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(Research Article)

Ship Hull Form Optimization for Improved Resistance and Effective Power

MacPepple Blessing James, Azubuike John Chuku * and Aja-Ukpabi Benson Onwuzurike

Department of Marine and Offshore Engineering, Faculty of Engineering, Rivers State University, Port Harcourt, Nigeria.

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Abstract

This study is focused on modifying streamline an existing offshore supply vessel (OSP) hull form to an IMO standard one so as to obtain an improved ship hull form with low resistance and power and also with highly efficient energy-saving performance. Using an analytical method there was significant increase in the design variables during the process of hull form modification and this was validated when Maxsurf software was used to modify the hull form. The analytical method used to perform the modification of pacific wrestler using response amplitude operator (RAOs) from Maxsurf then MATLAB to consider the modified and initial resistance values gotten from Maxsurf motion analysis used as the input values in comparing the resistance and power as against the vessel forward speed at 180 Degree and 135 Degree. Main dimensions of the ship were used to generate various hull models and Autodesk inventor used to present the various vessel hull form in solid form. The optimization was to improve on the vessel hydrodynamic performance in calm water as to achieve good sea-keeping condition, comfortability, manoeuvrability, reduced fuel consumption at 0,5,10,15,20,23 and 25 knots on regular sea wave condition of 4m. The various NURBs design diagrams gotten were used to run a computer motion simulation on regular sea wave of 4 meters for the both hull forms to ascertain a more favourable resistance, stability and rang at various speed on transit. MATLAB coding was used to calculate for the required power for both vessel considering the resistance values gotten from the maxsurf motion analysis which shows that there was reasonable reduction in the modified resistance of about 40 to 45%, and also power of about 30 to 25% and hydrodynamic location RAOs of up to 8 to 2% results. Comparing the results of the parent hull form to the modified hull form at 0 to 25 knots of the ship speeds on various location of the sea state towards the different degree of movement of the ship which demonstrates the validity of the proposed modification design strategy after bulb was designed into the bow section of the ship hull given the ship a better forward buoyancy, 20 to 25% of fuel efficiency, and increased speed.

Keywords: Ship redesign; Resistance; Propulsion; Thrust Power

1. Introduction

A hull form with the minimum resistance is a common pursuit in the field of ship design. Previous hull form optimization schemes were mainly dependent on a series of ship model tests carried out at the initial stage, through which a new hull form was obtained via through transformation of the original hull form. Designers generally conduct hull form modifications according to principles derived from personal experience of determining the preferable resistance performance. Therefore, the optimal process of practical hull form becomes a system which lacks scientific evaluation in terms of engineering [1]. However, first the ranges of heel to be investigated need to be set, and for this analysis the range of heel angle is set from 0 - 1800 insteps of 10 degrees. Also, the desired vessel trim for each damage condition is set, at free to trim and the direction of trim is to be starboard assuming that all damages occurring on the passenger vessel hull takes place at the starboard [2] (Chuku & Oludi, 2025).

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* Corresponding author: Azubuike John Chuku

This current research is aimed at improving on the existing parent ship hull form in achieving optimal performance of the new design hull form with minimum resistance and power. In order to achieve this aim, key objectives like estimating the minimum resistance, power and fuel consumption of the design ship hull forms on operation at various speed, evaluating the ship hull form with optimum stability, at the higher hydrodynamic performance and out of phase waves at the designed service speeds were set. Additional objective included to provide basic critical knowledge for the design of new vessel from an existing vessel design parameters as ship building professional establishing the required hull form that can withstand any environmental forces [3]. The entire work scope was concerned about achieving a new design ship with minimum resistance acting on the hull of the ship during operation on regular sea wave at various forward speeds at a required power using Maxsurf 3-D design modellers with MATLAB. [4], effectively analysed the calm water resistance, added resistance, and RAOs for a VLCC operating under typical Gulf of Guinea wave conditions. The calm water resistance results showed a clear increase with both vessel speed and draft, highlighting the impact of frictional forces as more hull surface interacts with water at deeper drafts and higher speeds. The sharp reversals in both forces indicate critical points that may require special attention in structural design to ensure safety and integrity of the DUC vessel [5].

Also, it may be seen that the RAOs for the optimised hull are less than the initial hull form. Minimum fuel consumption and maximum comfort on board (minimum vibration and noise) are usually the primary targets in ship hull design. It has been demonstrated that minimizing the total resistance by obtaining a very hull form design to sustain a given speed is a better goal than minimizing the power [6].

The resistance generated from the hullform can affect the structural response of the vessel. The report of [7]. (Chuku et al., 2024) which states that the hogging and sagging shear forces exhibit similar trends, with initial increases, fluctuations, sharp reversals, and gradual recoveries. Both forces reach their maximum values at different vessel length. Previous work done on related past work, hull form modification was achieved by the Bow and aft shape section of either a V or U form, draught increase, stabilizers and fin Installation at the port and starboard sides of the vessel without putting much consideration on the international maritime organisation (IMO) and safety of life at sea (SOLAS) 1988 as amended when optimising in ship design. This dissertation was able to achieve using modern sophisticated ship design Software and approach.

2. Materials And Methods

2.1. Materials

- Basis vessel: An existing supply vessel pacific wrestler an offshore supply ship registered and sailing under the flag of Malaysia. Her gross tonnage is 2332 and deadweight is 2131 built in 2003. With length overall (LOA) of 68.95 m, beam 15.54 m and draft of 5.8 m.
- Auto-Cad: Autocad was utilised for the structural response
- Maxsurf: Maxsurf was used for the modeller and hullform and lines plan design.
- MATLAB: Matlab was used to generate the codes for the analysis.

Table 1 Parent Ship Main Dimensions

Parameters	**Dimensions**
Length of ship	68.95m
Breadth	15.54m
Depth	6.80 m
Draft	5.8 m
Deadweight	2131 t

2.2. Research Methodology

A modified ship's hull form with reduced resistance and highly efficient energy saving performance is always the aim if a Naval Architect. A ship having a total resistance and power corresponding to the objective function. A hull geometry parameter corresponding to design variables where reduced resistance of power are evident at all ship's displacement in water. The method deployed to achieve these design objectives were maxsurf non-uniform rotational basis spline (NURBS) and MATLAB. NURBs was used to design and model the parent hull form and then MATLAB was used to calculate the required power for both vessel from the resistance values gotten from the maxsurf motion analysis. The modified ship's hull form result showed that there was reasonable reduction in both resistance and power when compared with the parent one at different sea states. These results have clearly demonstrated the validity of the proposed modification designs strategy.

2.2.1. Methods

The ship principle dimensions such as the length (L), breath (B) and draft (T) were used to achieving the models which were used in the various maxsurf analysis to achieving the heave, pitch and roll responses and the various resistance at 45-degree and 90-degree sea. The resistance values were use as input values in Matrix laboratory (MATLAB) to estimate the effective power and also plotting the various speeds to power and resistance to power graphs of the vessel. Ship hull form Coefficients which are dimensionless numbers that describe hull fineness and overall shape characteristics the coefficients are ratios of areas or volumes for the actual hull form compared to rectangles defined by the ship's length, breadth and draft length and breadth on the waterline as well as draft vary with displacement, coefficient of form also vary with displacement tabulated coefficient.

They are usually based on the moulded breadth and draft at designed displacement length between perpendiculars (Lpp). Some designers prefer length on the waterline coefficients of form that is be used to simplify area, volume and calculations for stability analysis considering the below equations.

Volume of displacement : ∇

Waterline area : A_{WL}

Block coefficient, L_{WL} based

$$C_{B,WL} = \frac{\nabla}{l_{WL} \, x \, B_{WL} \, x \, D} \qquad \text{……….} \quad (0)$$

Mid ship section coefficient:

$$C_{WL} = \frac{A_W}{B_{WL} \, x \, D} \qquad \text{…………}(1)$$

Longitudinal prismatic coefficient:

$$C_p = \frac{\nabla}{A_w \, x \, L_{WL}} \qquad \text{…………}(2)$$

Water plane area coefficient:

$$C_{WL} = \frac{A_{WL}}{L_{WL} \, x \, B_{WL}} \qquad \text{……….} \quad (3)$$

Length between perpendiculars :

$$L_{PP} = 0.97 \text{ x } L_{WL} \qquad \text{…………} \quad (4)$$

2.2.2. Brettschneider Spectrum Method

This criterion is used in places where the wave formation region is a constraining factor for wave generation, it is a variation of the Brettschneider spectrum. Seakeeping Analyses Seakeeping ability of how well a vessel is to condition when underway. It also refers to the analysing the behaviour of a vessel in regular and irregular waves, represented through the RAOs (Response Amplitude Operator). RAO is a linear operator that represents the input wave output movement transfer, it being of key relevance to determine vessel design parameters, [8]. The RAO describes how the response of the vessel changes with frequency variations. The various graphs in chapter 5 shows a classic example of a RAO response representing the Heave and Pitch amplitudes from PSV Case study.

We can see how RAO approaches one for low frequencies and it is when the vessel shifts up and down with the wave, acting as a cork. For high frequencies, the response approaches zero while the effect of many short waves in cancelled along the vessel's length. Normally, the vessel would also have a peak higher than one, which occurs close to the natural period of the vessel response. The above one indicates that the vessel's response is higher than the amplitude of the wave (or than the slope) while also the Spectral Crossing is the product of the Sea spectrum times the transference function (RAO) Response Amplitude Operator.

$$S_{\zeta}(\omega) = \frac{172.8.H_{1/3}{}^{2}.\omega^{-5}}{}.\exp\{\frac{-691.2}{T_1^3}.\omega^4\}.A.r^5 \quad \text{.........} \quad (5)$$

With

$$A = 0.658^5$$

$$B = \exp\left\{ \left(\frac{\frac{\omega}{\omega_p} - 1.0}{\sigma.\sqrt{2}} \right) \right\}$$

$$r = 3.3 \qquad peakedness\ factor$$

$$\omega_p = \frac{2.\pi}{T_p} \quad (circular\ frequency at\ spectral\ peak)$$

$$\sigma = a\ step\ function of\ \omega: \qquad \begin{array}{l} if\ \omega < \omega_p\ then: \sigma = 0.0.7 \\ if\ \omega > \omega_p\ then: \sigma = 0.09 \end{array}$$

The Brettschneider definition multiplied by the frequency function $A.r^B$.

The nth order spectral moments of the wave spectrum, defined as a function of the circular wave frequency *w*, are:

$$m_{n\zeta} = \int_0^{\alpha} S_{\zeta}(\omega).\omega^n.d\omega \quad \text{............} \quad (6)$$

The breadth of a wave spectrum is defined by:

$$\varepsilon = \sqrt{1 - \frac{m_{2\zeta}{}^{2}}{m_{0\zeta}.m_{4\zeta}}}$$

The significant wave height is defined by:

$$H_{1/3} = 4.\sqrt{m_{0\zeta}} \quad \text{.......} \quad (7)$$

The several definitions of the average wave period are:

T_p peak or modal wave period, corresponding to peak of spectral curve

$T_1 = 2.\pi.\dfrac{m_{0\zeta}}{m_{1\zeta}}$ Average wave period, corresponding to centroid of spectral curve

$T_2 = 2.\pi.\sqrt{\dfrac{m_{0\zeta}}{m_{1\zeta}}}$ average zero-crossing wave period, corresponding to radius of inertia of spectral curve

$$\begin{array}{ccccc} T_1 & = & 1.073.T_2 & = & 0.834.T_p \\ 0.932.T_1 & = & T_2 & = & 0.777.T_p \\ 1.199.T_1 & = & 1.287.T_2 & = & .T_p \end{array}$$

for Brettschneider wave spectra

Truncation of wave spectra during numerical calculations can cause differences between input and calculated wave periods. Generally, the wave heights will not differ much.

The energy spectrum of the responses $r(i)$ of a sailing ship in the regular waves follows from the transfer function of the response and the wave energy spectrum by: $S_r(\omega) = \left(\dfrac{r_a}{\zeta_a}\right)^2.S_\zeta(\omega) \;\; or \;\; S_r(\omega_e) = \left(\dfrac{r_a}{\zeta_a}\right)^2.S_\zeta(\omega)$ …….(8)

The moments of the response spectrum are given by:

From the spectral density function of a response the significant amplitude can be calculated. The significant amplitude is defined to be the mean value of the highest one-third part of the highest wave heights, so:

$$r_{a\,1/3} = 2.\sqrt{m_{or}} \qquad \ldots \qquad (9)$$

A mean period can be found from the centroid of the spectrum by:

$$T_{1r} = 2.\pi.\frac{m_{or}}{m_{1r}} \qquad \ldots\ldots\ldots \qquad (10)$$

Another definition, which is equivalent to the average zero-crossing period, is found from the spectral radius of inertia by:

$$T_{2r} = 2.\pi\sqrt{\frac{m_{or}}{m_{2r}}} \qquad \ldots\ldots\ldots\ldots \; (11)$$

The probability density function of the maximum and minimum values, in case of a spectrum with a frequency range that is not too wide, is given by the Rayleigh distribution: $f(r_a) = \dfrac{r_a}{m_{or}}.\exp\,\{\dfrac{-r_a^2}{2.m_{or}}\}.dr_a$ ………..(12)

This implies that the probability of exceeding a threshold value a by the response amplitude r_a becomes:

$$P\{r_a > a\} = \int_a^\alpha \frac{r_a}{m_{or}}.\exp\{\frac{-r_a^2}{2.m_{or}}\}.\, dr_a = \exp\{\frac{-a^2}{2.m_{or}}\} \qquad \ldots\ldots\ldots \qquad (13)$$

The number of times per hour that this happens follows from:

$$N_{hour} = \frac{3600}{T_{2r}}.P\{r_a >\}$$

The spectral value of the waves $S_\zeta(\omega_e)$, base on ω_e, is not equal to the spectral value $S_\zeta(\omega)$, based on ω. Because of the requirement of an equal amount of energy in the frequency bands $\Delta\omega_e$ and $\Delta\omega$, it follows:

$$S_\zeta(\omega_e)\ .d\omega_e = S_\zeta(\omega).\ d\omega \qquad (14)$$

From this the following relations is found:

$$S_\zeta(\omega_e) = \frac{S_\zeta(\omega)}{d\omega_e / d\omega} \qquad \text{..........} \ (15)$$

The relations between the frequency of encounter and the wave frequency, of which is

$$\omega_e = \omega - k.V.\cos\mu \qquad \text{........} \quad (16)$$

From the relation between ω follows:

$$\frac{d\omega}{d\omega} = 1.0 - \frac{V.\cos\mu}{d\omega / dk}$$

The derivative $d\omega / dk$ follows from the relation between ω and k : $\omega = \sqrt{k.g.\tanh[k.h]}$ .... (17)

So:

$$\frac{d\omega}{dk} = \frac{g.\tanh[k.h] + \dfrac{k.g}{h.\cosh^2[k.h]}}{2.\sqrt{k.g.\tanh[k.h]}} \qquad \text{.........}(18)$$

$d\omega_e / d\omega$ can approach from both sides, a positive or a negative side, to zero. As a result of this, around a wave speed equal to twice the forward ship speed component in the direction of the wave propagation, the transformed spectral values will range from plus infinite to minus infinite. This implies that numerical problems will arise in the numerical integration routine.

This is the reason why the spectral moments have to be written in the following format:

$$m_{or} = \int_{\circ}^{\infty} S_r(\omega_e).d\omega_e \qquad = \int_{\circ}^{\infty} S_r(\omega).d\omega$$

$$m_{1r} = \int_{\circ}^{\infty} S_r(\omega_e).\omega_e.d\omega_e \qquad = \int_{\circ}^{\infty} S_r(\omega).\omega_e.\ d\omega \quad \text{With:}$$

$$m_{2r} = \int_{\circ}^{\infty} S_r(\omega_e).\omega^2.d\omega_e \qquad = \int_{\circ}^{\infty} S_r(\omega).\ \omega_e^2.d\omega$$

$$S_r(\omega) = \left(\frac{r_a}{\zeta_a}\right)^2.\ S_\zeta(\omega) \qquad \text{..........}(19)$$

2.2.3. The Total Ship Resistance (RT)

Any propulsion system interacts with the ship hull. The flow field is changed by the (usually upstream located) hull. The propulsion system changes, in turn, the flow field at the ship hull. However, traditionally naval architects have considered propeller and ship separately and introduced special efficiencies and factors to account for the effects of interaction.

While this decomposition is seen by many as an important aid in structuring the complex problems of ship hydrodynamics, it also hinders a system approach in design and can confuse as much as it can help. Since it is still the backbone of our experimental procedures and ingrained in generations of naval architects, the most important concepts and quantities are covered here. The hope is, however, that CFD will in future allow a more comprehensive optimization of the ship interacting with the propeller as a whole system

The total calm-water resistance of the ship excluding resistance of appendages related to the propulsive organs. Sometimes the rudder is also excluded and treated as part of the propulsion system. This gives a glimpse of the conceptual confusion likely to follow from different conventions concerning the decomposition. Remember that in the end the installed power is to be minimized, [9]. As a ship moves through calm water, the ship experiences force acting opposite to its direction of motion. This force is the water's resistance to the motion of the ship, which is referred to as total ship hull resistance [10]. It is this resistance force that is used to calculate a ship's effective horsepower. A ship's calm water resistance is a function of many factors, including ship speed, hull form draft, beam, length, wetted surface area, and water temperature and also total hull resistance increases as speed increases.

2.2.4. The Various Components of Ship Hull Resistance

As a ship moves through calm water, there are many factors that combine to form the total resistance force acting on the hull. The principal factors affecting ship resistance are the friction and viscous effects of water acting on the hull, the energy required to create and maintain the ship's characteristic bow and stern waves, and the resistance that air provides to ship motion. In mathematical terms, total resistance can be written as:

$$R_T = R_V + R_W + R_{AA} \qquad (20)$$

Where: RT is the total hull resistance, RV is the viscous (friction) resistance, RW is the wave making resistance and RAA is the air resistance caused by ship moving through calm air

2.2.5. Ship Dimensionless Coefficients

Naval architects, as well as all engineers and scientists use dimensionless coefficients to describe the performance of a system or to compare different systems to each other. Automotive engineers use a drag coefficient to describe the performance of a car. Aviators use the Mach number to compare the speed of an aircraft to the speed of sound. Naval architects use many dimensionless coefficients to describe the design and performance of a ship's hull. Dimensionless coefficients allow the naval architect to compare model test data to full-scale ship data, or to compare the performance of several ship types. The field of ship resistance and propulsion makes extensive use of standard dimensionless coefficients.

The derivation of these standard coefficients is accomplished through dimensional analysis. Dimensional analysis is beyond the scope of this text; however, you can learn about dimensional analysis from any text on fluid mechanics or from Volume 2 of Principles of Naval Architecture published by the Society of Naval Architects and Marine Engineers [11]. Just as total hull resistance is the sum of viscous, wave making, and air resistance, we can write an equation for total resistance in terms of dimensionless coefficients.

$$C_T = C_V + C_W \qquad \ldots\ldots\ldots\ldots \quad (21)$$

Where: CT is the coefficient of total hull resistance, CV is the coefficient of viscous resistance and CW is the coefficient of wave making resistance.

$$C_T = \frac{R_T}{1/2\rho V^2 S} \qquad ,\ldots\ldots\ldots\ldots\ldots (22)$$

Where: RT is Total hull Resistance, is water density , V is Velocity (ship speed) (m/s), and S is Wetted surface area of the underwater hull (m2).

Naval architects also use a dimensionless form of velocity called the Froude number (fn).

$$F_n = \frac{V}{\sqrt{gL}} \qquad \ldots\ldots\ldots \quad (23)$$

Where: V is Velocity (ship speed) (m/s), g is Acceleration of gravity (m/s2), L is Length of the ship (m)

Mathematically, laminar and turbulent flow can be described using the dimensionless coefficient known as the Reynolds Number:

$$R_n = \frac{LV}{\nu} \qquad \ldots\ldots. \quad (24)$$

Where: Rn is Reynolds number, L is Length of ship (m), V is Velocity (ship speed) (m/s), and is Kinematic Viscosity of water (m2/s).

2.2.6. Ship Required Effective Power

The effective power at any speed is defined as the power needed to overcome the resistance of the naked hull at that speed, it is sometimes referred to as the low rope power that would be expanded if the ship were to be towed through the water without the flow around it being affected by the means of towing another, higher effective power would apply if the ship to wave has a poor hydrodynamic performance, [12]. It is also noted that appendages coefficient required is referred as the ratio of this power to that needed for the naked ship for effective performance at sea which is as for a given speed the effective power is the product of the total resistance and the vessel speed thus;

$$P_E = R_T\,(\text{KN}) \times V_s\,(\text{m/s}) \qquad \ldots\ldots. \quad (3.25)$$

The fuel consumption, FC, of a hull is proportional to the product of RT and the speed experienced by the vessel hull.

$$FC = P_E \times Vs \quad \ldots\ldots\ldots \ (3.26)$$

3. Results and Discussion

3.1. Ship resistance computation of the modified hull form

Analytical methods were used to getting the results in the dissertation and after comparing the both hull form analysis values as shown below it was released that the modified hull form results gave a better satisfied resistance to power results as seen on table 4.1. This work has provided important information regarding seakeeping performance of the supply vessel that can withstand any form of sea conditions during operation.

Table 2 The Estimated Resistance as Against the Effective Power from MAXSURF and MATLAB Analysis @ 45-Degree and 90-Degree Sea

S/N	Vessel Speed (knots)	Resistance (1) (KN)	Power (1) (KW)	Resistance (2) (KN)	Power (2) (KW)	Resistance (3) (KN)	Power (3) (KW)	Resistance (4) (KN)	Power (4) (KW)
1	0	241.614	0.00	193.112	0.00	241.408	0	192.489	0.00
2	5	225.053	578.39	192.471	494.65	200.000	514.00	182.923	470.11
3	10	221.425	1138.12	181.136	931.04	196.210	1008.52	170.658	877.18
4	15	229.652	1770.62	178.010	1372.46	185.389	1429.35	166.590	1284.41
5	20	237.086	2437.24	160.604	1651.01	176.074	1810.4	155.314	1596.63
6	25	248.344	3191.22	152.178	1955.49	167.882	2157.28	140.003	1800.00

A ship's water resistance is a function of many factors, including ship speed, hull form (draft, beam, length, wetted surface area), and water temperature. Total hull resistance increases as speed increases but increases more steeply at higher speeds which are demonstrated on the various power to speed graphs. This increase and decrease in power as shown on the graph is felt directly in the amount of fuel consumed during the ship transit. Voyage planning requires careful attention as to ascertain the required fuel consumption to ensure that the ship arrives its destination with an adequate supply of fuel on board.

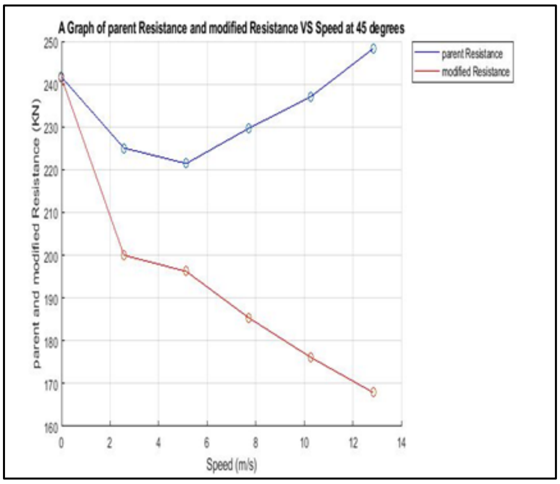

Figure 1 Graph of variation of ship speed vs resistance for the initial hull at 45-degree Sea

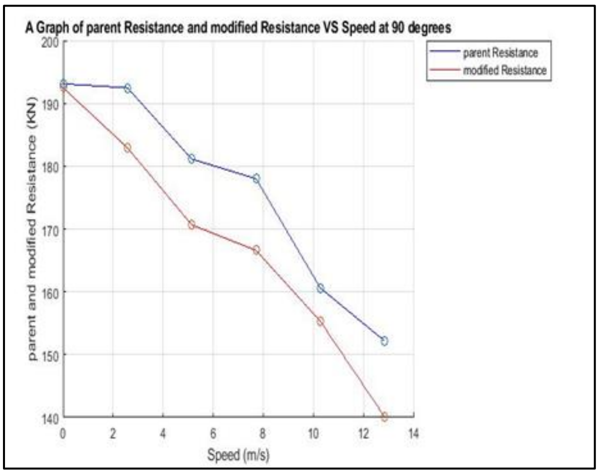

Figure 2 Graph of Variation of ship speed vs resistance for the initial hull at 90-degree sea

Knowing the power required to propel a ship enables the naval architect professional to select the adequate propulsion plant and also to determine the amount of fuel storage required. The resistance of the modified hull and the parent hull form were selected based on the realistic result gotten from the above graph. Ships use large quantities of fuel to provide the necessary propulsive power to overcome resistance in their motion across ocean surfaces.

Bulb is designed into the bow side of the hull shapes in order to decrease the wave making resistance on the modified ship.

Voyage planning requires careful attention as to ascertain the required fuel consumption to ensure that the ship arrives its destination with an adequate supply of fuel on board.

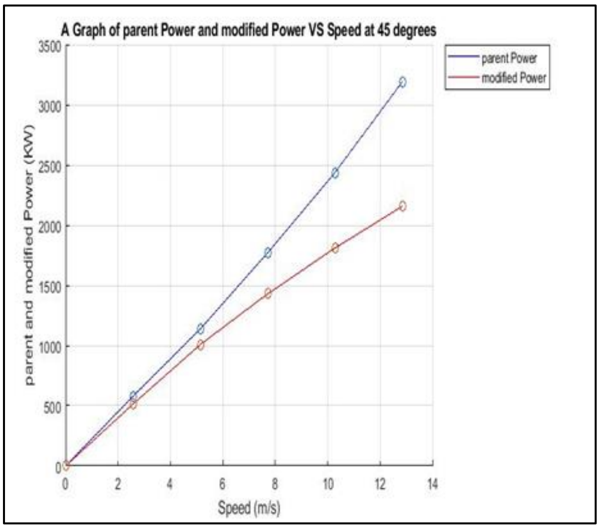

Figure 3 Graph of variation of ship speed vs power for the modified hull at 45-degree sea

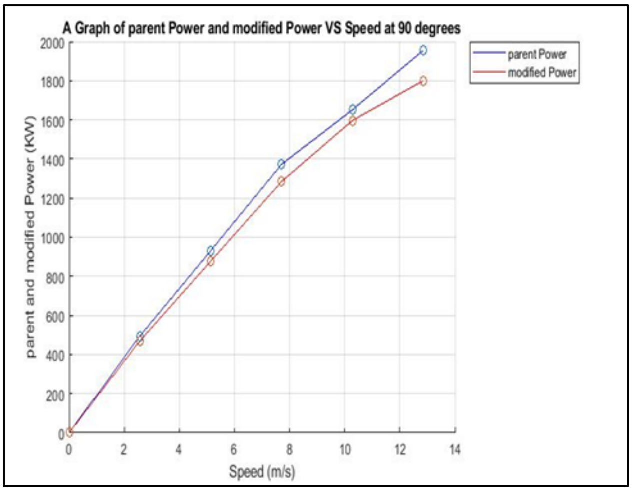

Figure 4 Graph of variation of ship speed vs power for the modified hull at 90-degree sea

From the above graphs it can be observed from comparisons that the modified hull is the optimum hull with minimal resistance and power not only because it has simple geometrical form but good mathematically defined shape. This may also serve as a basis for application of such approach to ship hull form design modification and improvement of its propulsion efficiency with minimal power.

The variation of motion characteristics with increasing sea state can be established and resistance for the floating hull is also estimated. The objective of this study has been successfully achieved seeing the positive results from the modified ship hull from the analyse on resistance against power in achieving a good ship hull which possesses minimal resistance as well as power in producing a satisfactory optimum result.

3.2. Hydrostatic Analysis of the modified hullform

The results on table 3.2 have shown that the best choice of ships hydrostatic parameters so depends on the hull form designed for any kind of seakeeping and stability analysis that can offer a very simple, optimum and realistic results from the sea keeping studies with vessels that has bulb design.

Table 3 The hydrostatic parameters used for the design of the optimized hull from SACs Design Analysis

Draft Amidships m	**0.000**	**0.500**	**1.000**	**1.500**	**2.000**	**2.500**	**3.000**	**3.500**	**4.000**	**4.500**
Displacementt	0.0000	289.0	716.4	1168	1641	2126	2623	3131	3652	4189
Heel deg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Draft at FP m	0.000	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
Draft at AP m	0.000	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
Draft at LCF m	0.000	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
WL Length m	56.902	64.144	66.523	67.768	68.413	68.674	68.494	69.203	70.463	72.002
Beam max extents on WL m	0.000	15.635	15.933	16.062	16.137	16.169	16.202	16.238	16.276	16.315
Wetted Area m^2	0.000	796.916	907.337	991.51	1067.8	1153.76	1232.4	1313.0	1398.67	1488.4
Waterpl. Area m^2	0.000	791.039	865.409	906.43	930.83	960.245	979.87	1003.1	1031.1	1061.7
Prismatic coeff. (Cp)	0.000	0.757	0.766	0.774	0.787	0.799	0.814	0.818	0.814	0.808
Block coeff. (Cb)	0.000	0.562	0.659	0.698	0.725	0.747	0.769	0.777	0.777	0.773
Max Sect. area coeff. (Cm)	0.000	0.743	0.861	0.902	0.925	0.938	0.945	0.951	0.955	0.958
Waterpl. area coeff. (Cwp)	0.000	0.789	0.816	0.833	0.843	0.865	0.883	0.893	0.899	0.904
LCB from zero pt. (+ve fwd) m	-35.999	-2.719	-2.320	-1.914	-1.707	-1.564	-1.496	-1.472	-1.480	-1.525
LCF from zero pt. (+ve fwd) m	-35.999	-2.363	-1.697	-1.291	-0.939	-1.171	-1.286	-1.422	-1.659	-1.937
KB m	0.000	0.301	0.571	0.836	1.100	1.363	1.626	1.890	2.155	2.424
KG m	4.500	4.500	4.500	4.500	4.500	4.500	4.500	4.500	4.500	4.500
BMt m	0.000	46.138	21.784	14.444	10.874	8.800	7.388	6.415	5.709	5.172
BML m	0.000	728.393	357.289	241.95	181.28	149.788	126.81	112.32	103.170	96.931
GMt m	-4.500	41.939	17.855	10.780	7.473	5.662	4.514	3.805	3.364	3.096
GML m	-4.500	724.194	353.360	238.29	177.88	146.651	123.94	109.71	100.825	94.855
KMt m	0.000	46.439	22.355	15.280	11.973	10.162	9.014	8.305	7.864	7.596
KML m	0.000	728.694	357.860	242.79	182.38	151.151	128.44	114.21	105.325	99.355
Immersion (TPc) tonne/cm	0.000	8.108	8.870	9.291	9.541	9.843	10.044	10.282	10.569	10.882
MTc tonne.m	0.000	29.069	35.162	38.662	40.539	43.310	45.155	47.711	51.143	55.186
RM at 1deg = GMt.Disp.sin(1) tonne.m	0.000	211.530	223.253	219.76	214.00	210.125	206.64	207.89	214.421	226.33
Max deck inclination deg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trim angle (+ve by stern) deg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Motion Analysis that was performed using the SACs design module and MATLAB to achieve the various satisfied results in tables 4.4 and 4.5 for the initial and optimised hull form and to analyse the various activities as to investigate on the vessel sea performance. After comparing the both hull form analysis values as shown it was released that the optimised hull form results gave a better power result that can withstand hydrodynamic pressure.

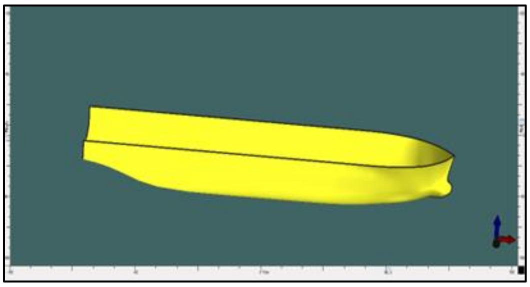

Figure 5 Streamlined Modified Hull Form from Parent Vessel

4. Conclusions

- In this study, Analytical investigation has been performed in two sections using powerful software such as maxsurf and MATLAB in determining the ship resistance as against the required power at various speed.
- The hydrodynamic response amplitude operators (RAOs) against time within regular sea state of 4m at 45-degree and 90-degree sea impact on vessel.
- Required minimal power of say 30 to 25% reduction has been achieved from the modified vessel due to the bow modification with well over 20 to 25% fuel economy, stability efficiency and increase speed.
- It can be seen that with the combination of Maxsurf and MATLAB optimised results were achieved with a vessel design that can withstand any form of sea states condition in deep sea operation from an existing ship.

4.1. Recommendation

In the new design series of supply vessels, the bow section of the ship should be modified with knuckle bulb which can help in reducing wave making resistance at the bow as well as the pitching responses with better fuel and stability efficiency and also to achieving minimal resistance and power.

4.2. Contribution to knowledge

- This dissertation has uncovered the various hiding relationship in maxsurf design modeler and analysis.
- The secret behind the design of supply vessel and modelling was achieved with the possibilities of the development of optimum design standard in ship building for various types and class of vessels.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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APPENDIXES A: matlab program used to estimate the minimal required power

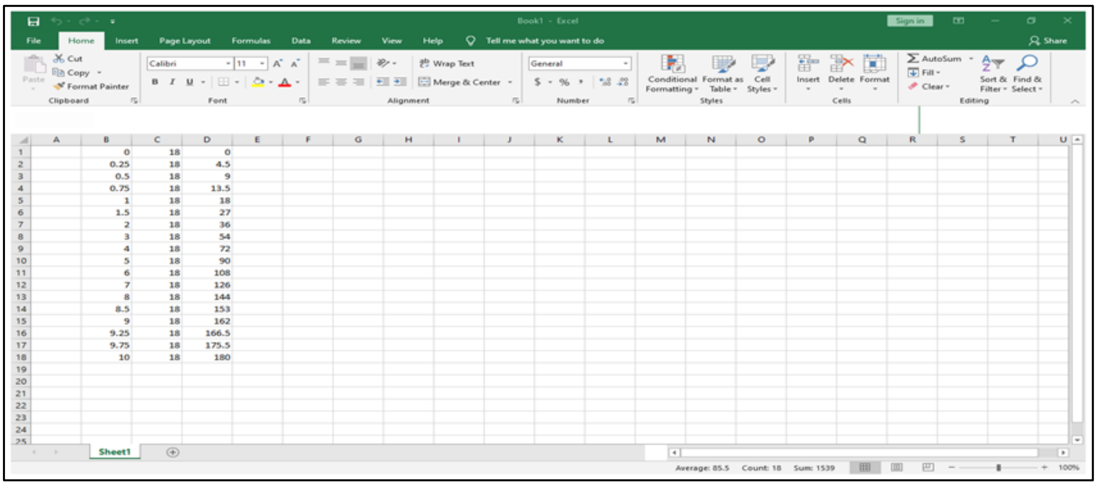
```
clc

clear all

V45=cell(1,2); V90=cell(1,2);

R45=cell(1,2); R90=cell(1,2);

P45=cell(1,2); P90=cell(1,2);

 v=[0 2.57 5.14 7.71 10.28 12.85];

R45{1}=[241.614 225.053 221.425 229.652 237.086 248.344];

R45{2}=[241.408 200.000 196.210 185.389 176.074 167.882];

 R90{1}=[193.112 192.471 181.136 178.010 160.604 152.178];

R90{2}=[192.486 182.923 170.658 166.590 155.314 140.083];

n=length(v);

for i=1:1:2

 V45{i}=v; V90{i}=v;

 P45{i}=V45{i}.*R45{i};

 P90{i}=V90{i}.*R90{i};

end

 for ii=1:1:2 % parent hull VS modified hull

for d=1:1:2 % 45 deg VS 90 deg
```

```
if ii==1
  disp('For parent values:')
elseif ii==2
  disp('For modified values:')
end
if d==1
  disp('for angle = 45 degrees')
for i=1:1:n % each entry
  fprintf('Speed = %0.2f m/s, Resistance = %0.2f kN, Power = %0.2f \n',v(i),R45{ii}(i),P45{ii}(i))
end
  disp(' ')
elseif d==2
  disp('for angle = 90 degrees')
for i=1:1:n % each entry
  fprintf('Speed = %0.2f m/s, Resistance = %0.2f kN, Power = %0.2f \n',v(i),R90{ii}(i),P90{ii}(i))
end
  disp(' ')
end
end
end

close all

figure(1)
plot(v,P45{1},'b-',v,P45{2},'r-',v,P45{1},'o',v,P45{2},'o')
title('A Graph of parent Power and modified Power VS Speed at 45 degrees')
xlabel('Speed (m/s)');ylabel('parent and modified Power (KW)');
legend('parent Power','modified Power','Location','NorthEastOutside')
set(gca,'box','off')
```

```
grid on
 figure(2)
plot(v,R45{1},'b-',v,R45{2},'r-',v,R45{1},'o',v,R45{2},'o')
title('A Graph of parent Resistance and modified Resistance VS Speed at 45 degrees')
xlabel('Speed (m/s)');ylabel('parent and modified Resistance (KN)');
legend('parent Resistance','modified Resistance','Location','NorthEastOutside')
set(gca,'box','off')
grid on
 figure(3)
plot(v,P90{1},'b-',v,P90{2},'r-',v,P90{1},'o',v,P90{2},'o')
title('A Graph of parent Power and modified Power VS Speed at 90 degrees')
xlabel('Speed (m/s)');ylabel('parent and modified Power (KW)');
legend('parent Power','modified Power','Location','NorthEastOutside')
set(gca,'box','off')
grid on
 figure(4)
plot(v,R90{1},'b-',v,R90{2},'r-',v,R90{1},'o',v,R90{2},'o')
title('A Graph of parent Resistance and modified Resistance VS Speed at 90 degrees')
xlabel('Speed (m/s)');ylabel('parent and modified Resistance (KN)');
legend('parent Resistance','modified Resistance','Location','NorthEastOutside')
set(gca,'box','off')
grid on
```

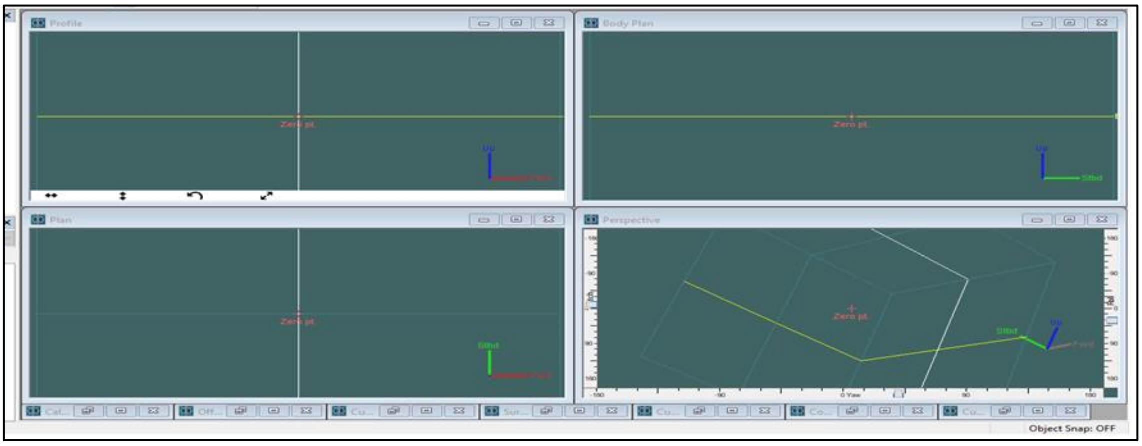
APPENDIX B: offshore supply vessel pacific wrestler

Appendix C: Excel User Interface of the Design Offset Table

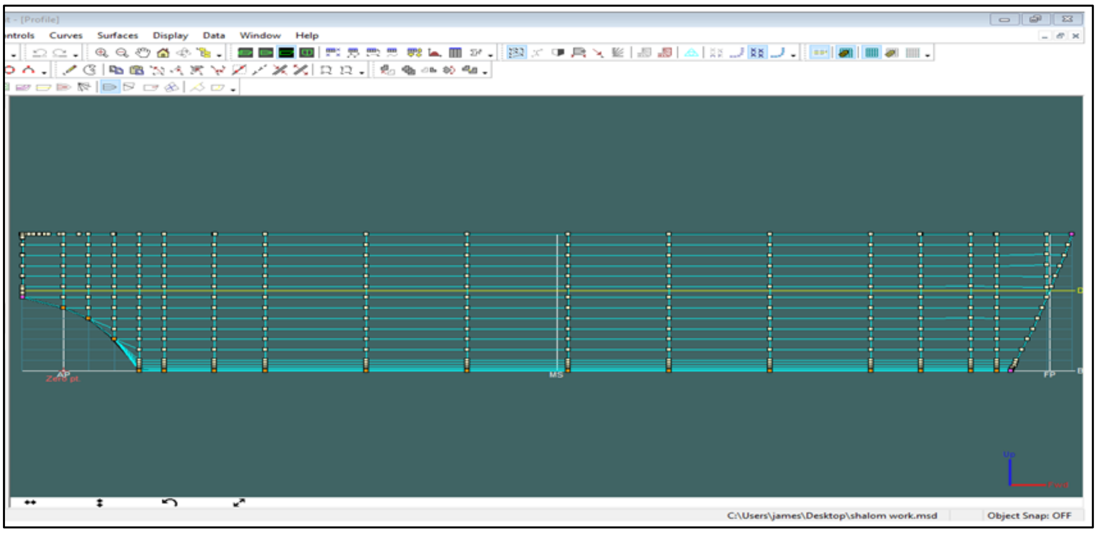


	A	B	C	D
1		0	18	0
2		0.25	18	4.5
3		0.5	18	9
4		0.75	18	13.5
5		1	18	18
6		1.5	18	27
7		2	18	36
8		3	18	54
9		4	18	72
10		5	18	90
11		6	18	108
12		7	18	126
13		8	18	144
14		8.5	18	153
15		9	18	162
16		9.25	18	166.5
17		9.75	18	175.5
18		10	18	180

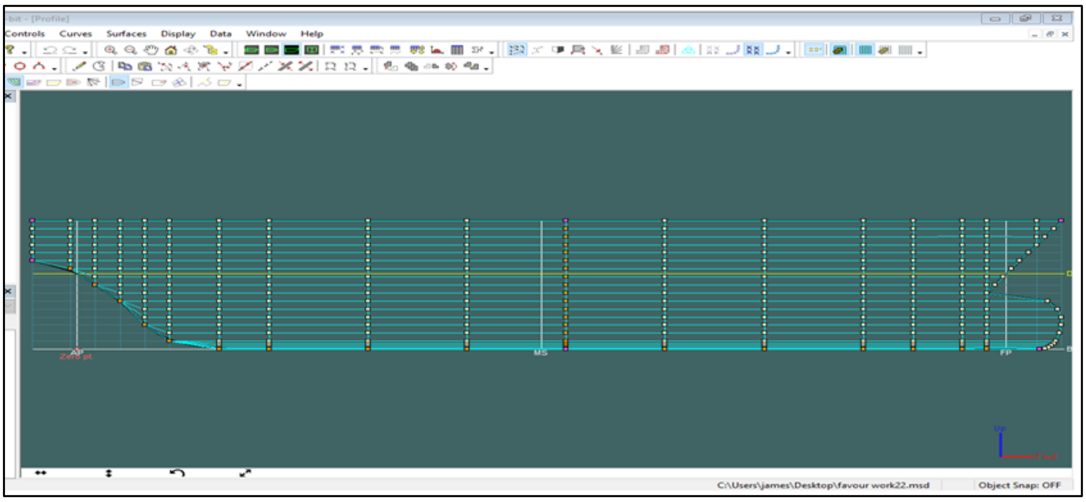
Appendix D: Maxsurf User Interface, Bentley (2019)



Appendix E: The Parent Maxsurf Modeler Interface, Bentley (2019)



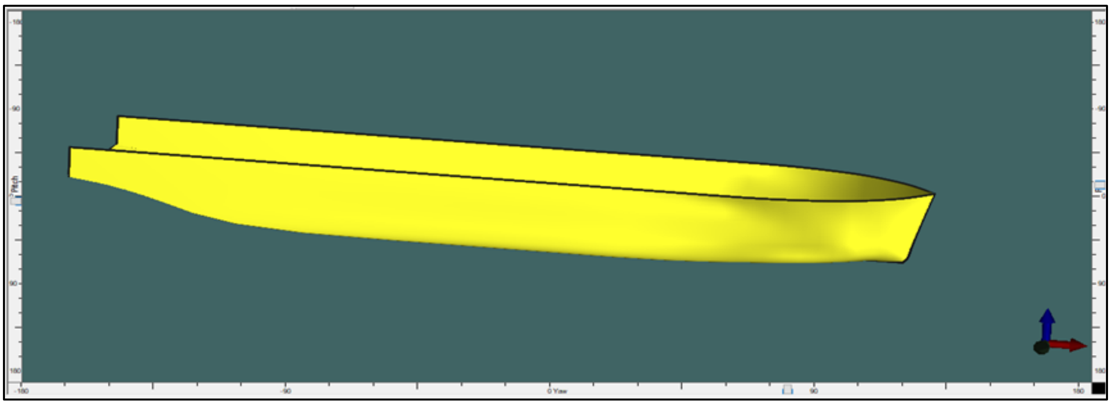
Appendix F: The Modified Modeler Interface, Bentley (2019)



C:\Users\james\Desktop\favour work22.msd

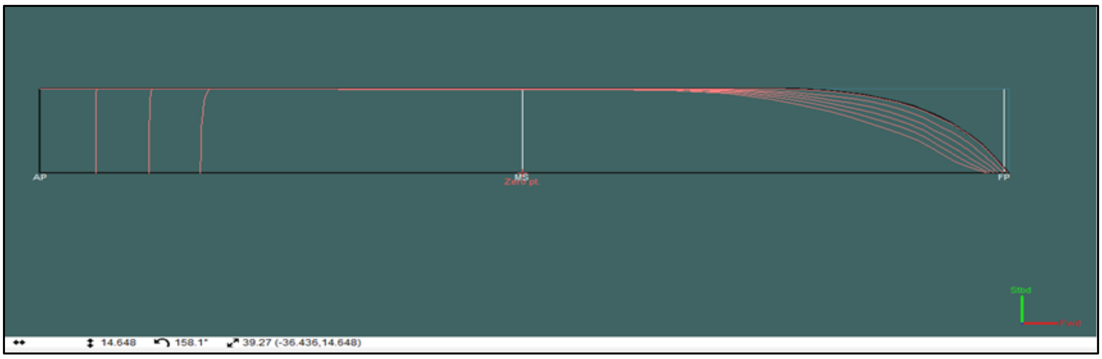
Object Snap: OFF

Appendix G: Maxsurf Design Parent Vessel Hull Form

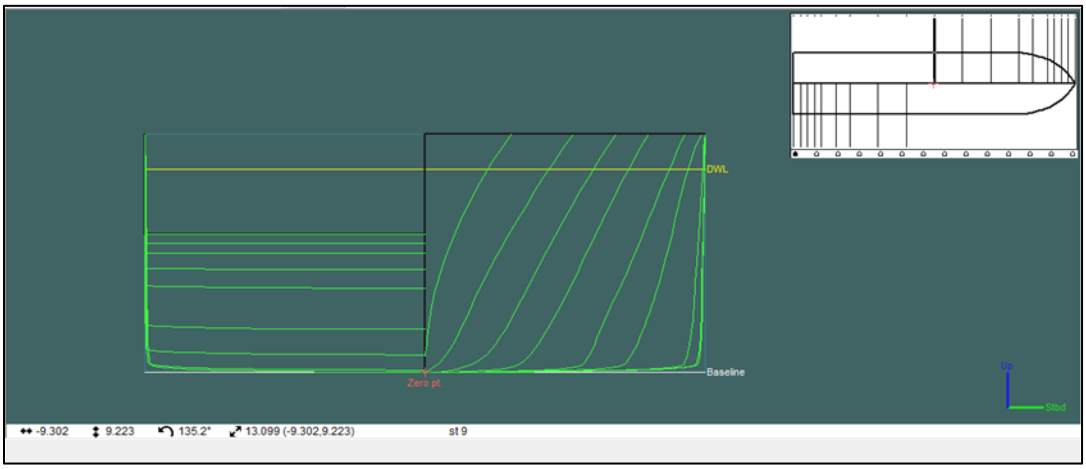


Appendix H: Maxsurf Design Parent Profile Vessel Hull Form

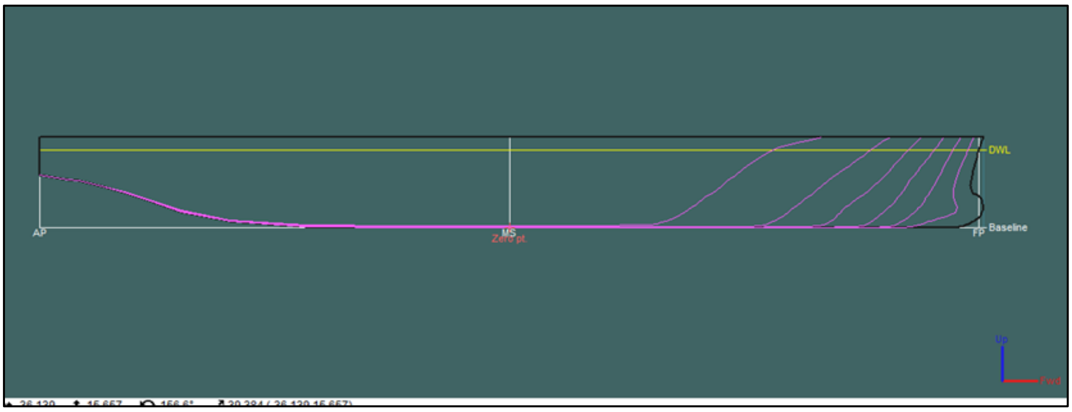
Appendix I: Maxsurf Design Parent Sheer Vessel Hull Form



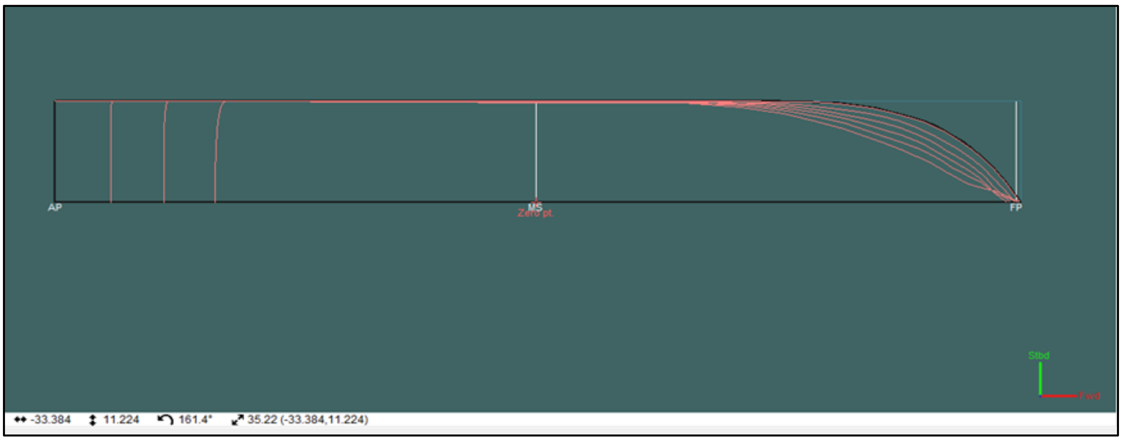
Appendix J: Maxsurf Design Parent Body Plan Vessel Hull Form



PPENDIX K: MAXSURF DESIGN MODIFIED PROFILE HULL FORM



Appendix L: Maxsurf Design Modified Sheer Hull Form



Appendix M: Maxsurf Design Modified Body Plan Hull Form