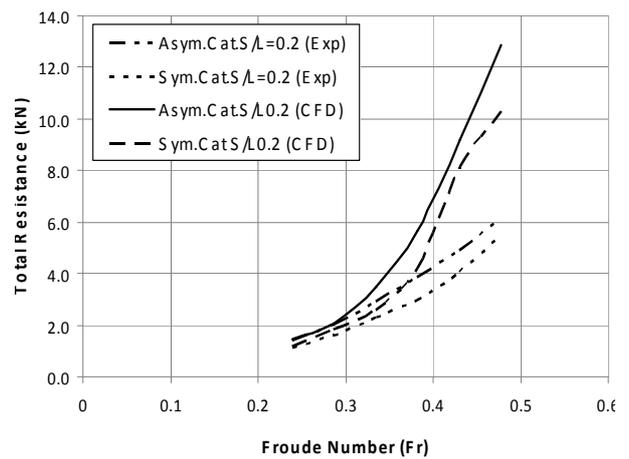


Fig. 14. Catamaran resistance of S/L=0.2 from experiment and CFD simulation

