

## DESIGN OF MALYSIAN FISHING VESSEL FOR MINIMUM RESISTANCE

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**Abstract.** Due to the economic and operational reasons, there is a need to reduce resistance of fishing boats. One of the ways to reduce resistance is to modify the boat hull form to reduce its drag in water. However, designers normally have problems in choosing which hull form parameter to change, in which direction, and the degree of changes required. This paper describes a methodology of incorporating resistance optimization in the design of fishing boats. By producing easily understood design charts, the designer is guided in making his choice. An example of application of this method on the design of a Malaysian fishing boat is given. It is shown that by using this method, the hull can be modified without changing the principal dimensions and displacement and this slight modification of the hull form can produce up to 12% saving in fuel consumption.

*Keywords:* Resistance, fishing boats, fishing vessel design

**Abstrak.** Berdasarkan sebab-sebab ekonomi dan operasi, terdapat keperluan bagi mengurangkan rintangan bot nelayan. Salah satu cara mengurangkan rintangan ialah dengan mengubahsuai bentuk badan bot. Walau bagaimanapun, pereka bentuk biasanya mempunyai masalah memilih angkubah yang perlu diubah, ke arah mana diubah dan sebanyak mana perlu diubah. Kertas kerja ini membentangkan satu kaedah bagi memperolehi bentuk badan kapal yang optimum daripada sudut rintangan. Dengan menggunakan carta reka bentuk yang mudah difahami, pereka bentuk akan memperolehi panduan dalam membuat perubahan yang diperlukan. Satu contoh penggunaan kaedah ini ke atas sebuah bot nelayan Malaysia ditunjukkan. Dengan menggunakan kaedah ini, perubahan bentuk badan boleh dibuat tanpa melibatkan penukaran dimensi utama dan sesaran kapal. Perubahan kecil ini mengurangkan rintangan keseluruhan kapal dan membolehkan penjimatan penggunaan minyak sebanyak 12%.

*Kata kunci:* Rintangan, bot nelayan, reka bentuk vesel perikanan

### 1.0 INTRODUCTION

Malaysian fishing vessels operate on short trips ranging from a few hours to about one week. With such short operating cycles, operating cost figures are very high in terms of the economics of operation. Moreover, Mohd Pauzi *et al.* [1] has shown that fuel cost normally account for more than 50% of the annual operating expenses. In order to reduce operating costs, reduction of fuel consumption could be a good starting point.

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One of the primary objectives in ship design is to have an energy efficient system consisting of a hull form with low resistance and a good propulsion system. This will ensure that the ship will have the desired speed with minimum power consumption. In addition, lower engine power for the given ship speed normally translates into lower fuel consumption.

In the operation of Malaysian fishing vessels, speed is essential. It is important to increase speed so that the time to reach the fishing ground can be reduced. Speed is also essential to shorten the time for returning to port so that the fish remain fresh. Also, early arrivals will get better markets. In addition, in the case of trawling and purse seining, speed is essential for hunting process.

High speed could be obtained in two ways. For a particular hull form, higher speed can be obtained if a higher-powered engine is installed. However, this will usually result in higher fuel consumption, leading to uneconomic return.

Alternatively for a particular size of boat, if the hull form is modified such that the resistance is minimised, then there is a possibility of obtaining a good speed at a much lower power; i.e. reduces operating cost.

This paper describes a methodology for modifying the hull form in the preliminary design stages to obtain the minimum resistance and hence generate a hull form with least power requirement.

## 2.0 RESISTANCE-OPTIMISED DESIGN METHODOLOGY

Hull form parameters play a major role in influencing the resistance of floating vessels. When the principal dimensions and fullness coefficients have been chosen, the resistance then depends chiefly upon the following elements of ship form [2]:

- Distribution of displacement along the length, as typified by the curve of cross-sectional areas and the longitudinal centre of buoyancy
- Shape of the water plane, particularly in the fore body
- Shape of the transverse sections, especially near the ends
- Midship-section area coefficient
- Type of stern; i.e., raised counter, cruiser, transom, and so on

Although the influence of hull form parameters on resistance is known, it is difficult for designers to incorporate this in the preliminary design process. One of the problems for the designer is to choose which parameter to change first and by how much should the parameter be changed, to be most effective in reducing resistance. Often changes in one parameter will affect other parameters, besides changing the resistance value. There is a need to give a visual indication to the designer on how he should alter the original design.

This paper describes a method to incorporate resistance optimisation in the design of fishing boats. In this method, the parent hull form was systematically changed so as

to provide cause and effect relationships about the resistance characteristics of the vessel. The cause and effect is displayed on three-dimensional charts, giving clear guidance to the designer.

Provided the hull forms are varied systematically then the effects of changes in hull form geometry, as measured through the secondary parameters of prismatic coefficient ( $C_p$ ) and the longitudinal position of the centre of buoyancy (LCB), upon the resistance characteristics of fishing boats can be investigated and understood. The proposed methodology consists of the following steps:

- (i) Choosing the hull form to be used as parent hull.
- (ii) Choosing the right resistance estimation method suitable for the parent hull form chosen.
- (iii) Defining the boundaries for the systematic parameter space for the variants hull forms that are not only practical but also within the limitations of suitability of the chosen resistance estimation method.
- (iv) Creating a systematic series of variants within the parameter space.
- (v) Estimating resistance of the various variants using the chosen method.
- (vi) Construction of design charts and selection of the optimum hull form.

The application of the above methodology is demonstrated by implementing it on a fishing boat design.

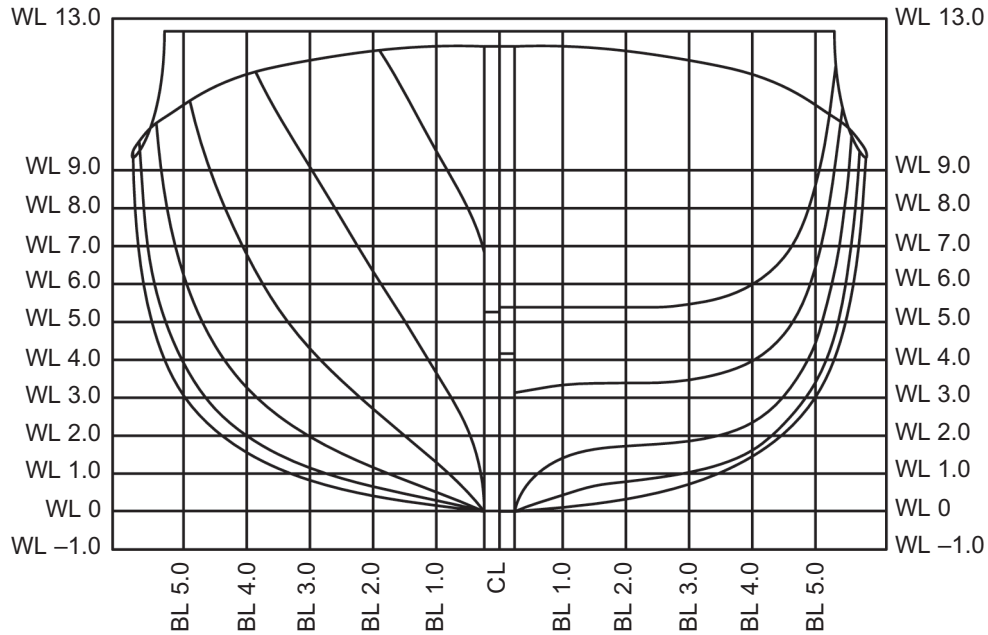
### 3.0 IMPLEMENTATION OF THE METHODOLOGY ON A FISHING BOAT

#### 3.1 Choosing Parent Hull Form

In this project, fishing boat '*Perintis*' designed by Universiti Teknologi Malaysia Marine Technology Group will be used as the parent hull form. The body plan of this hull form is shown in Figure 1 while its main particulars are shown in Table 1. The design of this vessel has been reported by Afifi *et al.* [3], Yahya [4] and Omar *et al.* [5].

#### 3.2 Choosing a Suitable Resistance Estimation Method

To predict the resistance of the boat, methodical series are employed. These methods are normally based on theoretical, empirical, or statistical methods. There are various methodical series that are available for predicting resistance of ships of various types and geometry. Every method has its own range of applicability; thus choosing the suitable methods in predicting resistance and powering for a particular ship is essential. The process of selection of these methods and their applicability has been described by Omar *et al.* [5]. One important conclusion by the authors was that designers must pay particular attention to the limitations inherent in each of the method. In the case of



**Figure 1** Body plan of the fishing vessel 'Perintis'

**Table 1** Principal particulars of 'Perintis'

|                     |                             |
|---------------------|-----------------------------|
| LBP                 | 22.40 meter                 |
| Breadth             | 5.90 meter                  |
| Draft               | 1.80 meter                  |
| Displacement        | 92.62 tonnes                |
| LCB                 | 0.75 meter aft of amidships |
| Wetted surface area | 140.94 m <sup>2</sup>       |
| $C_b$               | 0.38                        |
| $C_p$               | 0.63                        |
| B/T                 | 3.28                        |
| Design speed        | 10.00 knots                 |

Tribon software, ten resistance estimation methods are available, as described by Anon [6]. Table 2 provides a review of the methodical series and how the parent hull compares with the respective parametric limitations imposed by their originators.

Table 2 indicates that only two methods available in Tribon could be used for resistance estimation of the parent hull without contravening the limitations of the respective methods. For the purpose of this study, Van Oortmerssen [7] method will be used due to its ease of use.

**Table 2** Limitations of each methodical series in program Tribon [6]

| Methodical series in 'Tribon'      | Status of parent hull                         |
|------------------------------------|---|
| Holtrop & Mennen                   | L/B and B/T ratio out of range                |
| Guldhammer & Harvard               | Fulfill all those limitations                 |
| Takashiro                          | $C_b$ out of range: $0.4 \leq C_b \leq 0.86$  |
| Series 60                          | $C_b$ out of range: $0.6 \leq C_b \leq 0.8$   |
| Van Oortmerssen                    | Fulfill all those limitations                 |
| Taylor-Gertler                     | Speed-length ratio out of range               |
| Dankwardt                          | Length out of range                           |
| BSRA methodical series             | $C_b$ out of range: $0.55 \leq C_b \leq 0.85$ |
| Radojic (Series 62 type hullforms) | LCB/chine ratio out of range                  |
| Radojic (Series 65 type hullforms) | LCB/chine ratio out of range                  |

### 3.3 Defining the Boundaries for the Systematic Parameter Space and Creating the Variants

To create the variant hull forms, a parameter space must be defined. This space will indicate systematically the variation in the respective values of LCB and  $C_p$  of the parent hull form. Later, in presenting the results, the values of resistance coefficient as calculated by the analysis program will be plotted on this parameter space to construct what is called the design chart. This chart can be used to visually assist the designer to choose the hull form having the least resistance.

To define this systematic parameter space, two factors will determine its boundary. First, the variants produced must not be out of range of validity of the chosen resistance estimation method, in this case, Van Oortmerssen method. The second factor to consider is that all variant hull forms produced must be practical and acceptable. For this reason, the hull is gradually modified and the maximum limit of range of modification is considered reached when visual checks show odd shapes or unwieldy lines.

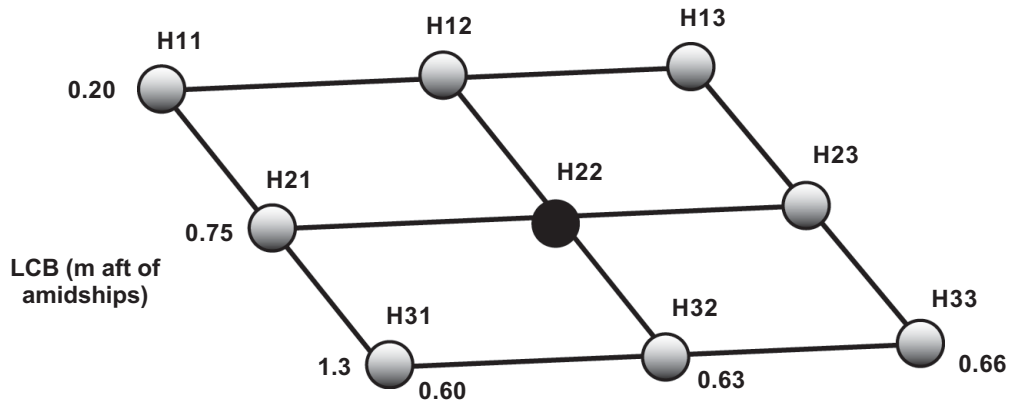
Once the extreme values of  $C_p$  and LCB based on the above two limitations are defined, other variants can be created within those boundaries. For this study, a set of 9 variants of this parent hull were produced. Each variant has a specific combination of LCB and  $C_p$ . The variants were systematically produced using Tribon Lines module that is based on Lackenby [8] hull transformation method. The designations of each of the alternative designs are shown in Table 3 and on the parameter space of Figure 2, with H22 corresponding to the parent hull form. In this case, the primary parameters of Length per Pendicular ( $L_{pp}$ ), Breadth (B)B, Draught (T), Displacement ( $\nabla$ ), and Block Coefficient ( $C_b$ ) were fixed at the parent hull value.

### 3.4 Estimating Resistance of the Various Variants

The offsets from each variant were used as input data for Hydro Modules in Tribon. The program reads in the data regarding the geometry of the boats and calculates

**Table 3** Parameters of the parent hull form and its variants

|            |      | $C_p$ |      |      |
|------------|------|-------|------|------|
|            |      | 0.6   | 0.63 | 0.66 |
| LCB        | 0.20 | H11   | H12  | H13  |
| (m aft of  | 0.75 | H21   | H22  | H23  |
| amidships) | 1.30 | H31   | H32  | H33  |

**Figure 2** Parameter space for the systematic series

resistance using Van Oortmerssen's method and outputs the resistance estimates in terms of total resistance coefficient,  $C_T$ . The analysis has been carried out at the full load displacement and speeds of 6 to 10 knots. The values of total resistance coefficient,  $C_T$ , is given in Table 3.

The Van Oortmerssen method uses formulae and data published in [7] to calculate the residuary resistance coefficient of any small ship hull form within the following ranges:

$$\begin{aligned}
 8.0 &\leq L_D \leq 80.0 \\
 0.5 &\leq C_p \leq 0.725 \\
 3.0 &\leq L_D/B \leq 6.2 \\
 1.9 &\leq B/T \leq 4.0 \\
 -8.0 &\leq \text{LCB} \leq 2.8
 \end{aligned}$$

where,

$$L_D = (L_{pp} + L_{wl}) / 2.0$$

$$\begin{aligned} \therefore L_{pp} &\equiv \text{Length perpendicular} \\ L_{wl} &\equiv \text{Length at waterline} \end{aligned}$$

The resulting residuary resistance coefficient is then added to the frictional resistance coefficient obtained from the ITTC 1957 model-ship correlation line.

#### 4.0 RESULTS

The effects of systematically changing LCB and  $C_p$  on the resistance coefficient are given in Table 4 and plotted in Figures 3 and 4.

**Table 4**  $C_T \times 10^3$  of each hullforms

| Speed<br>(Knots) | H11   | H12   | H13   | H21   | H22   | H23   | H31   | H32   | H33   |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 6                | 3.943 | 4.021 | 4.155 | 3.947 | 4.042 | 4.164 | 3.954 | 4.051 | 4.176 |
| 7                | 4.264 | 4.448 | 4.694 | 4.278 | 4.524 | 4.732 | 4.320 | 4.482 | 4.799 |
| 8                | 5.097 | 5.464 | 5.764 | 5.149 | 5.479 | 5.873 | 5.260 | 5.643 | 6.112 |
| 9                | 6.163 | 7.056 | 7.902 | 6.264 | 7.139 | 8.227 | 6.478 | 7.440 | 8.711 |
| 10               | 7.053 | 7.987 | 8.924 | 7.191 | 8.040 | 9.350 | 7.457 | 8.453 | 9.500 |

#### 4.1 Effect of Varying $C_p$

Curves of  $C_T$  at constant LCB but at different values of  $C_p$  are given in Figure 3. The results indicate that  $C_T$  is sensitive to variation of  $C_p$  where a small reduction in  $C_p$  results in a significant reduction in total resistance.

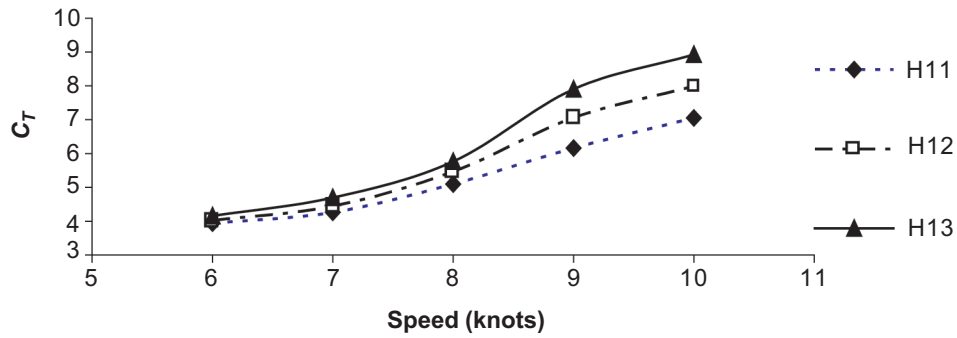
#### 4.2 Effect of Varying LCB

Figure 4 shows the curves of  $C_T$  at constant  $C_p$  but at different values of LCB. From this figure, it can be seen that moving the center of buoyancy forward will give a reduction in total resistance. The reduction is however less significant compared with those of Figure 3.

#### 4.3 Resistance Design Charts

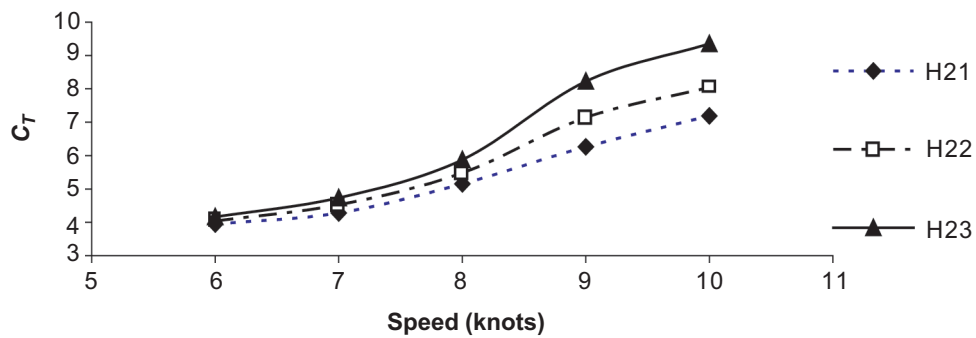
A plot of resistance coefficient  $C_T$  based on the design space is shown in Figure 5. The  $C_T$  values are taken at the design speed of 10 knots. Using this chart, the designer can visually observe the effect of changing secondary parameters on resistance. Moreover, the chart helps in deciding the direction to be taken in changing a combination of parameters, to obtain favourable resistance characteristics.

Total resistance coefficient at varying  $C_p$   
LBC=0.2 m aft of amidship



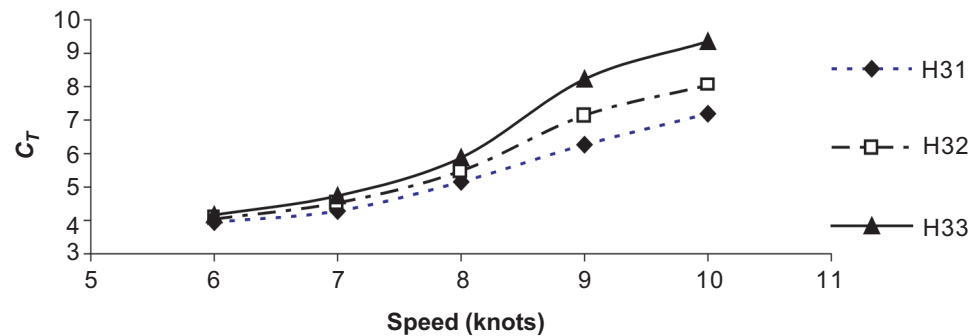
(a)

Total resistance coefficient at varying  $C_p$   
LBC=0.75 m aft of amidship



(b)

Total resistance coefficient at varying  $C_p$   
LBC=1.30 m aft of amidship

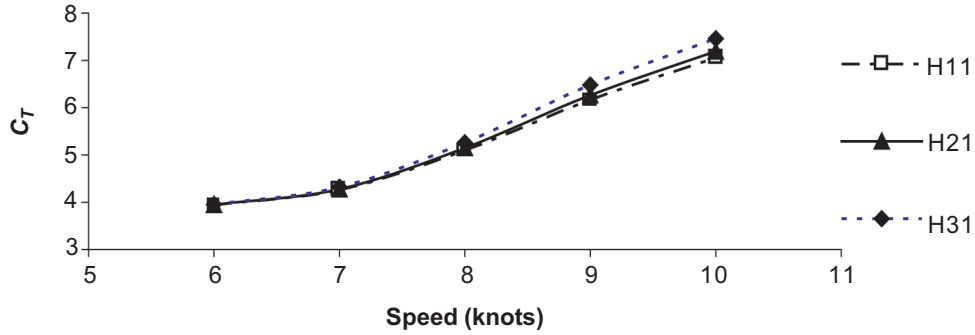


(c)

**Figure 3** Total resistance coefficient at constant LCB and varying  $C_p$

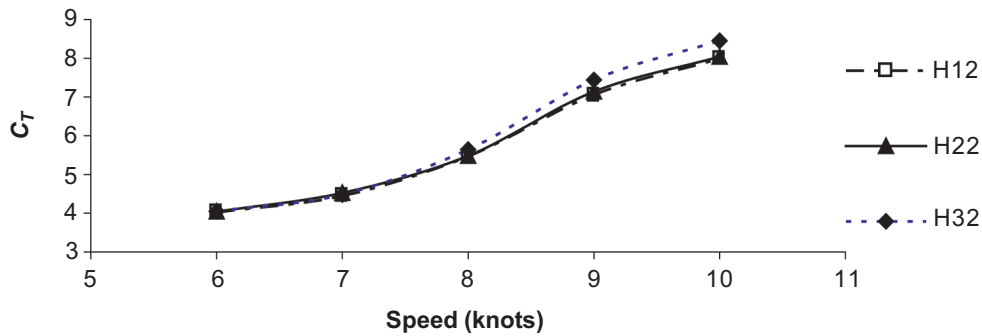


Total resistance coefficient at varying LBC  
 $C_p = 0.60$  m aft of amidship



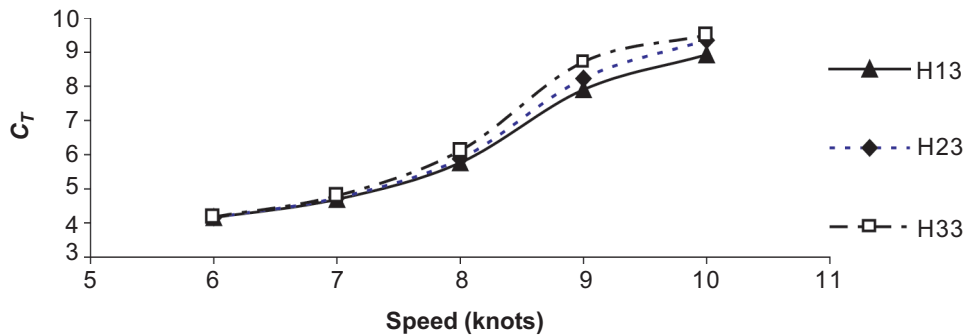
(a)

Total resistance coefficient at varying LBC  
 $C_p = 0.63$  m aft of amidship



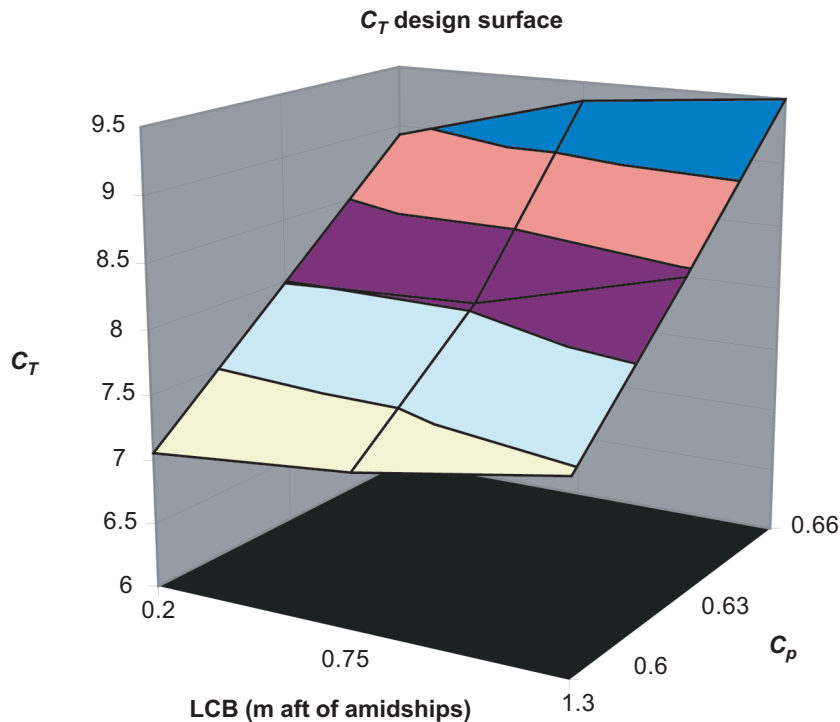
(b)

Total resistance coefficient at varying LBC  
 $C_p = 0.66$  m aft of amidship



(c)

**Figure 4** Total resistance coefficient at constant  $C_p$  and varying LCB



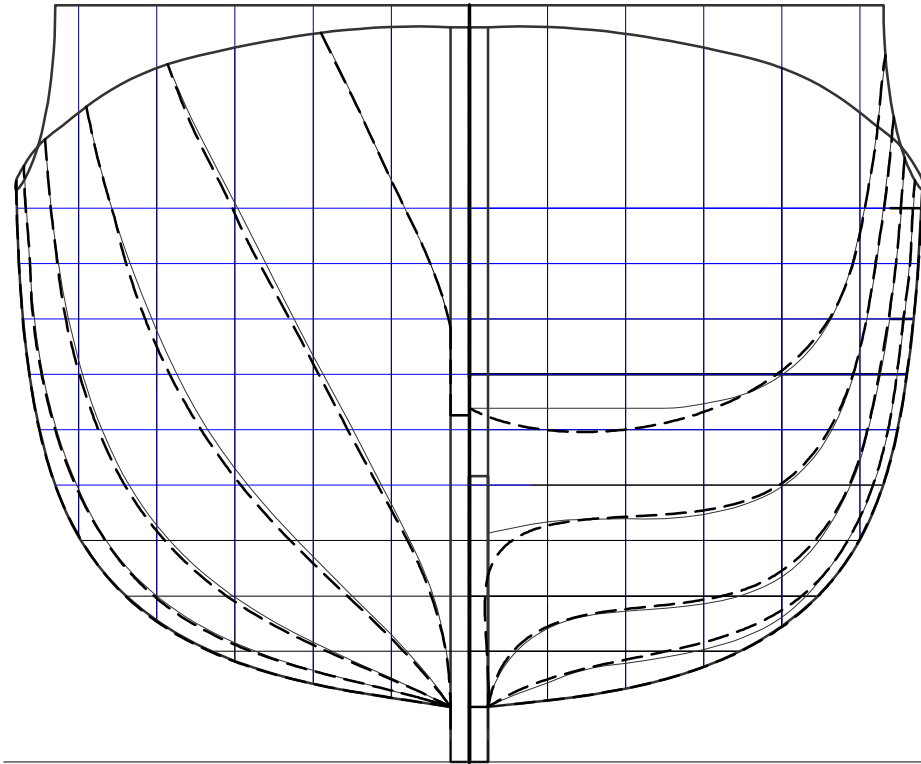
**Figure 5** Design chart based on systematic parameter space

Figure 5 indicates that the optimum hull form associated with the minimum resistance is H11, with a  $C_p$  of 0.60 and LCB of 0.3 m aft of amidships. Translated in terms of percentage of parent hull parameters, 4.96% reduction in  $C_p$  and 5.31% movement of LCB forward lead to a 12.28% reduction of  $C_T$ . Comparison of H11 and parent hull body plans is shown in Figure 6.

#### 4.4 Quantifying Improvement

As has been shown above, using this method, an optimum hull associated with minimum resistance has been identified. The hull form H11 is expected to have more than 12 % reduction in  $C_T$  at 10 knots. It is noted from Table 4 that the  $C_T$  value at 10 knots for H11 is considerably less than even the 9 knots  $C_T$  of the parent hull H22. It means that the new hull form running at 10 knots needs less power than the parent hull running at 9 knots.

The relationship between  $C_T$  and fuel cost can be shown to be of the first order. Therefore, the reduction in  $C_T$  and the corresponding improvement in fuel consumption has a direct relationship; i.e. the 12% reduction in  $C_T$  will lead to a similar 12% reduction in fuel consumption.



**Figure 6** Optimum hull form H11 (dotted lines) compared with parent hull (solid)

In monetary terms, a typical boat of this size will spend approximately 50% of its annual operating expenses on fuel, as shown by Mohd Pauzi *et al.* [1]. If fuel costs can be reduced by 12%, the total annual expenses can be reduced by about 6%. This reduction is significant, considering that it is achieved by simply redesigning the hull form without a major change in other characteristics.

## 5.0 CONCLUDING REMARKS

A practical method to obtain resistance optimised hull form of fishing boats has been presented. In this method, a visual representation of the cause and effect relationships of changes in basic hull form parameters has been introduced. It is also shown that the resistance of fishing boats is more sensitive to changes in  $C_p$  than shifting LCB. This fact can be used by the designer in order to identify the hull form with least resistance. In the example presented, the small changes in hull form have produced quite significant reduction in fuel costs. However, changes in hull form may affect not only resistance, but also other design characteristics. Further investigations are being made to see the influence of these changes on boat sea keeping and stability characteristics.

## REFERENCES

- [1] Mohd Pauzi, A. G., Y. Omar, and A. S. Ahmad Fuaad. 1991. Powering Estimates of Deep Sea Fishing Boat. Proc. National Seminar on Fishing Technology. Universiti Pertanian Malaysia, Kuala Terengganu.
- [2] Lewis, E. 1988. *Principles of Naval Architecture Vol II*. Jersey City: Society of Naval Architects and Marine Engineering.
- [3] Mohd. Afifi, A. M., A. Mohd. Zamani, and I. Nasrudin. 1994. Preliminary Evaluation on the Economic Performance of the UTM Deep Sea Fishing Vessel. Science and Technology Congress, COSTAM. Kuala Lumpur, Malaysia.
- [4] Yahya, S. 1994. Strength Analysis of an Offshore Fishing Vessel. Science and Technology Congress, COSTAM. Kuala Lumpur, Malaysia.
- [5] Omar, Y., M. S. Abdul Razak, and I. Nasrudin. 2000. Resistance and Powering Predictions of an Offshore Fishing Vessel. Seminar on Ship Design, Model Testing and Sea Trial Activities. Universiti Teknologi Malaysia, Malaysia.
- [6] Anon. 2000. Tribon User Guide. Tribon Solutions A B. Malmo.
- [7] Van Oomertsen, G. 1971. A Power Prediction Method and its Application to Small Ships. *International Shipbuilding Progress*. 18(207)
- [8] Lackenby, H. 1950. On the Systematic Geometrical Variations of Ship Forms. *Trans INA*. 92: 289-316.