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THE EFFECT OF HULL ELONGATION TO THE VESSEL'S PERFORMANCE FOR SMALL SHIP

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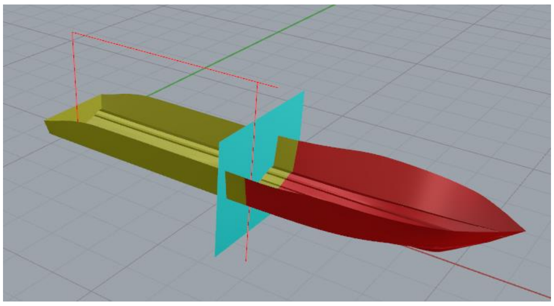
GRAPHICAL ABSTRACT



ABSTRACT

This thesis project presents the proposed method of modifying the length of the passenger vessel hull. The aim of this thesis project is to evaluate the method proposed and validate the performance of the hull. The scope of the work covers the literature and background study of previous work regarding the effect of changing the hull's length, performing different cases of lengthening the hull and finally suggesting the new elongate hull form that gives the best performance. Few types of software are used such as Maxsurf Modeler, Maxsurf Resistance, Maxsurf Stability and Rhinoceros 5 3D. Along with that, results of ship hull's performance with different types of lengthening cases would be beneficial to ship designers to select the hull with best design parameters.

KEYWORDS

Hull Elongation, Small Vessel, Hull performance.

INTRODUCTION

1.1 BACKGROUND OF STUDY

A local ship repair company in Pasir Gudang, Malaysia named Pancaran Selatan has produce its own hull mould of length 11.0 metre. It is a proven hull. The company would like to join a new tender by a client which require them to produce a new longer hull. Since the mould is already available at the shipyard, the beam and depth of the mould is fixed. Only some other parameters are allowed to change mainly the length of the hull which would influence other parameters such as the centre of gravity of the hull and its displacement.

There are only two ways of modifying the hull which are lengthening at the middle body of the hull and at the stern part of the hull. Few lengthening cases would be implemented and its performance would be obtain to find the best hull form.

Figure 1.1: 11.0 metre mould (forward view)

Figure 1.2: 11.0 metre mould (aft view)

1.2 PROBLEM STATEMENT

From this project, the issue that needs to be addressed is the effect on the performance of the hull when the ship is lengthen at the middle or at the stern.

The performance that will be going to analyse is resistance and stability. The value of resistance and stability will be the guide in choosing the best way to lengthen the small ship either at the middle or at the stern.

1.3 OBJECTIVE OF THE STUDY

The objectives of the thesis project are as follows:

1. To study the effect of lengthening of hull to the performance of a small vessel.
2. To suggest effective way of lengthening hull of small vessel.

1.4 SCOPE OF THE STUDY

The followings are the limitations of this study:

1. Background and literature study including previous research works.
2. Identify ways of lengthening of hull form for small vessel.
3. Develop the new hull forms.
4. Carry out analysis on vessel performance due to hull lengthening.
5. Suggest the effective ways of lengthening hull for small vessel.

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss the research material. This discussion will cover the effect of elongation of the vessels and its performance which is resistance and stability.

2.2 HULL FORM DESIGN

2.2.1 11.5 METRE PASSENGER VESSEL

The 11.0 metre passenger vessel is a project from a shipyard called Pancaran Selatan for Lembaga Kemajuan Johor Tenggara. This passenger vessel is intended for tourism purpose at Tanjung Surat, Johor. This craft is a type of planing hull which could be recognized by straight run of the chine and buttock lines from amidships aft. The chine and V-bottom of the hull will generally run parallel to the waterline and constant from just aft of amidships to the stem.

2.3 RESISTANCE OF A SHIP

Resistance is the force that the ship overcomes as it moves through the water. It is important to achieve accurate resistance prediction to avoid any losses in terms of cost. A new ship has to undergo trial resistance run under ideal conditions which means it has no winds and seaway or has no influence from restricted water or currents. There are few ways available to predict resistance as stated below:

i. Model testing
ii. Empirical method
iii. Computational techniques

Many experiments has been made as early as in the year 1452 by Leonardo da Vinci (Tursini, 1953) to the year 1764 by Benjamin Franklin (Rumble, 1955). The major problems encountered was the way to scale the model results to full scale. In 1868, William Froude proposed his law of comparison. His idea was to divide the total resistance into two parts, the frictional resistance and the residuary resistance. Hence the equation below:

$$R_T = R_F + R_R \qquad (2.3)$$

Where: R_T is the total resistance
R_F is the frictional resistance
R_R is the residuary resistance

2.3.1 EFFECT OF LENGTH ON SHIP'S RESISTANCE

In this part, further explanation will be shown to relate the length of the hull with the ship's resistance. Extending from the equation (2.3), the frictional resistance is determined as

$$R_F = {}^1\!/_2\, C_F \rho S V^2$$

Where $C_F = 0.075(log_{10} R_n - 2)^2$

$$S \approx (3.4.\nabla^{1/3} + 0.5L_{WL}).\nabla^{1/3}$$

Next, the residuary resistance is defined by

$$R_R = {}^1\!/_2\, C_R \rho S V^2$$

where R_R can be decomposed as

$$R_R = R_W + R_{PV}$$

R_W is the wave resistance,

$$R_W = {}^1\!/_2\, C_W \rho S V^2$$

C_W is the non-dimensional wave resistance coefficient.

R_{PV} is the pressure viscous resistance,

$$R_{PV} = {}^1\!/_2\, C_{PV} \rho S V^2$$

C_{PV} is the non-dimensional pressure viscous resistance.

For an increase of length with the ratio,

$$\lambda = {}^{L_1}\!/_{L_0}$$

where L_0 is the parent hull and L_1 is the present hull and the frictional resistance increase with the ratio of $\frac{(R_F)_1}{(R_F)_0} = \lambda^{3/10}$.

The ratio of the residuary resistance is concluded as $\frac{(R_R)_1}{(R_R)_0} = \lambda^{-(\alpha-1)/2}$ where $3 \leq \alpha \leq 5$.

Thus, the total resistance is

$$(R_T)_1 = (R_F)0.\lambda^{3/10} + (R_R)_0.\lambda^{-(\alpha-1)/2}$$

In terms of wave length versus ship speed, the length of a free wave on the surface is related to velocity as

$$L_W = \frac{2\pi V^2}{g}$$

Where L_W = wavelength (ft)
V = ship velocity (ft/s)
g = acceleration due to gravity (ft/s^2)

When ship is at low speed, more wave crests would be available at its side but as the speed increase, the wavelength also increase. As for planing boat, at some speed, the bow would come up very high. This shows the worst scenario for the ship to operate in terms of hull efficiency and to prevent the hull from damaging, but as the ship continue to speed up, the wavelength increase results in reducing the wave making resistance.

Ships would create their own wave system. The crests and troughs would either add the stern wave system which also increase the resistance or cancelling it. This lead to the graph of total resistance coefficient versus speed showing that at as the speed to length ratio increase, the total resistance also increase, but at some point of speed to length ratio, the resistance would drop significantly.

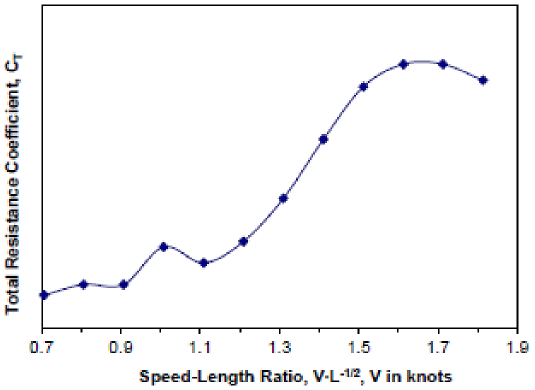


Figure 2.1: Speed-length ratio versus total resistance coefficient graph

In short, increasing the length of the ship would increase the speed a which the length of the wave system generated by the ship is equal to the ship length therefore reduce the wave making resistance. These steps could be implemented at the early stage of designing a hull.

2.4 THEORETICAL APPROACH BY SAVITSKY (1976)

Savitsky has given formula for the lift and drag forces on planing hulls. These formulas are based on a large number of resistance test with prismatic or wedge-type surfaces in which the trim angle (τ), deadrise angle (β), wetted length (L_k) and length-beam ratio were varied systematically.

Initially, the vessel's speed (v), the maximum chine beam (B_{px}), length of the vessel (L), the displacement volume (∇) shall be given in order to calculate. The following values are calculated:

- The volume Froude number, $F_n\nabla$
$$F_{n\nabla} = \frac{v}{\sqrt{(g\nabla^{1/3})}}$$
- The Froude number based on B_{px}, C_v
$$\boldsymbol{C_v} = \frac{\boldsymbol{v}}{\sqrt{(\boldsymbol{gB_{px}})}}$$
- The equivalent flat plate lift coefficient, $C_{L\beta}$
$$C_{L\beta} = \frac{\Delta g}{{}^1/_2\rho V^2 {B_{px}}^2}$$
- The lift coefficient for a finite deadrise, C_{L0}
$$C_{L\beta} = C_{L0} - 0.0065\ \beta\ {C_{L0}}^{0.6}$$

Where β = deadrise angle (º) at the mid-chine position.

Speed coefficient, C_v is used to justify whether the craft is in pre-planing or planing condition. For C_v greater than 1.5, it is considered fully planing. Instead, if C_v less than 1.5, it is in preplaning condition. Therefore, this coefficient is important to estimate hydrodynamic particulars.

It is assumed that the hydrodynamics pressure forces pass through the center of gravity (CG) in which the thrust axis and viscous forces are coincided. The resultant normal force on the planing bottom N, acts on the CG, that is p = LCG, where p is the distance of the center of pressure forward of the transom (Figure 2.1).

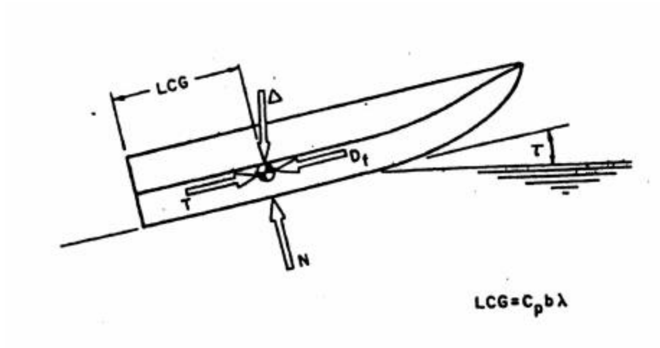


Figure 2.2: All forces pass through center of gravity

With appropriate value of C_v and p/b = LCG / Bpx, the corresponding β and $C_{Lo}/\tau^{1.1}$ are then can be read off the Nomograph .

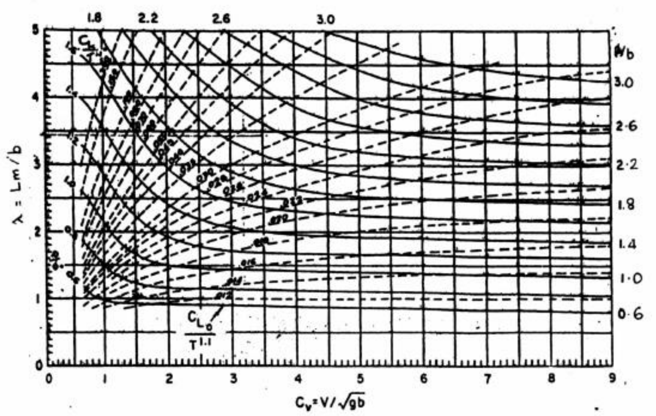


Figure 2.3: Nomograph for equilibrium conditions when all forces act through LCG

This graph is the combination of the empirical equations for planing lift, wetted area, and center of pressure which is presented in a simple plot by Koelbel. However, this graph is valid only when all of the forces, act through the CG. Thus, the trim angle, τcan be determined by using equation below,

$$C_{Lo} = \tau^{1.1}(0.012\sqrt{\lambda} + (0.0055\lambda^{5/2}/{C_v}^2))$$

Another approach to determine the λ is by solving the following equations below:

$$Cp = \frac{LCG}{B_{px}\lambda} = 0.75 - \frac{1}{\frac{5.21{C_v}^2}{\lambda^2} + 2.39}$$

it can be solved as below:

$$\begin{aligned} \mathbf{0.7925\lambda^3 - 2.39(LCG/B_{px})\lambda^2 + 3.9075{C_v}^2\lambda} \\ \mathbf{- 5.21(LCG/B_{px}){C_v}^2 = 0} \end{aligned}$$

the τ can be solved,

$$C_{Lo} = \tau^{1.1}\left[0.012\sqrt{\lambda} + \left(0.0055\lambda^{5/2}\right)/{C_v}^2\right]$$

Savitsky also gives a formula to correct the mean wetted length ratio, $\lambda$to the keel wetted length ratio, $\lambda_k$if desired,

$$\lambda_k = \lambda - 0.03 + {}^{1}/_{2}\,(0.57 + \beta/1000)(\tan\beta\,/2\tan\tau - \beta/167)$$

where the value of β should be taken at the mid-chine length position.

2.5 STABILITY OF A SHIP

Ship stability is the ability of the ship to return to its original position when displaced from its upright position. A ship is normally stable to a certain degree of heel and will topple afterwards. Next, ship stability is divided into two; longitudinal and transverse stability.

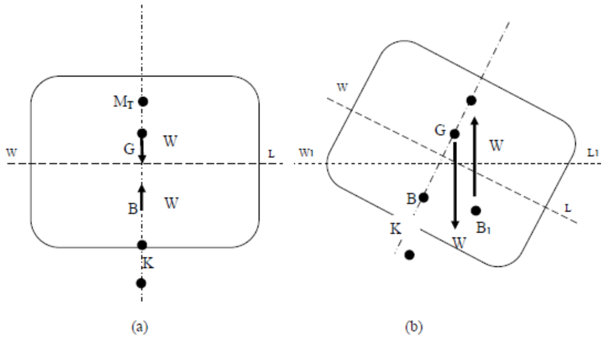
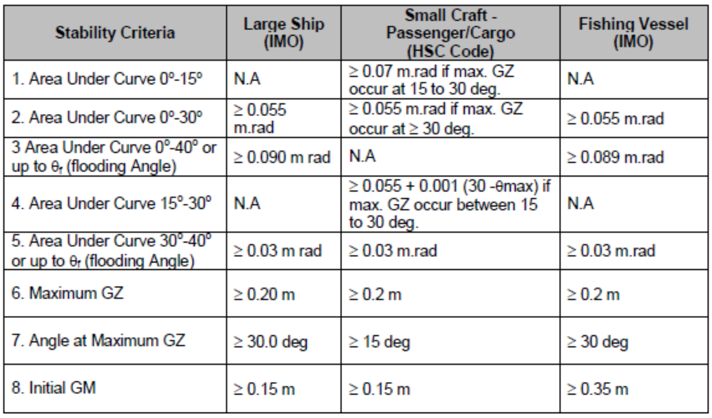


Figure (a) shows when a ship is in its upright condition while (b) is when ship heel to one side. The points B,G and M are the centre of buoyancy, centre of gravity and metacentre respectively. In (b), M was originally above G and we can see that the righting moment is positive, therefore the ship is stable. If M was below G, the GM is negative, the righting moment will be negative hence the ship is unstable. If M is at G, the ship is neutrally stable. The larger the writing moment, the better stability is

2.5.1. INTERNATIONAL MARITIME ORGANIZATION LOAD LINE CRITERIA

These criteria are prepared by the IMO for us to be able to assessed stability of a ship. All requirement must be pass and that indicates a ship is stable



Stability Criteria	Large Ship (IMO)	Small Craft - Passenger/Cargo (HSC Code)	Fishing Vessel (IMO)
1. Area Under Curve 0°-15°	N.A	≥ 0.07 m.rad if max. GZ occur at 15 to 30 deg.	N.A
2. Area Under Curve 0°-30°	≥ 0.055 m.rad	≥ 0.055 m.rad if max. GZ occur at ≥ 30 deg.	≥ 0.055 m.rad
3 Area Under Curve 0°-40° or up to θ_f (flooding Angle)	≥ 0.090 m rad	N.A	≥ 0.089 m.rad
4. Area Under Curve 15°-30°	N.A	≥ 0.055 + 0.001 (30 -θmax) if max. GZ occur between 15 to 30 deg.	N.A
5. Area Under Curve 30°-40° or up to θ_f (flooding Angle)	≥ 0.03 m rad	≥ 0.03 m.rad	≥ 0.03 m.rad
6. Maximum GZ	≥ 0.20 m	≥ 0.2 m	≥ 0.2 m
7. Angle at Maximum GZ	≥ 30.0 deg	≥ 15 deg	≥ 30 deg
8. Initial GM	≥ 0.15 m	≥ 0.15 m	≥ 0.35 m

Figure 2.4: IMO Load Line Criteria

METHODOLOGY

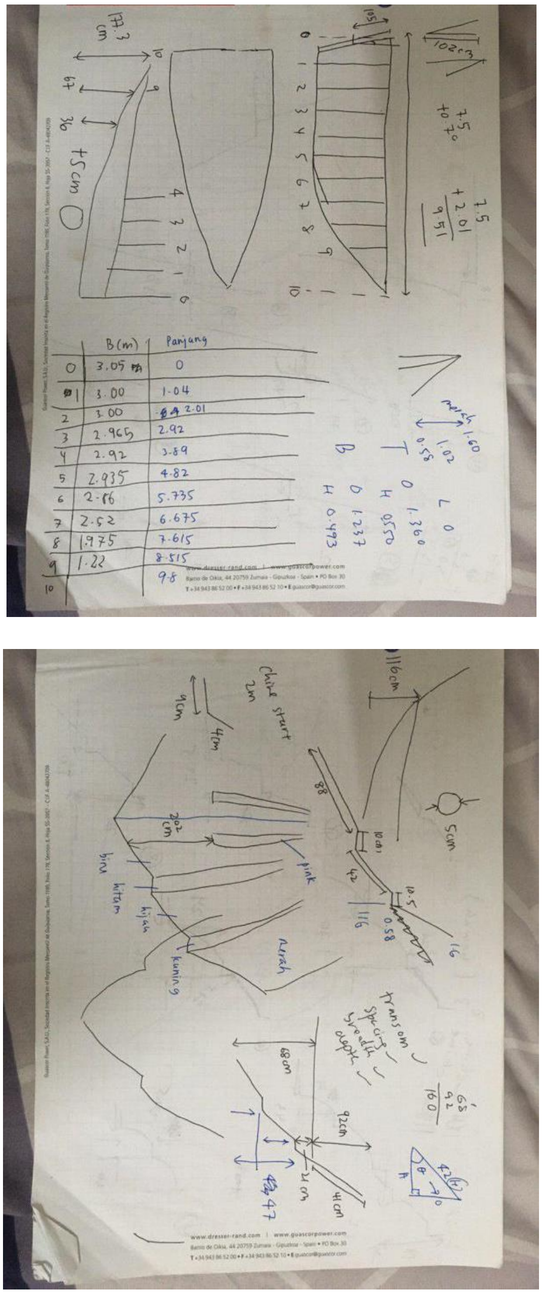
3.1 INTRODUCTION

This section will discuss the approach of this study. The main purpose of this study is to create a few new hull form with different length using Maxsurf Modeler and Rhinoceros 3D. To analyse the resistance, the hull forms will be run using Maxsurf Resistance.

3.2 ORIGINAL HULL

As stated at the beginning of the thesis, there is an existing mould prepared by the local ship repair company. As I have to use the proven hull mould as my parent hull, therefore the measurement of the parameters of the hull are to taken manually. The figure below shows the manually written data measured using various equipment such as measuring tape, 1-metre ruler, L-shaped ruler and more.

Figure 3.1: Measuring the mould



	B(m)	Panjang
0	3.05	0
1	3.00	1.04
2	3.00	2.01
3	2.965	2.92
4	2.92	3.89
5	2.935	4.82
6	2.86	5.735
7	2.52	6.675
8	1.975	7.615
9	1.22	8.515
10		9.8

Figure 3.2: Example of manual data collected from measuring the mould

After obtaining all the data needed, a hull form is generated from Maxsurf Modeler by creating surfaces, input the coordinates and bind them together to produce a perfect hull. Figure 3.3 shows the result after completing this part and Table 3.1 shows the vessel's main dimension.

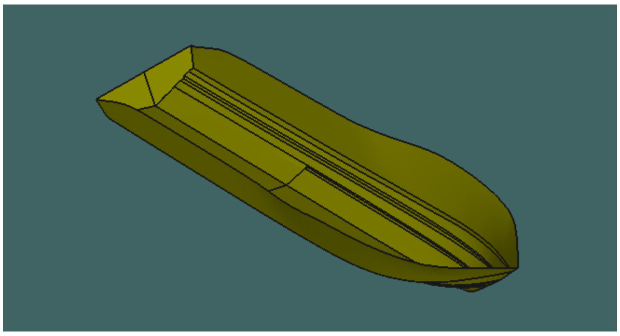


Figure 3.3: Original parent hull form in Maxsurf Modeler

Table 3.1: Original hull main dimension

Length overall (LOA)	11.80 metre
Length of hull	11.00 metre
Breadth moulded	2.37 metre
Depth moulded	1.37 metre
Depth main deck	0.57 metre
Design draught	0.42 metre
Hull	FRP
Complement	2 crews and 12 passengers
Main engine	150HP MERCURY SeaPro 110kW
Fuel oil capacity	102 litres
Speed	26 knotts

Next, the parent hull from the Maxsurf Modeler was exported to a .3dm files and is import to Rhinoceros 3D software to smoothen the surface of the hull.

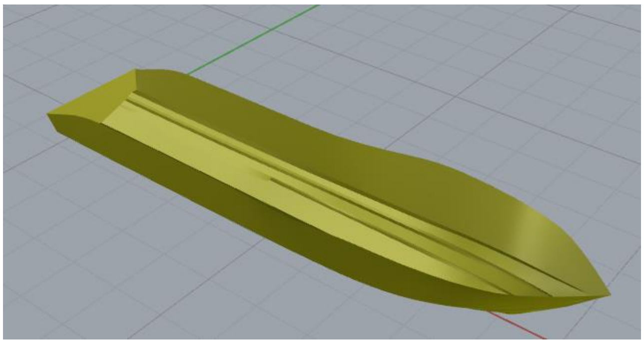


Figure 3.4: Original parent hull form in Rhinoceros 3D

3.3 LENGTHENING THE HULL FORM

The new hull forms are the elongation version of the parent hull form. All other parameters especially breadth and depth are kept constant. There are two lengthening cases that will be done. Firstly, to lengthen at the middle part of the ship.

The new length would from 11.5 metre to 14.0 metre. Secondly is to lengthen at the stern part of the ship. Also, as before, the new length would be between 11.5 metre to 14.0 metre.

The elongation process takes part in Rhinoceros 3D software. Earlier before, we had imported the .3dm files from Maxsurf, then, for lengthening the midship of the hull form, we cut the hull form into two.

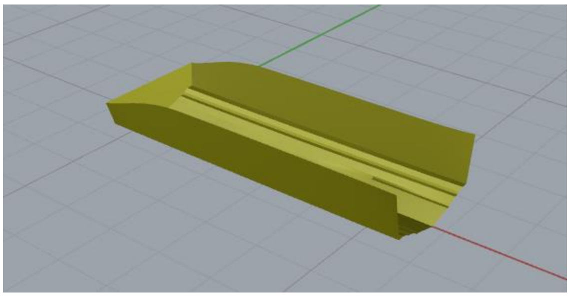


Figure 3.5: Original parent hull form cuts into half

After splitting into two, we have to make necessary lines (as shown in Figure) for us to be able extend the hull to 11.5 metre and so on. When done making the lines, we use the command Scale1D to extend the hulls to the respective length.

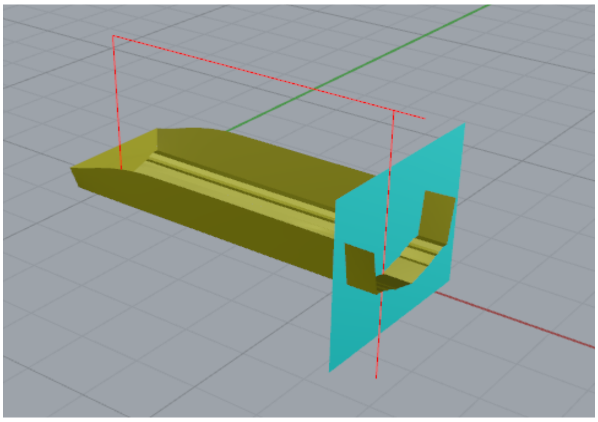


Figure 3.6: Making necessary lines on parent hull (midship)

As you can see in the above figure, the behind part is the original parent hull while the front part is the part that has been extended for example in this case is 0.5 metre. Next step is to join the other half of the hull form to the new hull form. The same process were repeated for each new length

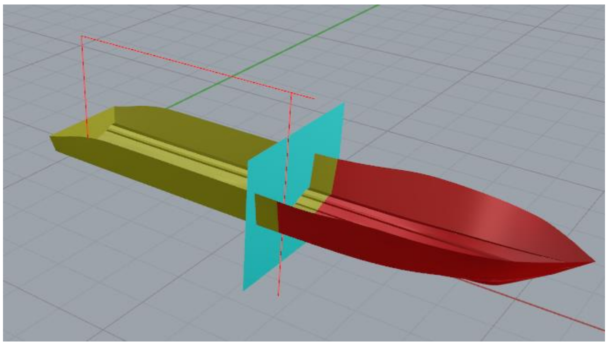


Figure 3.7: Attach the other half of the hull form to the extended part of the hull form

For lengthening the stern part of hull form, same early process involved. The original parent hull is imported in the Rhinoceros 3D and necessary lines is drawn to extend the hull. In conjunction with that, the stern was extended using the command Scale1D.

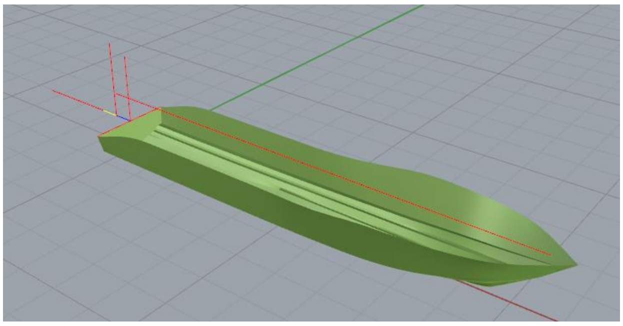


Figure 3.8: Making necessary lines on parent hull (stern)

As shown in Figure 3.8, the red lines are the original parent hull form, it will be then extend to the blue line , yellow line and so on. Again, the same process was repeated until all new length is obtained.

The following tables are the new hull's parameters that I had collected after completing all 12 lengthening cases.

Table 3.2: 11.5 metre hull parameters (lengthening at stern)

LOA (metre)	12.3
LBP (metre)	11.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	4.632
Displacement (t)	4.748
LCB	-0.699 from z

Table 3.3: 12.0 metre hull parameters (lengthening at stern)

LOA (metre)	12.8
LBP (metre)	12.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	4.839
Displacement (t)	4.960
LCB	-0.731 from z

Table 3.4: 12.5 metre hull parameters (lengthening at stern)

LOA (metre)	13.3
LBP (metre)	12.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37

Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.046
Displacement (t)	5.173
LCB	-0.762 from z

Table 3.5: 13.0 metre hull parameters (lengthening at stern)

LOA (metre)	13.8
LBP (metre)	13.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.254
Displacement (t)	5.385
LCB	-0.793 from z

Table 3.6: 13.5 metre hull parameters (lengthening at stern)

LOA (metre)	14.3
LBP (metre)	13.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.461
Displacement (t)	5.597
LCB	-0.825 from z

Table 3.7: 14.0 metre hull parameters (lengthening at stern)

LOA (metre)	14.8
LBP (metre)	14.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.668
Displacement (t)	5.810
LCB	-0.856 from z

Table 3.8: 11.5 metre hull parameters (lengthening at midship)

LOA (metre)	12.3
LBP (metre)	11.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	4.842
Displacement (t)	4.963
LCB	-0.732 from z

Table 3.9: 12.0 metre hull parameters (lengthening at midship)

LOA (metre)	12.8
LBP (metre)	12.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.257
Displacement (t)	5.389
LCB	-0.797 from z

Table 3.10: 12.5 metre hull parameters (lengthening at midship)

LOA (metre)	13.3
LBP (metre)	12.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	5.672
Displacement (t)	5.814
LCB	-0.861 from z

Table 3.11: 13.0 metre hull parameters (lengthening at midship)

LOA (metre)	13.8
LBP (metre)	13.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	6.087
Displacement (t)	6.239
LCB	-0.926 from z

Table 3.12: 13.5 metre hull parameters (lengthening at midship)

LOA (metre)	14.3
LBP (metre)	13.5
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545
Volume displaced (m^3)	6.501
Displacement (t)	6.663
LCB	-0.990 from z

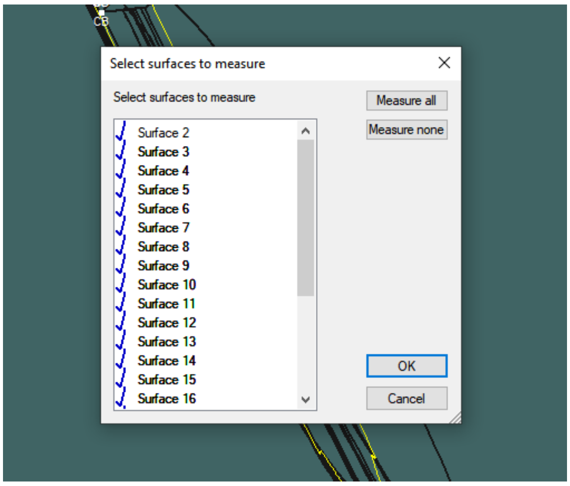
Table 3.13: 14.0 metre hull parameters (lengthening at midship)

LOA (metre)	14.8
LBP (metre)	14.0
Breadth (metre)	2.37
Depth moulded (metre)	1.37
Draught (metre)	0.42
Block coefficient, C_B	0.545

Volume displaced (m^3)	6.914
Displacement (t)	7.087
LCB	-1.055 from z

3.4 OBTAINING RESISTANCE RESULTS

After completing developing new hull forms in Rhinoceros 3D, we then export the file in form of .msd to continue obtain resistance of each hull form. The .msd file type would be open in Maxsurf Resistance. When opening, make sure we measure every surface of the hull form.

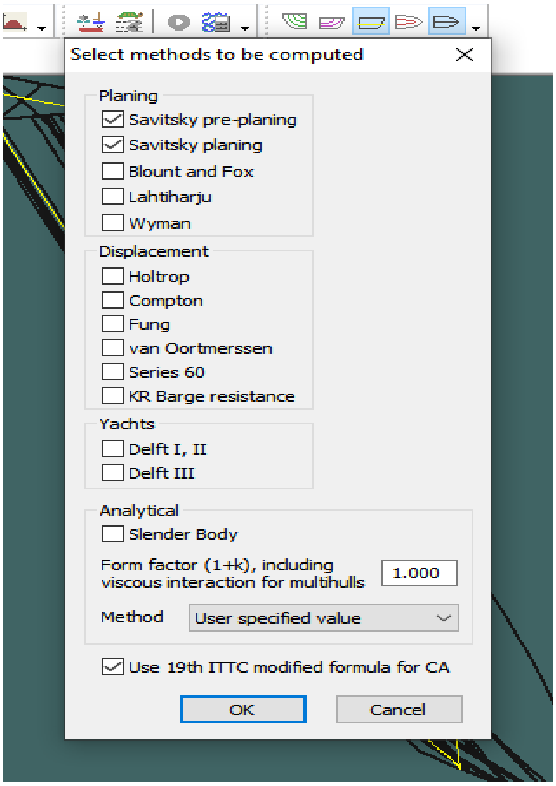

Select surfaces to measure

Select surfaces to measure

☑ Surface 2
☑ Surface 3
☑ Surface 4
☑ Surface 5
☑ Surface 6
☑ Surface 7
☑ Surface 8
☑ Surface 9
☑ Surface 10
☑ Surface 11
☑ Surface 12
☑ Surface 13
☑ Surface 14
☑ Surface 15
☑ Surface 16

Figure 3.9: Measuring every surface on Maxsurf Resistance

Then, we input the method to analyse resistance, which in this case is Savitsky resistance. Also, choose the range of speed needed which is from 10 knotts to 50 knotts.


Select methods to be computed

Planing
☑ Savitsky pre-planing
☑ Savitsky planing
☐ Blount and Fox
☐ Lahtiharju
☐ Wyman

Displacement
☐ Holtrop
☐ Compton
☐ Fung
☐ van Oortmerssen
☐ Series 60
☐ KR Barge resistance

Yachts
☐ Delft I, II
☐ Delft III

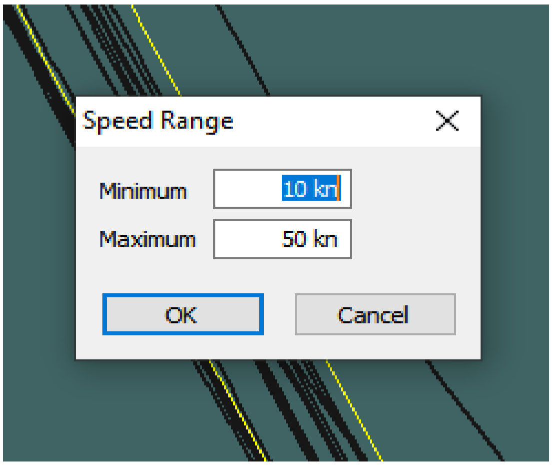
Analytical
☐ Slender Body

Form factor (1+k), including viscous interaction for multihulls: 1.000

Method: User specified value

☑ Use 19th ITTC modified formula for CA

Figure 3.10: Selecting the type of resistance to be analysed on Maxsurf Resistance


Speed Range

Minimum: 10 kn

Maximum: 50 kn

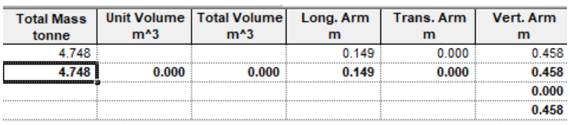
Figure 3.11: Key in the speed range on Maxsurf Resistance

Next, if we enter every value correctly, we are able to obtain few particulars an results from this software such as resistance results itself, graphs and curve of areas. The results will be shown in next chapter.

3.5 OBTAINING STABILITY RESULTS

Next is obtaining stability results from Maxsurf Advanced Stability. Again, the .msd file will be open in the software. After the design was opened, we create a new loadcase and input the mass, longitudinal arm and vertical arm value that can be calculated from Maxsurf Modeler.

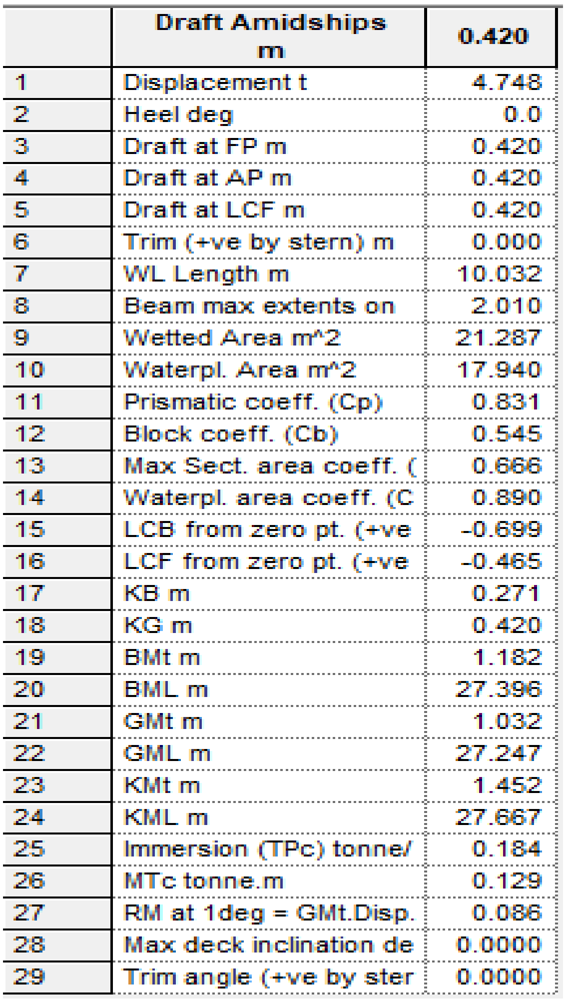
Table 3.14:



Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m
4.748			0.149	0.000	0.458
4.748	0.000	0.000	0.149	0.000	0.458
					0.000
					0.458

When we run analysis, the result for upright hydrostatics obtained are as follows:

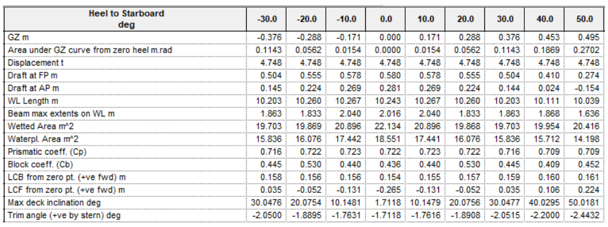
Table 3.15:



	Draft Amidships m	0.420
1	Displacement t	4.748
2	Heel deg	0.0
3	Draft at FP m	0.420
4	Draft at AP m	0.420
5	Draft at LCF m	0.420
6	Trim (+ve by stern) m	0.000
7	WL Length m	10.032
8	Beam max extents on	2.010
9	Wetted Area m^2	21.287
10	Waterpl. Area m^2	17.940
11	Prismatic coeff. (Cp)	0.831
12	Block coeff. (Cb)	0.545
13	Max Sect. area coeff. (	0.666
14	Waterpl. area coeff. (C	0.890
15	LCB from zero pt. (+ve	-0.699
16	LCF from zero pt. (+ve	-0.465
17	KB m	0.271
18	KG m	0.420
19	BMt m	1.182
20	BML m	27.396
21	GMt m	1.032
22	GML m	27.247
23	KMt m	1.452
24	KML m	27.667
25	Immersion (TPc) tonne/	0.184
26	MTc tonne.m	0.129
27	RM at 1deg = GMt.Disp.	0.086
28	Max deck inclination de	0.0000
29	Trim angle (+ve by ster	0.0000

In addition, the analysis for large angle stability were also run. From this analysis, we obtained the GZ value at each angle and the GZ curve.

Table 3.16:



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0
GZ m	-0.376	-0.288	-0.171	0.000	0.171	0.288	0.376	0.453	0.495
Area under GZ curve from zero heel m.rad	0.1143	0.0562	0.0154	0.0000	0.0154	0.0562	0.1143	0.1869	0.2702
Displacement t	4.748	4.748	4.748	4.748	4.748	4.748	4.748	4.748	4.748
Draft at FP m	0.504	0.555	0.578	0.580	0.578	0.555	0.504	0.410	0.274
Draft at AP m	0.145	0.224	0.269	0.281	0.269	0.224	0.144	0.024	-0.154
WL Length m	10.203	10.260	10.267	10.243	10.267	10.260	10.203	10.111	10.039
Beam max extents on WL m	1.863	1.833	2.040	2.016	2.040	1.833	1.863	1.868	1.636
Wetted Area m^2	19.703	19.869	20.896	22.134	20.896	19.868	19.703	19.954	20.416
Waterpl. Area m^2	15.836	16.076	17.442	18.551	17.441	16.076	15.836	15.712	14.198
Prismatic coeff. (Cp)	0.716	0.722	0.723	0.722	0.723	0.722	0.716	0.709	0.709
Block coeff. (Cb)	0.445	0.530	0.440	0.436	0.440	0.530	0.445	0.409	0.452
LCB from zero pt. (+ve fwd) m	0.158	0.156	0.156	0.154	0.155	0.157	0.159	0.160	0.161
LCF from zero pt. (+ve fwd) m	0.035	-0.052	-0.131	-0.265	-0.131	-0.052	0.035	0.106	0.224
Max deck inclination deg	30.0476	20.0754	10.1481	1.7118	10.1479	20.0756	30.0477	40.0295	50.0181
Trim angle (+ve by stern) deg	-2.0500	-1.8895	-1.7631	-1.7118	-1.7616	-1.8908	-2.0515	-2.2000	-2.4432

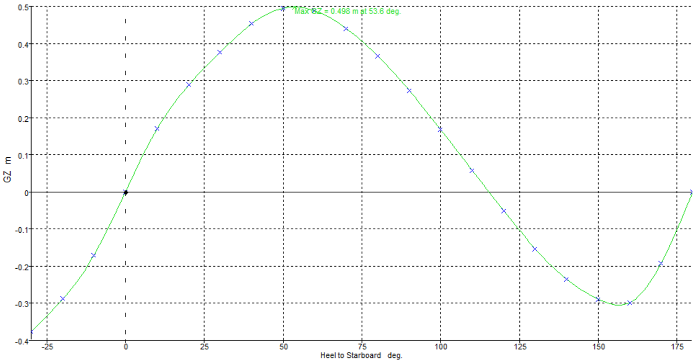


Figure 3.12:

RESULTS AND DISCUSSION

4.1 INTRODUCTION

To study the effect of hull elongation to the vessel's performance, a parent hull passenger vessel is selected and was modified using Rhinoceros 3D software. Then the resistance of the modified hull were assessed by using Maxsurf Resistance software. Resistance is the importance one of hydrodynamic particular of hull form either in smooth or rough water. It needs to determine or calculate to look at the performance of the hull form. For this thesis project, the value of resistance will be predicted by using Savitsky method to check the performance of the developed hull form either reasonable or not if compared to basic hull form. The performance is presented in tables and graphs.

4.2 PARENT HULL

Based on the parent hull, new hull forms are generated by varying the length. All other particulars were maintained and the draught was set to 0.42 metre for all sets of new hull form. Figure shows the profile view of the parent hull and Table shows the resistance of the vessel starting from 10 knots to 50 knots.

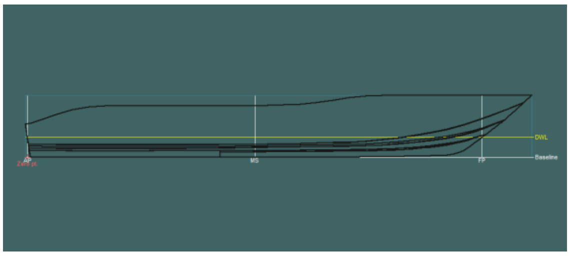


Figure 4.1: Profile view of the original parent hull

Table 4.1: Resistance result for original parent hull

Speed, knott	Resistance, kN
10.00	3.0

Speed, knott	Resistance, kN
11.00	3.3
12.00	3.6
13.00	3.9
14.00	4.2
15.00	4.5
16.00	4.8
17.00	5.1
18.00	5.4
19.00	5.7
20.00	6.0
21.00	6.2
22.00	6.5
23.00	6.7
24.00	6.9
25.00	7.1
26.00	7.3
27.00	7.5
28.00	7.7
29.00	7.9
30.00	8.2
31.00	8.4
32.00	8.6
33.00	8.9
34.00	9.1
35.00	9.4
36.00	9.7
37.00	10.0
38.00	10.3
39.00	10.6
40.00	10.9
41.00	11.3
42.00	11.6
43.00	12.0
44.00	12.3
45.00	12.7
46.00	13.1
47.00	13.5
48.00	13.9
49.00	14.3
50.00	14.8

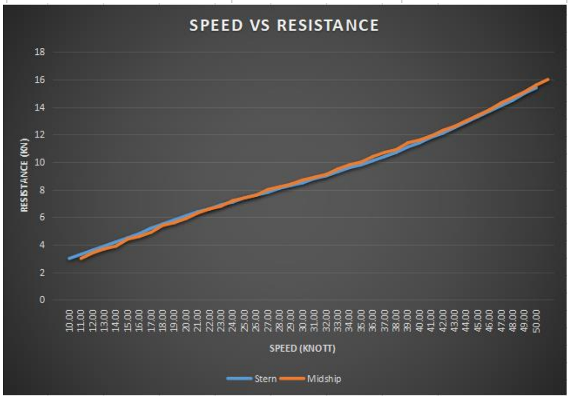
4.3 RESISTANCE RESULTS

Based on the design of the parent hull, 12 new hull forms were developed from it. Six hulls using lengthening the midship method and another six using the lengthening the stern of the vessel method. The new length is between 11.5 metre to 14.0 metre. In the following illustrated figures and tables, the resistance results of each new length will be compared between the two types of the lengthening ways. The range of speed where the resistance results are recorded is between 10 knots to 50 knots. On top of that, for each speed, a speed versus resistance graph is plotted.

4.3.1 11.5 METRE

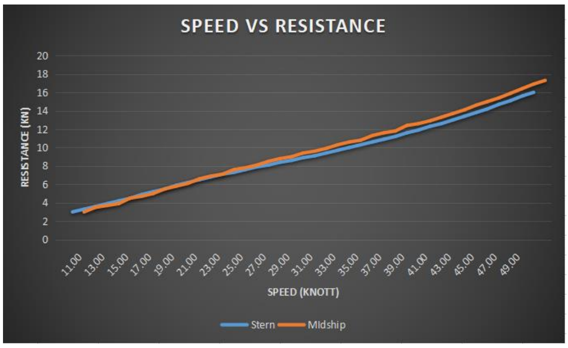
Table 4.3: Resistance results for 11.5 metre hull (midship)

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.0	3.0
20	6.3	6.1
30	8.9	8.5
40	11.9	11.4
50	16.0	15.4



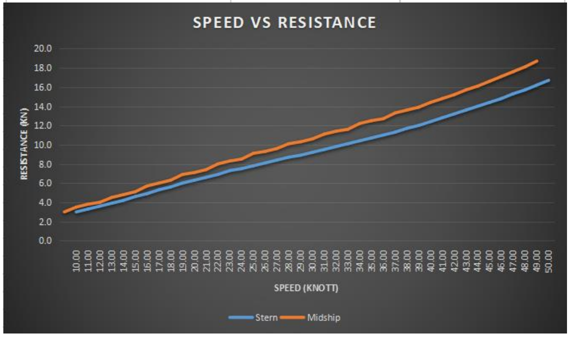
4.3.2 12.0 METRE

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.0	3.0
20	6.6	6.2
30	9.6	8.9
40	12.9	11.9
50	17.3	16.0



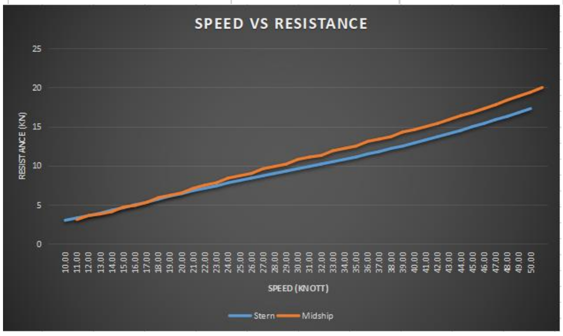
4.2.3 12.5 METRE

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.0	3.0
20	6.9	6.3
30	10.3	9.2
40	13.9	12.4
50	18.7	16.7



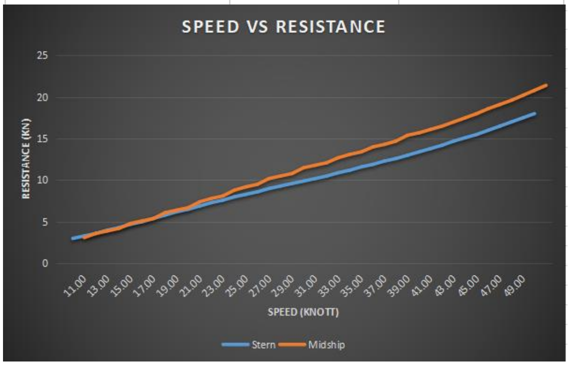
4.3.4 13.0 METRE

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.1	3.0
20	7.1	6.4
30	11.1	9.6
40	15.0	12.9
50	20.0	17.3



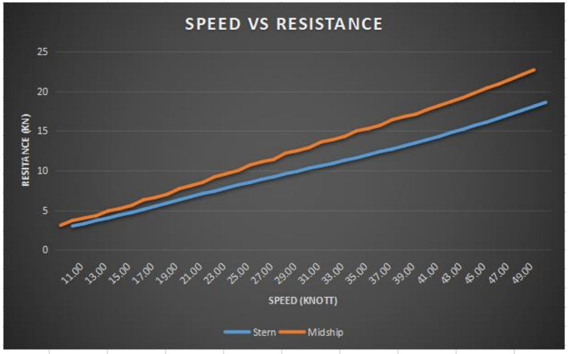
4.3.5 13.5 METRE

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.1	3.0
20	7.4	6.5
30	11.8	9.9
40	16.1	13.4
50	21.4	18.0



4.3.6 14.0 METRE

Speed (knott)	Resistance (kN)	
	Midship	Stern
10	3.1	3.0
20	7.7	6.7
30	12.5	10.3
40	17.1	13.9
50	22.7	18.6



4.4 RESISTANCE DISCUSSION

Based on the results above, we can see that the new hull forms were successfully developed from its original parent hull. In Figure 5, the value of the resistance at 10 knotts are constant from 11.5 metre to 12.5 metre and only increase by 0.1 for the following speeds. While for the stern, the resistance is constant throughout all the length. Next, at 20 knots, the resistance only increase gradually by 0.1 kN to 0.3 kN as the length increases. Move on hull's speed at 20 knots, the resistance starts to show a significant increment for each length. Furthermore, the resistance increase by 1.0 kN at 40 knots and 50 knots respectively.

In general, at every speed, the resistance increases as the speed increases on both type of elongation cases whether at the midship section or at the stern. On top of that, as seen, the value of resistance at the midship is higher compared to the stern for every six new lengths.

As for the graphs, for 11.5 metre, the curves are as in the same line. When the length is at 12.0 metre, the curve starts at the same point and starts to diverge at speed of 25 knots. For the following graphs, the midship curves are higher than the stern curve showing that the resistance at the midship is higher compared to the stern. In short, the speed is directly proportional to resistance. When the speed increases, the resistance increases. At higher speed, it is shown that, lengthening at the stern give less resistance. compared to lengthening at the stern section.

4.5 STABILITY RESULTS

Based on the 12 new hull forms, a stability assessment was also done to figure out few stability criteria such as the upright hydrostatic and large angle stability of each hull forms. The results were then compared to International Maritime Organization Load Line Criteria (LLC) to see if each of the hull forms meet the stability requirement. There are only five criteria that was taken into account for passenger vessel

Table 4.15: IMO Load Line Criteria

	Stability Criteria	**Small Craft**
a	Area Under Curve 0º - 30º	≥ 0.055 m.radius if maximum GZ occur at 30º
b	Area Under Curve 30º-40º or up to θ_f (flooding Angle)	≥ 0.03 m.radius
c	Maximum GZ	≥ 0.2 m
d	Angle at Maximum GZ	≥ 15 degree
e	Initial GM	≥ 0.15 m

Table 4.16: 11.5m to 12.5 results to meet the LLC

LLC	**11.5 metre**		**12.0 metre**		**12.5 metre**	
	Midship	Stern	Midship	Stern	Midship	Stern
a	0.1143	0.1143	0.1144	0.1143	0.1144	0.1143
b	0.356	0.356	0.355	0.356	0.356	0.356
c	0.498	0.498	0.498	0.498	0.499	0.498
d	53.6	53.6	53.6	53.6	53.6	53.6
e	1.033	1.032	1.034	1.032	1.034	1.032

Table 4.17: 13.0m to 14.0m results to meet the LLC

LLC	13.0 metre		13.5 metre		14.0 metre	
	Midship	Stern	Midship	Stern	Midship	Stern
a	0.1144	0.1143	0.1146	0.1144	0.1146	0.1144
b	0.356	0.356	0.357	0.357	0.357	0.357
c	0.499	0.498	0.5	0.499	0.5	0.499
d	53.6	53.6	53.6	53.6	53.6	53.6
e	1.035	1.032	1.035	1.032	1.036	1.032

4.6 STABILITY DISCUSSION

Based on the stability results above, it is clear that all hull forms passed the IMO Load Line Criteria requirement. However, there is no big difference for each length in terms of values. They increased only by 0.0001 for most of the criteria. On top of that, there are two consecutive length which the value remains constant.

As for the lengthening at midship section, the range of values of GMT are from 1.033 metre to 1.036 metre. On the other hand, the value of GMT for lengthening at the stern section constant for all lengthening cases. This means that stern cases is a little bit unstable compared to the midship cases because the lower the value of the GM, the higher the value of KG thus the ship is unstable.

CONCLUSION & RECOMMENDATIONS

In this thesis project, a method of lengthening the hull form for passenger vessel has been proposed. A software or computer program also has been used to develop the new hull forms. The resistance and stability of the new hull form of the passenger vessel has also been predicted by the software.

From the results, in terms of resistance analysis, the lengthening at the stern produce less resistance compare to lengthening at the midship. However in terms of stability analysis, the lengthening at the midship shows a better results in the GM_T values.

I would suggest the most effective ways to elongate a hull form is by lengthening the stern of the vessel. This is because, although it has low GM_T compares to the midship, it still meet the IMO Load Line Criteria. The difference between the GM_T value is also low which is from 0.0001 to 0.0004 metre.

Next, here have some causes to be discussed and suggested in how to come out with a more accurate new hull form than the proposed method for the thesis project, although it is quite effective. The following are the several causes that have been discussed and suggested:

i. The shape of the hull form after elongate in Rhinoceros 3D software is not smooth. A smooth curve of the hull form is not obtained because we cannot alter the breadth of the hull. This is because, the focus of this thesis is to alter the length and other particulars are kept constant. If the breadth was altered, it will change the resistance of the vessel.

ii. The results for resistance are just predicted for the bare hull condition and the result shows that the trend of the performance curves is has almost similar trend as the basis hull, so this is reasonable. However, for preliminary design stage, the prediction is considered applicable. For the suggestion, it need to do a model test to get the actual resistance by adding wave resistance, appendages resistance and residuary resistance.

ACKNOWLEDGEMENTS

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