Geometric Modeling and Analysis of Passenger Ship Hull Model Using FreeShip Plus

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ABSTRACT

The good quality of the parametric ship hull form model from Computer Aided Design (CAD) is indeed relevant to Computational Fluid Dynamics (CFD). The CAD must interact well with CFD to avoid too much error and problem on CFD analysis. To make a precise and an accurate geometric design of ship hull form CFD is essential because it relates to the prediction of hull performance in the CFD analysis. Thus, this research is to re-model the geometric of passenger ship hull form model (MTC 092) which was developed by Marine Technology Centre (MTC) by using CAD of open source software called FreeShip Plus. Initially, the geometric of passenger ship hull model was presented in the form of 2D lines plan drawing using AutoCAD software. Then, the lines plan drawing was imported into FreeCAD in 'iges' file format to undergo a digitized process by following the table of offset format. The ship hull form coordinates were next extracted into a Python script in an XYZ table which starts with '0' and ends with 'eof'. This is followedby generating the model in FreeShip Plus after importing the Python script into FreeShip Plus asa text fileusing the chine import tool in FreeShip Plus. Subsequently, FreeShip Plus generated half of the ship hull form and then exported it into Blender as an 'obj' file. In Blender software, the ship design process proceeded with a mirrored function then and clipped the half ship hull form into full ship hull form, after which the passenger ship hull model was saved in 'stl' file format. Lastly, the hydrostatic data results of the passenger ship hull model involving a set of geometric parameters in FreeShip Plus show a maximum error of 2.77% compared to the MTC 092 model in a towing tank test, thereby implying the validity and accuracy of the analysis. The significance of this study is expected to help proliferate the acceptance on the use of open source CAD Software in professional working environment.

Keywords: *Ship hull form, geometric model, FreeShip Plus, computer aided design*

1.0   INTRODUCTION

Shipbuilding industry in Malaysia lacks in advanced capability, especially in ship design area. However, the ship design area is normally associated with the use of commercial software that typically demands high initial and maintenance costs. As a result, small and

medium sized ship-building enterprises (SMEs) in Malaysia were burdened with limited cost and budget because of this situation. Besides, in order to be competitive in shipbuilding industry, Abt *et al*. (2001) said that the preliminary ship design proces has to be performed while at the same time reducing the time spanto complete the task [1].

Meanwhile, Park *et al*. (2013) reported that owing to the high cost of the commercial software packages, the interest in free computational fluid dynamics (CFD) codes has recently increased [2]. Due to this very reason, it is highly desirable to use and exploit the open source software (OSS) to perform geometric modeling of the ship hull form using *FreeShip Plus* software since the main motivation for using CAD OSS is primarily due to the cost and time-related factors.It is crucial because the geometric model usingopen source CAD software can be sufficiently accurate but low in computational cost and the total time consumed.

The above description reflects the main aim of this study which is to re-model the passenger ship hull form (*MTC092*) as shown in Figure 1 developed by the MTC using *FreeShip Plus* so that an accurate hydrostatic data of the geometric hull form design can be determined. *FreeShip Plus* software is designated for full parametric analysis of resistance and power prediction for a ship [3] and *FreeShip Plus* software also a software platform for initial ship design [4].Besides, it is desirable to determine the potential of CAD open source software for hull form design and evaluation on the ship models and later to build a database that will archive the details of ship models at MTC by keeping the relevant design parameters which have been studied by expert users who work on an open source solution.

In order to achieve the objective of this study, an integration of trial-and-error process of geometric modeling has been done using anopen source CAD software. Besides, an alternative workflow involving sets of CAD open source software platform that was done in modeling and developing the ship hull form; it is typically a complete process for any ship design process.

FreeCAD software is the previous open source CAD software that has been used to remodel a ship model [5]. However, *FreeCAD* software is specifically designated for handling the ship mechanical geometry. In other words, it can build a ship geometry but cannot produce the hydrostatic data of the ship model.

The key workflow set in this integration process is the freedom to incorporate the hull form design and performance test within MTC which ownsa 20-year collection of the model testing data. This requires the ability to access the relevant codes and compare them with the integration results.The expected result of this research is an effective workflow complete CAD package of the geometric hull development in which the passenger ship hull model was determined. Later, the potential workflow module comprising sets of open source software for hull form design and evaluation on selected number of modelswas determined. Lastly, a database that will archive the details of ship models at MTC wascreated.

Figure 1: The passenger ship model, *MTC 092* at the MTC, UTM

2.0   THEORETICAL FRAMEWORK

2.1   Geometrical Parameterization

According to Rodriguez and Fernandez (2012), geometric parameterization is the most common procedure or methodology that is typically provided by the CAD systems [6]. The ship design process method has changed over the years based on different CAD softwares.

Feruglio (2018) stated that the traditional approach in ship design process was actually based on the designer experience and knowledge [7]. In addition, he also noted that the ship design process improved basically based on the heuristic trial-and-error process by the designer. The traditional design process is carried out through three steps. Firstly, the main dimensions were established. Secondly, some of the coefficients value have to satisfy all the requirements. Lastly, the ship hull shape which are the sectional area curve (SAC) is defined and then the hull geometry is modeled. These three processes are often done iteratively until a satisfactory result is achieved.

2.1.1 Main dimensions

The main dimensions of a ship model are the length (L), breadth (B), draught (T) and free boards (F) as shown in Figure 2.These parameters have to be set to compute the volume of water (∇) as follows:

$$\nabla = L \times B \times T \times C_\text{B} \qquad\qquad (1)$$

where $C_\text{B}$is the block coefficient.

The early stage of the ship design is to define the estimation of the weight displacement (δ)=(∇) water density. Once the ship displacement has been established, the combination of the parameter dimensions based on Equation (1) will be chosen.
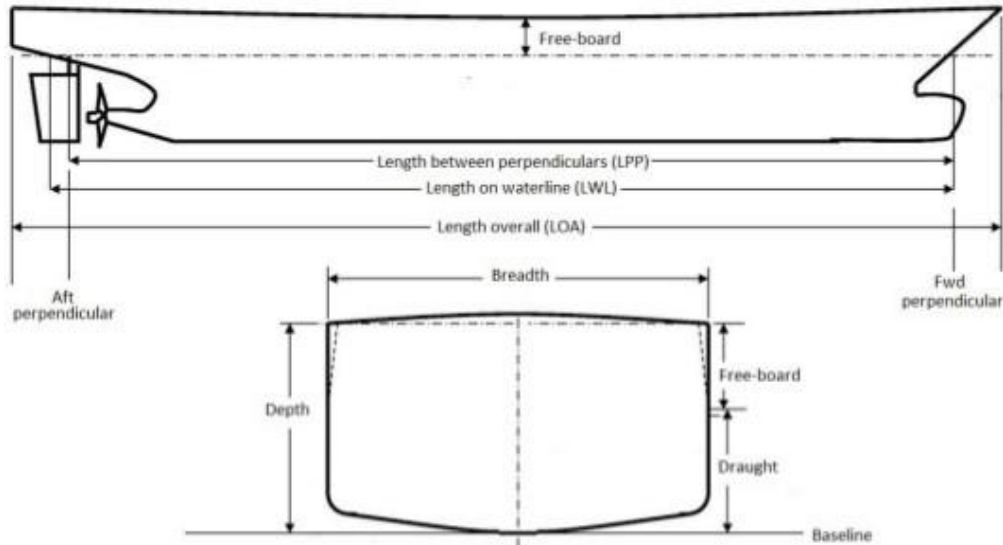
Figure 2: Main dimensions of a ship model[4]

The length parameter of a ship model has a great influence on the ship model especially on the ship hull weight which is strictly related to the ship hull drag. When the ship length is increased, the residuary drag (R_R) decreaseswhile the friction drag (R_F) also increases due to the corresponding increase in the area of wetted surface. Moreover, there are several methods to decide the hull length such as the length is chosen based on a database of similar characteristic of ships or the length is established by empirical formulae guidance which give an estimation of the economic efficiency [7]. Lastly, the draught and depth are inversely proportional to the breadth and these parameters arein fact related to the ship stability. When the value of these parameters is increased, the ship stability and resistance also accordingly increase.

2.1.2 Coefficients of form

The coefficients of form such as the block coefficient, midship coefficient, prismatic coefficient, etc. are actually a dimensional number that have been introduced in relation to the ship hull shape. These coefficients of form are in turn strictly associated with the ship hull performance such as resistance, vibration, stability, etc.

Biran and Pulido (2013) pointed out that normally, the values of the coefficients of form were chosen based on a database of similar ships [8].According to Feruglio (2018), the block coefficient is defined as the ratio between the displacement volume of submerged hull as shown in Figure 3 [7]. The analytical definition is expressed in Equation (2) and its schematic representation is shown in Figure 4.
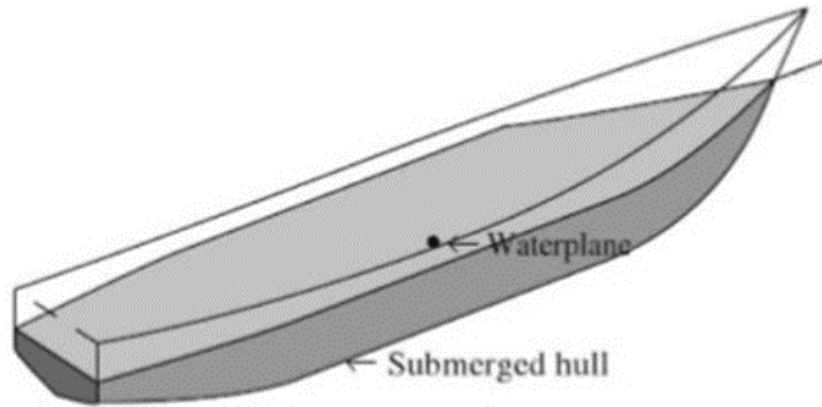
$$C_B = \frac{\nabla}{LBT} \qquad\qquad (2)$$

Figure 3: Displacement volume of the submerged hull [8]
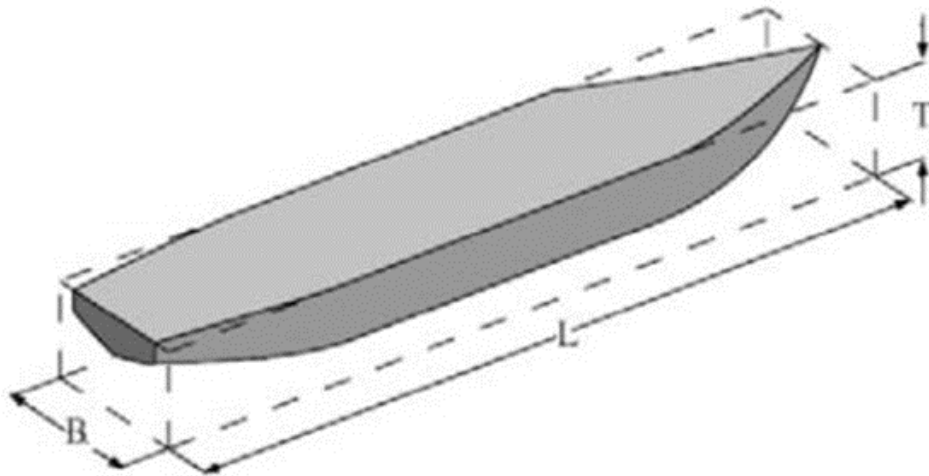

Figure 4: Parameters related to the block coefficient [8]

It is also mentioned thatthe prismatic coefficient is the ratio between the submerged displacement volume of the hull, a semi-cylinder of section (A_M) to the length of the ship hull (L) as shown in Figures5 and 6 [8]:

$$C_M = \frac{A_M}{LT} \qquad (3)$$

$$C_P = \frac{\nabla}{A_M L} = \frac{C_P}{C_M} \qquad (4)$$

Where,

    C_M :   Midship coefficient
    C_P :   Prismatic coefficient
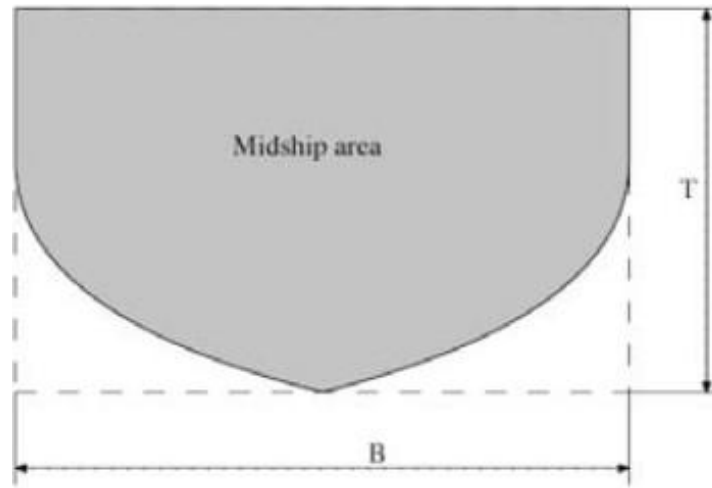
Figure 5: Parameters related to the midship coefficient [8]
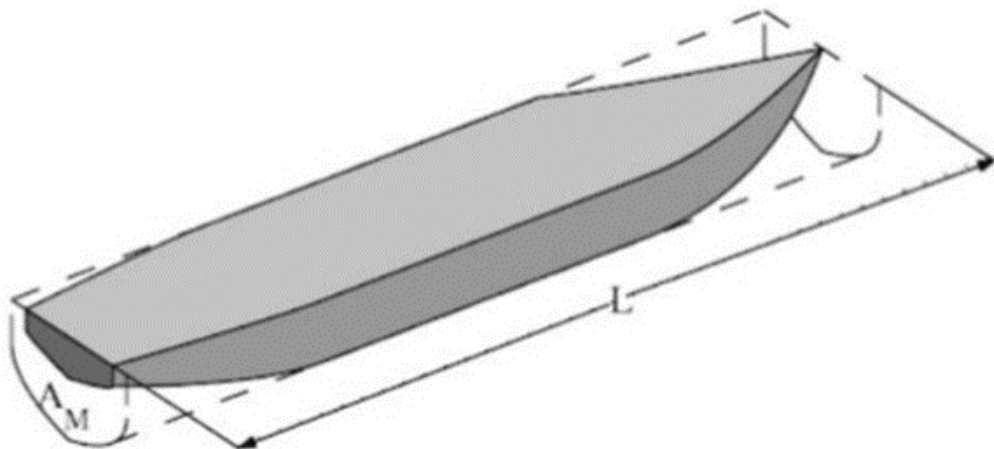
Figure 6: Parameters related to the prismatic coefficient [8]

Lastly, the waterplane-area coefficient (C_{WL}) and vertical prismatic coefficient (C_{VP}) are defined as follows:

$$C_{WL} = \frac{A_W}{LB} \tag{5}$$

$$C_{WP} = \frac{\nabla}{A_W T} \tag{6}$$

where A_W is the water plane area. The schematic meaning of the water plane-area coefficient and vertical prismatic coefficient are shown in Figures 7 and 8, respectively.
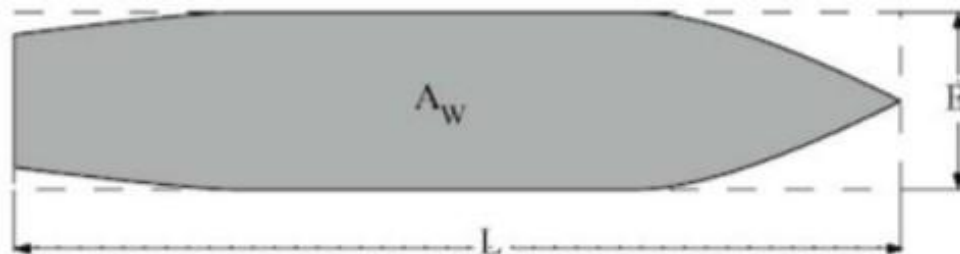
Figure 7: Parameters related to the water plane-area coefficient [8]
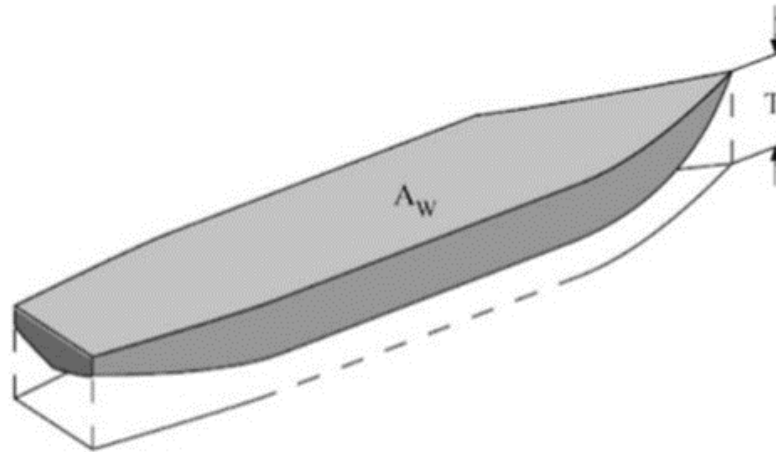
Figure 8: Parameters related to the vertical prismatic coefficient [8]

2.1.3 Traditional modeling approach

Once the designer has the main dimensions and the coefficients of form, the designer has to model the shape of the hull. The first step in traditional modeling approach is sketching the sectional area curve (SAC). The SAC consists of three different areas which are related to the stations, buttocks and waterlines as shown in Figures9 to 11and these constitute the lines plan drawing. After the drawing has been completed, all the ship hull parameters have to be evaluated. If the design presents some discrepancies between the calculated values of the parameters, the process has to be iterativelyrepeated until a satisfactory solution is achieved [7]. The last step is to create a lines plan drawing using a computer-aided design (CAD)software.
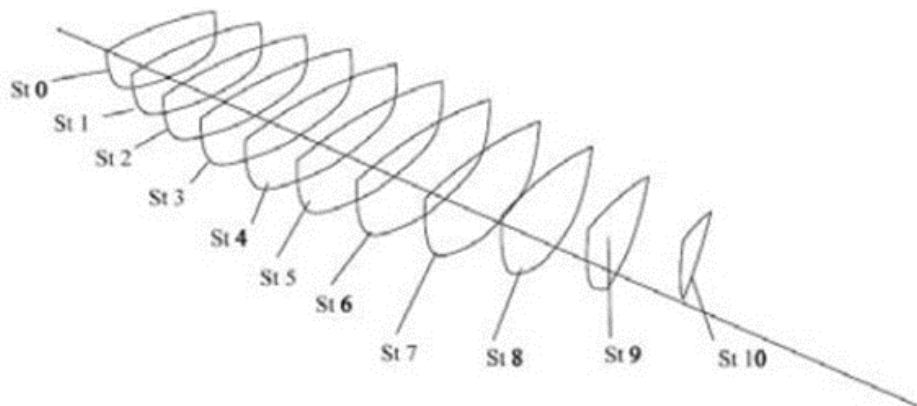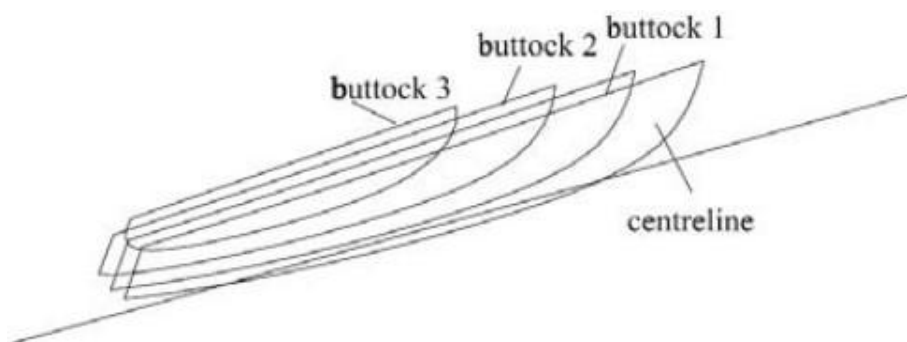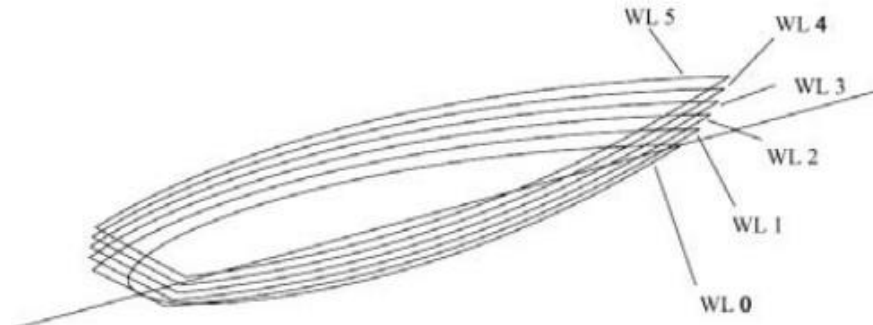

Figure 9: Stations [5]

Figure 10: Buttocks [8]

Figure 11: Waterlines [8]

3.0   OPEN SOURCE SOFTWARE

3.1   *FreeShip Plus*

FreeShip Plus is an open source software used in surface modeling program for the design of ships. However, this *FreeShip Plus* software was designed for only thin hull ship type. According to Ueng *et al.* (2008), thin ship hull can be defined based on its length (L), breadth (B), draft (D) and the wave length (λ) of the ship [9]. The thin hull ship shapes need to satisfy the following constraints:

$$B \ll L \tag{7}$$

$$D/\lambda = D/L \tag{8}$$

The *FreeShip Plus* software featuresthe modeling of a ship surface. Besides, *FreeShip Plus* can also act as a post-processing function since it can calculate the ship resistance, design hydrostatics, etc. Table 1 shows a list of the file types that can be imported or exported usingthe *FreeShip Plus* software and can be used in the process of importing or exporting the model.

Lastly, the *FreeShip Plus* software allows the user to view the completed format of a lines plan of the ship. The lines plan of the ship can be viewed in two different modes, which are the wireframe and filled modes as shown in Figure 12.

Table 1: List of file types that can be used in the import and export processes

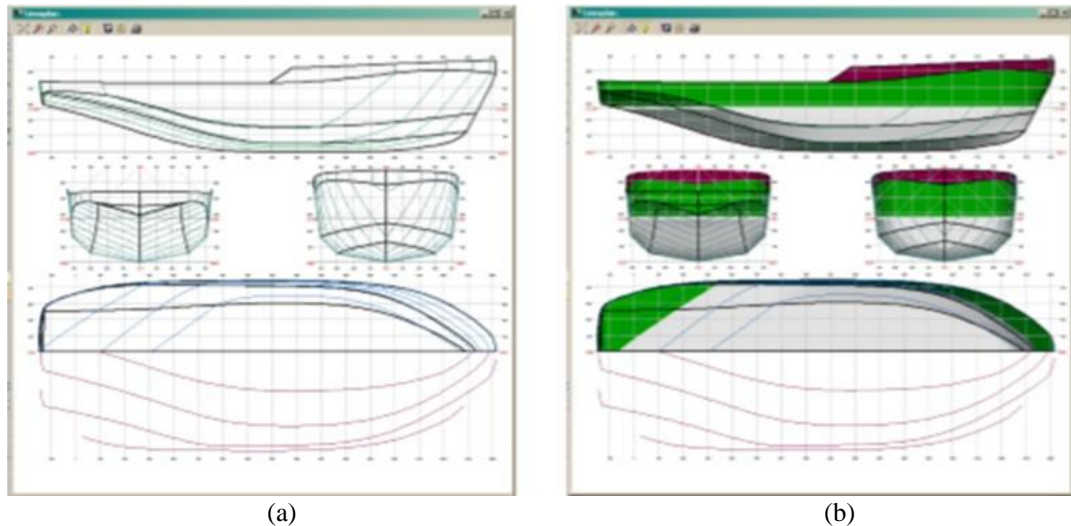| File type	Import	Export
Part	√	√
Carlson .hul file	√	
Import/Export .fef file	√	√
Surface	√	
Chines	√	
VRML	√	
PlyCad files	√	
Michlet waves	√	√
IGES		√
DXF 3D mesh		√
DXF 2D polylines		√
DXF 3D polylines		√
STL file		√

<table>
<tr><td>(a)</td><td>(b)</td></tr>
</table>

Figure 12: Lines plan of the ship in *FreeShip Plus*(a) wire frame mode (b) filled mode [4]

3.2 *FreeCAD*

*FreeCAD*is designedand developed as a modeling tool, focusing on the engineering aspectthat is particulalrly targeted for mechanical engineering and product design [10]. Riegel*et al*. (2013) stated that *FreeCAD* is a complete development of 3D CAD modeler in OSSenvironment [10].*FreeCAD* is one of the complete CAD packages in OSS and acts as pre-processor in CFD-based projects. The *FreeCAD* software can also be executed using a multi-platform operating system, i.e., it can run on *Windows*, *MacOS* and of course the *Linux* platforms [10]. Next is the workbenches, which are groups of tools in *FreeCAD* that were grouped together based on the specialty of the interface controls.

This workbench interface is the most important control of the *FreeCAD* software. Examples of the workbench selectors are *Draft*, *FEM*, *Arch* and *Ship*. There are several common import and export file types in *FreeCAD* such as *STEP*, *IGES*, *DXF*, *DWG* and *STL*.

The *STEP* file types are the most faithful import and export file types format that is available in *FreeCAD*. The *STEP* file type supports solid geometry and it can be used whenever possible. Meanwhile, *DXF* file type only supports the 2D data, either in import or export processes. Lastly, the *STL*type is in mesh-based format which is used for the 3D solid geometry which will be converted to mesh on export.

4.0 PASSENGER SHIP HULL MODEL (MTC 092) MODELING PROCESS

The detail steps of the works that have been implemented in this researchis shown in Figure 13. First of all, the lines plan of the passenger ship was obatained in *AutoCAD* file format.The lines plan of this passengership was then imported into the *FreeCAD* software for the digitizing process and the coordinateswere later extracted into the XYZ format in *Phyton* script as shown in the flow chart.The detailed explanation on each and every step in the workflow will be explained in the ensuing sub-section.
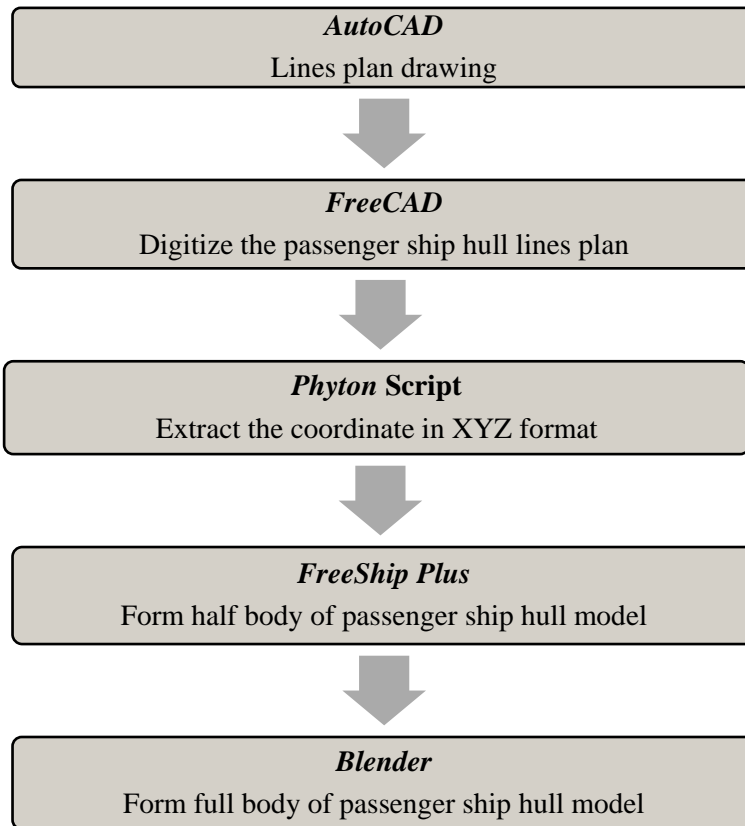
Figure 13: Passenger ship hull model (*MTC 092*) modeling process

4.1   Pre–Processing of the Passenger Ship Hull Model

The early geometric modeling process of the passenger ship hull model that is presented as a 2D lines plan drawing in *AutoCAD* software as shown in Figure 14. The 2D lines plan drawing was imported into *FreeCAD* software to undergo the digitized process as shown in Figure 15. The digitized process of the ship hull followed the rules table of the offset format.
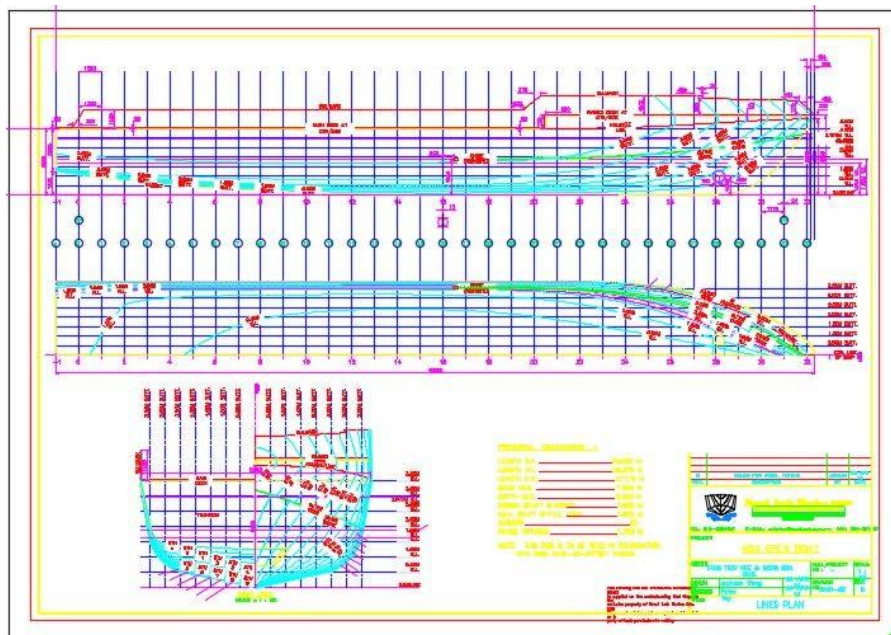

Figure 14: The lines plan of the passenger ship hull model in *AutoCAD*
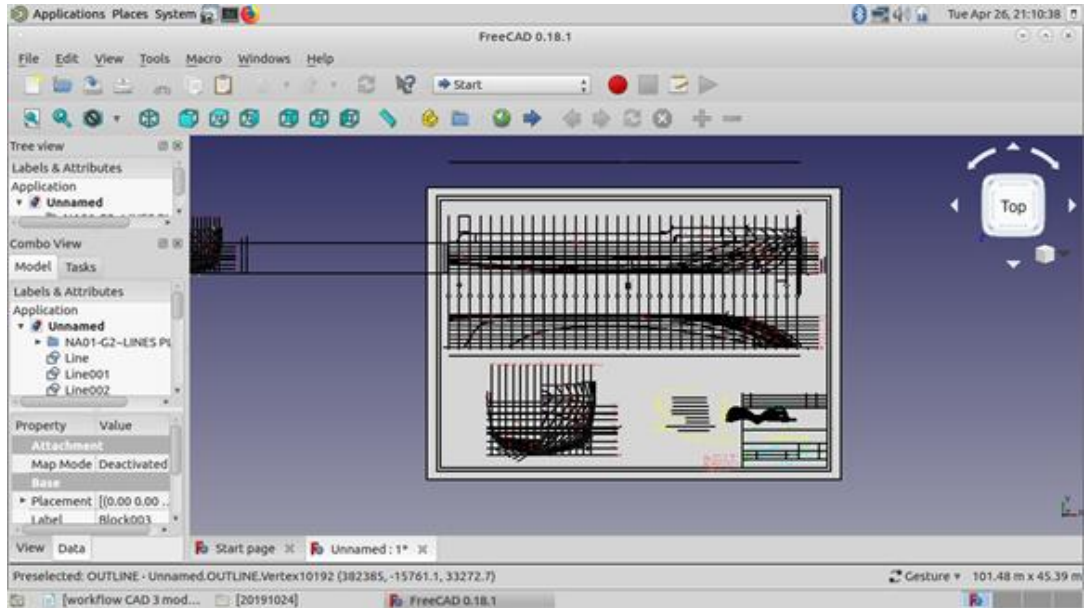
Figure 15: The lines plan of the passenger ship hull model in *FreeCAD*

The ship modeling process continuedby extracting the lines plan coordinates into a *Python* script in '*.txt' file format as shown in Figure 16. The next step is to export the coordinate into *FreeShip Plus* software and the ship hull form is generated as shown in Figure 17.

Figure 16: The coordinates of the lines plan passenger ship hull model in *Python* script

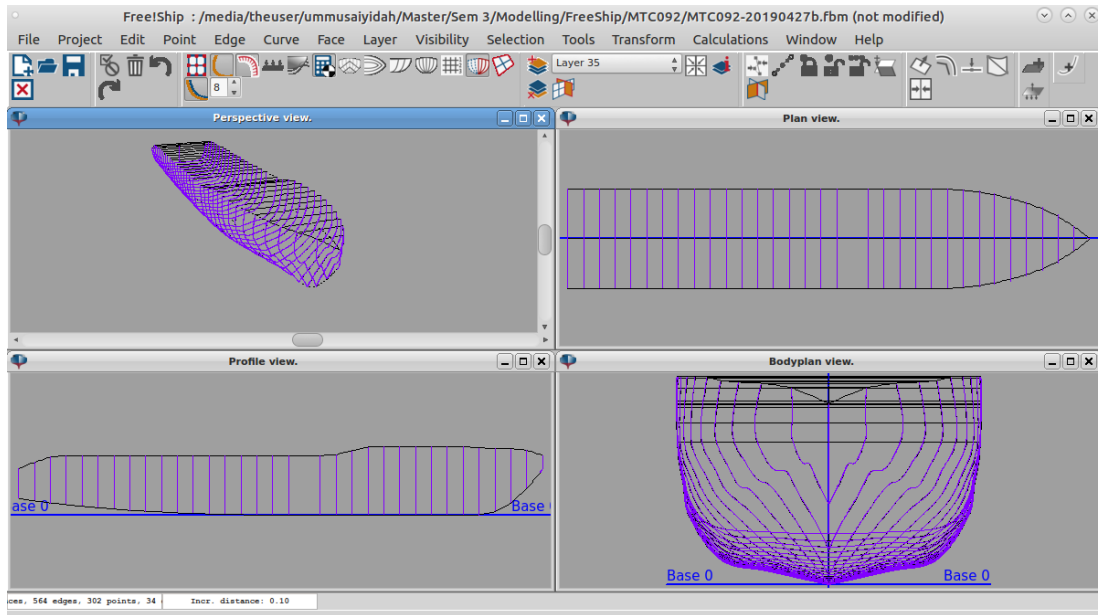It should be noted that *FreeShip Plus* only exports half of the ship hull form as depicted in Figure 18.

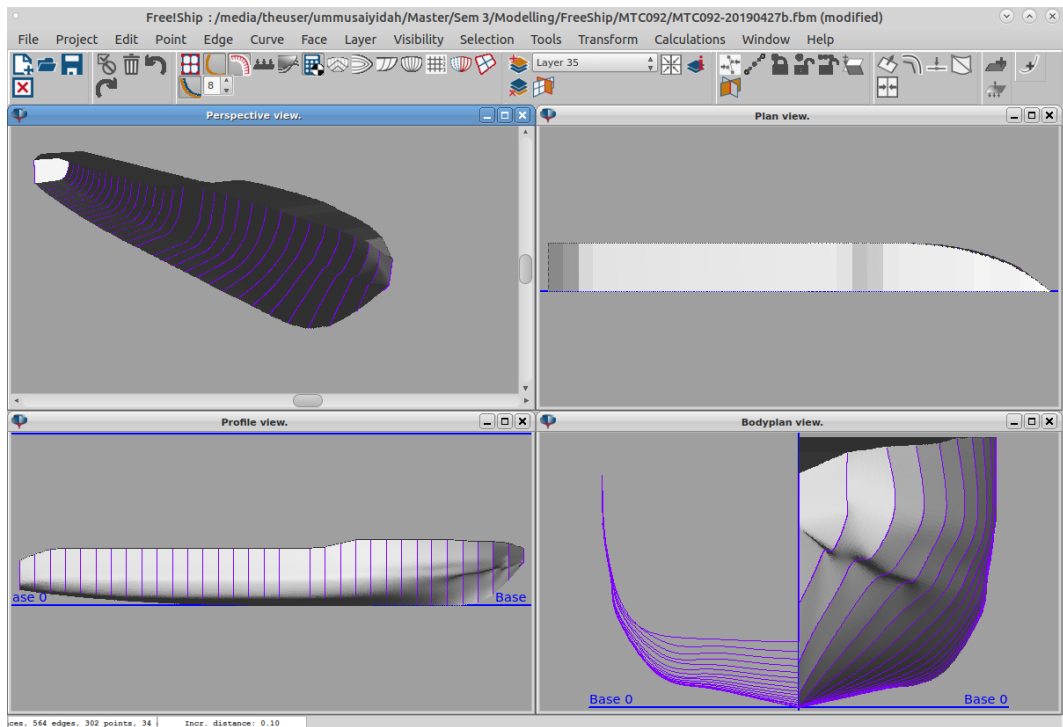**Figure 17**: The passenger ship hull model in *FreeShip Plus*

Figure 18: The half hull of the passenger ship model in *FreeShip Plus*

The last step of the ship modeling process is to export the half ship model into *Blender*software using the '*.stl' file format as shown in Figure 19and then mirrored and clipped the body into full passenger ship hull model as shown in Figure 20.
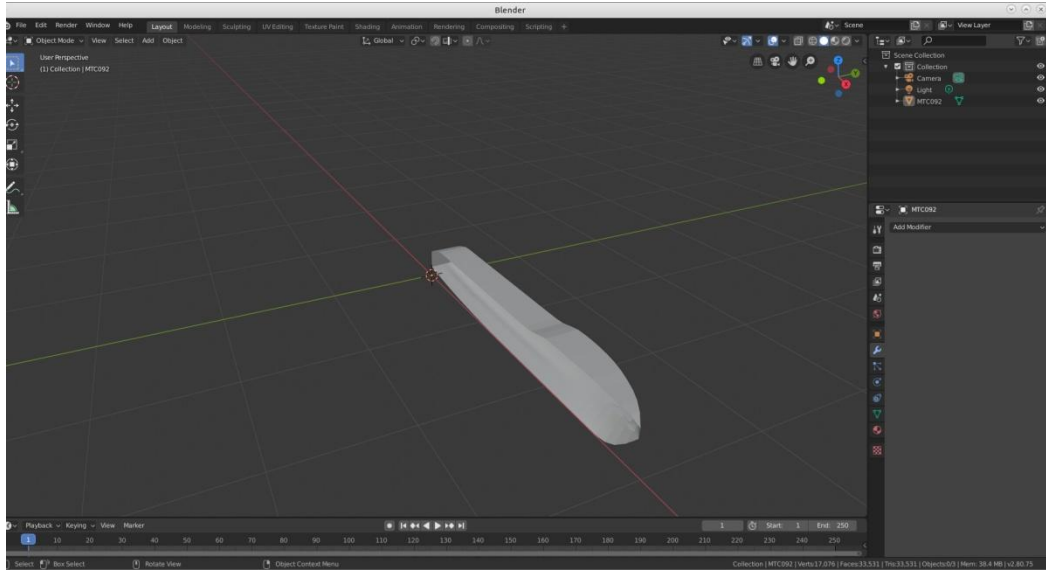
Figure 19: The half of passenger ship hull model that generated by *FreeShip Plus*
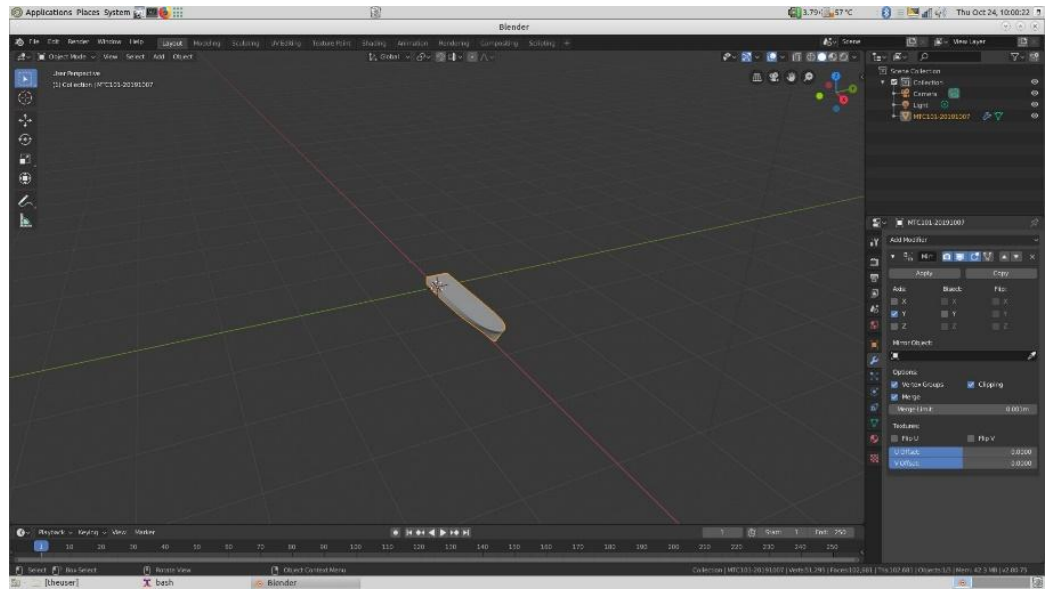

Figure 20: The passenger ship hull model that generated in *Blender* software

5.0   RESULTS AND CONCLUSION

Based on the hydro-static data of passenger ship hull model, the percentage of difference between the hydrostatic data from experimental and hydrostatic data from *FreeShip Plus* was calculated. The differences between these two data as shown in Table 2.

Table 2: Ship hydrostatic data particular difference from real model

Hydrostatic data	Unit	Experimental model	*FreeShip Plus* model	Differences (%)
Displacement	ton	0.0944	0.094	0.00
Wetted surface area	m^2	1.5050	1.470	2.33
Water length (WL)	m	2.7400	2.816	2.77
Beam	m	0.5130	0.511	0.39

As shown in Table 2, the differences of hydrostatic of passenger ship hull model between towing tank test and *FreeShip Plus* are close which n between range 0% and 2.77%. According to the ship design rules, the hydrostatic data exhibiting below than 10% difference from real model is accepted. However, the 2.77 and 2.33% differences (in errors) of the water length level and wetted surface area, respectively between the experimental and ship CAD modelsshow only minor discrepancy between them.

Based on the hydrostatic data, it showed that the sets of open source CAD can produce an accurate and precise ship model. Hence, it can serve as a viable option and an alternative to the commercial counterpart for the ship designers to remodel or design a ship hull.Lastly, an accurate and precise ship model from the CAD software leadsto getting an accurate result for the hull performance in the CFD software.

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REFERENCES

1. Abt C., Bade S.D., Birk L. and Harries S., 2001. Parametric Hull Form Design – A Step Towards One WeekShipDesign,*Practical Design of Ships and Other Floating Structures*, 67-74.
2. Park S.,Park S.W., Rhee S.H.,Lee S.B., Choi J.E. and Kang, S.H., 2013. Investigation on the Wall Function Implementation for the Prediction of Ship Resistance, *International Journal of Naval Architecture and Ocean Engineering*, 5(1):33-46.
3. *Capabilities of FreeShip Plus*, Retrieved from: http://hydronship.net/index.php?lang=en. [Accessed on 3 January 2020].
4. *FreeShip Plus - 3D Hull Design with Hydrodynamics Calculation Tools*. Retrieved from: https://freeship-plus.en.softonic.com/. [Accessed on 3 January 2020].
5. Falck B., Falck D. and Collette B., 2012. *FreeCAD [How-To]: Solid Modeling with the Power of Python*, Packt Publishing Ltd.
6. Rodriguez A. and Fernandez-Jambrina L., 2012. Programmed Design of Ship Forms, *Computer- Aided Design*, 44(7): 687-696.
7. Feruglio F., 2018. *Hydrodynamic Study of a Bow of a Combatant Hull*, Tesi di Laurea Magistrale (Master Thesis), University of Padua, Italy.
8. Biran A. and Pulido R.L., 2013. *Ship Hydrostatics and Stability*, 2nd Edition, Butterworth-Heinmann.
9. Ueng S.K., Lin D. and Liu C.H., 2008. A Ship Motion Simulation System, *Virtual Reality*, 12(1):65-76.
10. Riegel J., Mayer, W. and van Havre Y., 2013. *FreeCAD Python API Documentation*, Retrievd from: http://www.freecadweb.org/api/. [Accessed on: 3 January 2020].