



BACHELOR THESIS - ME141501

**BALLAST FREE SYSTEM ANALYSIS ON 20000 DWT
BULK CARRIER VESSEL**

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SURABAYA 2018**

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**ANALISIS SISTEM BALLAST FREE PADA KAPAL BULK CARRIER
20,000 DWT**

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APPROVAL FORM

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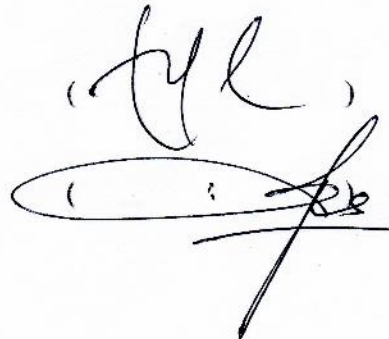
BACHELOR THESIS

Submitted to Fulfill One of the Requirement
To Obtain a Bachelor Engineering Degree
On
Marine Fluid Machinery and System (MMS) Laboratory
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APPROVAL FORM

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CARRIER VESSEL**

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ABSTRACT

Ballast Water are considered the main factor for the transfer of non-indigenous species of waters around the world. A new paradigm of thought firstly developed by Michigan University to see the ballast condition as a change of buoyancy, not weight gain, to bring the vessel to its safe ballast draft. The ballast tunnel will be added to the ship model as a ballast water flow path. The type of ship has been determined as Bulk Carrier with LOA 159 m. This tunnel is modeled by considering the need for ballast water on the vessel. Tunnel modeled with longitudinal pipe shape and dimensions adjusted to the needs of the ballast water required. To analyze the various effects of resistance, then 3 models have been made. Model is then tested on ansys with a speed of 13 knots. Simulation Result shows model a yielding resistance of 322.309 kN, and model b yields resistance of 222,884 kN, and in model c yields resistance of 251.883 kN. While the estimated time for CFT (Complete Flushing Time) in model a requires 0.340205484 hours, model b requires 27.12477396 seconds, and model c takes 24.31118314 seconds. Cost impact due to integrated ballast free system then be analyzed. The analysis is devoted to the analysis of changes in capital expenditure and operational expenditures before and after applying the ballast free system. The results showed that bulk carrier vessels with ballast free systems could cut capital expenditure of Rp 5,184,950,000,-. While in operating expenditure, vessels with ballast free system indicate an additional charge of Rp 6,869,491,800,- per year.

Keyword— Ballast Free Ship, Resistance, Computational Fluid Dynamic

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ANALISIS SISTEM BALLAST FREE PADA KAPAL BULK CARRIER 20000 DWT

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ABSTRAK

Air balas dianggap sebagai faktor utama menyebarnya spesies asing perairan di seluruh dunia. Paradigma pemikiran yang baru pertama kali dikembangkan oleh Universitas Michigan untuk melihat kondisi ballast sebagai perubahan daya apung, bukan penambahan berat kapal, untuk membawa kapal ke desain balast yang aman. Tunnel balas akan ditambahkan ke model kapal sebagai jalur aliran air balas. Jenis kapal telah ditentukan yaitu Bulk Carrier dengan LOA 159 m. Tunnel ini dimodelkan dengan mempertimbangkan kebutuhan akan air balas pada kapal. Tunnel dimodelkan dengan bentuk pipa memanjang dan dimensi sesuai air ballast yang dibutuhkan. Untuk menganalisa berbagai efek, maka 3 model telah dibuat. Model ini kemudian diuji pada ansys dengan kecepatan 13 knot. Hasil Simulasi menunjukkan model resistansi yang dihasilkan dari model A adalah 322.309 kN, dan model b menghasilkan resistansi 222.884 kN, dan dalam model c menghasilkan resistansi 251.883 kN. Sementara perkiraan waktu untuk CFT (Complete Flushing Time) dalam model A membutuhkan 0,340205484 jam, model b membutuhkan 27,12477396 detik, dan model c membutuhkan waktu 24,31118314 detik. Dampak biaya karena sistem ballast free terintegrasi kemudian dianalisis. Analisis ini dikhususkan untuk analisis perubahan dalam modal belanja dan biaya operasional sebelum dan sesudah menerapkan sistem ballast free. Hasil penelitian menunjukkan bahwa kapal bulk carrier dengan sistem ballast free dapat memangkas belanja modal sebesar Rp 5.184.950.000, -. Sementara dalam pengeluaran operasi, kapal dengan sistem ballast free menunjukkan biaya tambahan sebesar Rp 6.869.491.800, - per tahun.

Keyword— Ballast Free Ship, Resistance, Computational Fluid Dynamic

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PREFACE

Firstly, thanks to Allah SWT. for the grace and bless, so that the writer is able to finish this Bachelor Thesis with the title of “**Ballast Free Sstem Analysis on 20000 DWT Bulk Carrier Vessel**” well and on time. The final project is proposed as one of the requirements of graduation of undergraduate study program Department of Marine Engineering, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology Surabaya.

In the process of completion of the Bachelor Thesis and the success of taking the undergraduate course, help and support are obtained from various parties. Therefore, the authors express gratitude to the parties below:

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Surabaya, July 2018

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CHAPTER 1 INTRODUCTION

In this chapter will explain the things that become the background, problems encountered, problem definition, objectives, and systematic writing used in the making of this final project.

1.1. Background

Ballast water system is system to fill the ballast water on board and transport it. Ballast water is taken from the sea water taken through the seachest that is pumped into the main pipe then go into the branch pipe.

The ballast pump system is intended for adjusting the level of ship's trim and draft, as a result of the charge changes ship so the stability of the ship can be maintained. Ballast pipe installed in the after and fore peak tank, double bottom tank, deep tanks and side tanks. Ballast which is placed in the front niche tank and behind this to serve the trim condition of the ship desired

Ballast Water are considered the main factor for the transfer of non-indigenous species of waters around the world. The emergence of a species that was originally never found naturally in an area and traveled hundreds to thousands of kilometers away from its natural place of life in ecology called Jump Dispersal. In the end, however, the existence of these species extensively affected the habitats they invaded and caused serious ecological problems.

To address this problem, the International Maritime Organization (IMO) in 2004 adopted the the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). therefore shipowners and ship operators must select the appropriate BWTS to ensure they comply with IMO and / or USCG standards

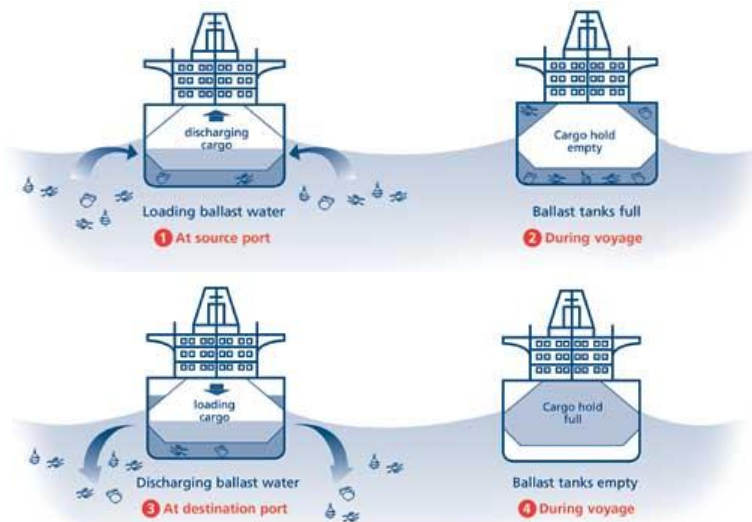


Figure 1.1 Microorganism Condition in Ballast Water Exchange Process
Source: www.imo.org

A new paradigm of thought developed by Miltiadis Kotinis and Michael G. Parsons to see the ballast condition as a change of buoyancy, not weight gain, to bring the vessel to its safe ballast draft. In this concept, the traditional ballast tanks are replaced by longitudinal, structural ballast trunks that extend beneath the cargo region of the ship below the ballast draft.

The trunks are connected to the sea through a plenum at the bow and a second plenum at the stern. These trunks are flooded with seawater to reduce the buoyancy of the vessel in the ballast condition in order to get the vessel to its design ballast drafts. Since there is a hydrodynamic pressure differential created between the bow region and the stern region of a ship due its motion through the water, a slow flow is induced in the ballast trunks. This ensures that the ballast trunks are always filled with “local seawater” and they will not transport nonindigenous aquatic species across the globe (Kotinis, 2004).

It can be concluded that the ballast water system can be replaced with ballast free system. With such a shortage of conventional systems that still use the ballast water treatment system, it can be handled without even installing the system. And in this thesis, the author will do the development of ballast free system design on bulk carrier, and analyze the change of resistance and change of capital cost, due to the impact of integration of the system

1.2. Statement of Problem

In conducting the study, there are some problems that have been formulated so that the assessment process can be done in a direction and those are:

1. How to integrate ballast free system into bulk carrier vessel with loa 159 m?
2. How to determine the impact of ship’s resistance by integrating ballast free system into bulk carrier vessel with loa 159 m?
3. How to determine the cost impact after integrating ballast free system?

1.3. Research Limitations

In order to be able to conduct a smoothly and well-directed study then it takes some limitations of the problem, such as:

1. This thesis is focusing on the integrating ballast free system to bulk carrier ship with investigating of ship resistance aspect.
2. Resistance analysis will be conducted by using CFD
3. reliability design are not calculated.
4. Ship design only focus for bulk carrier 20000 DWT with LPP 150 m.

1.4. Research Objectives

From the above problem formulation can be determined the purpose of this Final Project, and those are:

1. To integrate ballast free system into bulk carrier vessel with loa 159 m.
2. To determine the impact of ship’s resistance by integrating ballast free system
3. To determine the cost impact after integrating free ballast system.

1.5. Research Benefits

Benefits obtained from the following studies are:

1. Understand the requirement and regulation that should be implemented to integrate ballast free system into bulk carrier ship
2. Develop investigation regarding the impact of integrating ballast free system

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CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the basic theories and literature on which this final project works.

2.1. Ballast Water

Ballast water is taken on board vessels to achieve the required safe operating conditions during a specific voyage or portion of a voyage. Proper ballasting (in terms of the amount of water taken aboard and its distribution) fulfills the following functions:

- reduces stresses on the hull of the ship
- provides for transverse stability
- aids propulsion by controlling the submergence of the propeller
- aids maneuverability by submerging the rudder and reducing the amount of exposed hull surface (freeboard or windage)
- compensates for weight lost from fuel and water consumption

Ballast condition, including when and how much water is loaded, is determined by ships' officers, based on the specific vessel's operating needs and the national and international requirements for proper maintenance of the trim and stability of the vessel at sea. The master of the ship is responsible for ensuring that all ballasting operations are executed in a safe manner, commensurate with prevailing conditions (Committee on Ships' Ballast Operations, 1996)

A common type of ballast for small ships that avoids many of the problems of high-density ballast is water ballast. While it seems counter-intuitive that placing water in the hull (which is, after all, close to the same density as the water outside the hull- fresh vs salt water) would add any stability, adding water ballast below the vertical center of gravity increases stability. The water ballast does not need to be lifted above the waterline to affect stability, as any material having greater bulk density than air will have an effect on the centre of gravity. It is the relationship between centre of gravity and centre of buoyancy that dictates the righting moment.

The advantage of water ballast is that the tanks can be emptied, reducing draught or the weight of the ship and water added back in, simply by opening up the valves and letting the water flow in) after the ship is launched or cargo unloaded. Pumps can also be used to empty the ballast tank and fill the tank as the ship tacks, and the quantity of ballast can be varied to keep the ship at the optimum angle of heel. On empty cargo vessels water is added to ballast tanks to increase propeller immersion, to improve steering, and to control trim and draft.

A disadvantage of water ballast is that water is not very dense and therefore the tanks required take up more space than other forms of ballast. Some manufacturers offer flexible ballast bags that are mounted outboard of the hull on both sides, and pumps that use the ship's speed through the water for power. When under way, the pump can be used to fill the windward side, while the lee side is allowed to drain. This

system, while not very attractive, does allow significant gains in righting force with no modifications to the hull.

A trick commonly used on ships with water ballast is to link port and starboard tanks with a valved pipe. When preparing to tack, the valve is opened, and water in the windward tank, which is higher, is allowed to flow to the lee side, and the sheet is let off to keep the ship from heeling too far. Once as much water as possible has been transferred to the lee side, the ship is brought about and the sail sheeted in, lifting the newly full windward tank. A simple hand pump can then be used to move any remaining water from the lee to the windward tank.

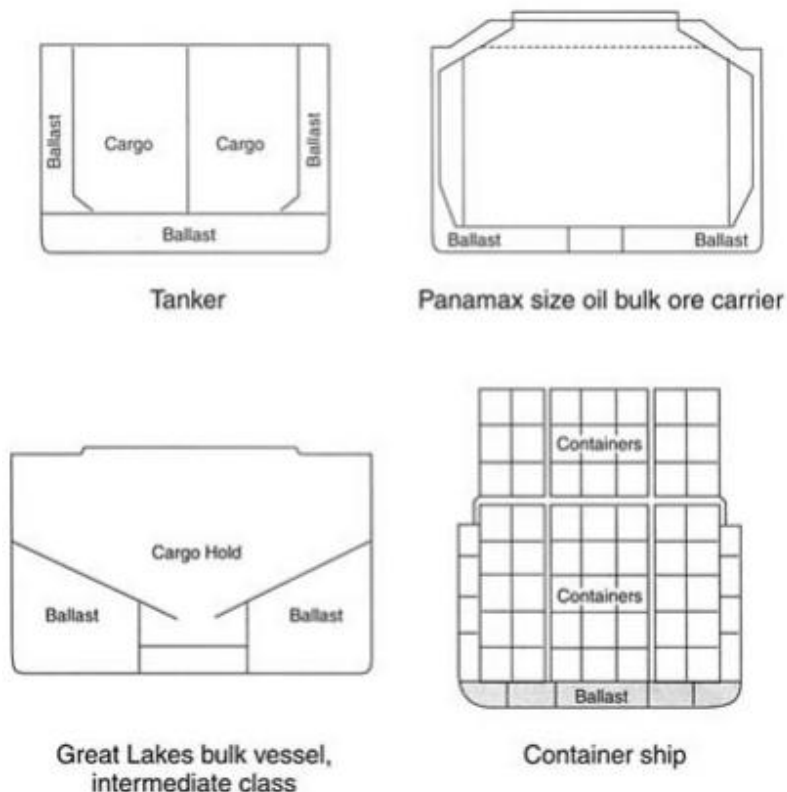


Figure 2. 1 Typical ballast tank arrangements.
Source: export-jatim.or.id

Wide range of ballast tank locations and configurations, as illustrated schematically in Figure 2-1. The capacity, location, and flexibility of use of ballast tanks is a focal point in ship design. Consideration of required drafts and trim, hull loading limitations, and required vertical center of gravity establishes the necessary ballast volume and location. Because of different cargo distributions or fuel and water quantities on board, sister ships can have different ballast needs, even though the locations and sizes of the ballast tanks are identical.

2.2. Ballast Free Ship

A new paradigm of thought developed by Miltiadis Kotinis and Michael G. Parsons to see the ballast condition as a change of buoyancy, not weight gain, to bring the vessel to its safe ballast draft. In this concept, the traditional ballast tanks are replaced by longitudinal, structural ballast trunks that extend beneath the cargo region of the ship below the ballast draft.

The trunks are connected to the sea through a plenum at the bow and a second plenum at the stern. These trunks are flooded with seawater to reduce the buoyancy of the vessel in the ballast condition in order to get the vessel to its design ballast drafts. Since there is a hydrodynamic pressure differential created between the bow region and the stern region of a ship due its motion through the water, a slow flow is induced in the ballast trunks. This ensures that the ballast trunks are always filled with “local seawater” and they will not transport nonindigenous aquatic species across the globe. (Kotinis, 2004)

The Different Concept also introduced in India by Avinash Godey to change the Ballast Trunk with Ballast free Pipe. He put a longitudinal pipe as a tunnel for water to flow trough. It makes the exchange of Ballast Water becomes faster.



Figure 2. 2 Model of Free Ballast Ship by Avinash Godey.
Source: (Godey, Development of Free Ballast Ship Design, 2012)

Figure 2.2 shows the free ballast ship developed by avinash godey diindia. testing is done with towink test in towing tanks in india. the ballast trunk on the initial concept is replaced with a ballast tunnel added to the double bottom. so the sea water is more freely to flow on the tunnel and the water problem stuck on the previous system could be spared, and the local sea water will be present in the ship at any point of time

2.3. Ship Resistance

Ships should be designed as efficiently as possible when moving in water with a minimum external force. Broadly speaking between Ship Resistance and Ship Propulsion has a very close relationship, and each has a dependency between the two. However, in practice Ship Arrest and Ship Propulsion are discussed separately. Ship Resistance is applied to find the needs of the Thrust Style required by the vessel, so that the ship can move with the Service Speed in accordance with its planning. Whereas, the Propulsion of the Vessel is emphasizing on how to provide the magnitude of the Thrust Drive of the ship propulsion system, and how the interaction between the vessel moves against the fluid flow across the ship's body (Hull).

Resistance are generally divided into two components given by different rules:

- Skin friction resistance provided by Reynolds "number.
- Residuary resistance caused by wave is given by Froude number.

A vessel moving forward at a certain speed will experience a drag force by a fluid that has opposite direction to the direction of motion of the ship. The inhibitory force is caused by a fluid force, which in this case tends to lead to a water fluid that is considered to be of considerable obstacle to the motion of the vessel. This fluid-induced drag force is called resistance or ship resistance. Resistance is a term commonly used in hydrodynamics, whereas in the aerodynamics of buried objects commonly used the term drag. In the curve of the resistance there is a ship body that moves above and below the surface of the water having viscosity. The Absis is Froude Number. Therefore the ship's resistance (R1) is defined as the force required by the vessel at constant velocity (U). The required energy moves the ship

2.3.1 Froude Number Dan Reynolds Number

Froude Numbers is an unity number used to measure the resistance of a body moving through water, and comparing objects of different sizes. The incidence of wavelength is equal to the length of the hull of the ship, so that at this critical velocity condition has been established equation of Froude number or type of flow as follows:

$$Fn = V / \sqrt{g \cdot L}$$

The large froude number given in the above equation is the maximum limit in the displacement hull condition. As for the equation Froude number on the condition of planning hull commonly used is Volumetric Froude Number:

$$F_{v} = \frac{V}{\sqrt{g \nabla^{1/3}}}$$

In fluid mechanics, the Reynolds number is the ratio between the inertial force ($v\rho$) to the viscous force (μ / L) which quantifies the relationship between the two forces with a particular flow condition. This number is used to identify. Different flow types, such as laminar and turbulent.

The Reynolds number is one of the most important dimensionless numbers in fluid mechanics and is used, as is the case with other dimensionless numbers, to provide the criterion for defining dynamic

similitude. If two geometrically similar flow patterns, perhaps on different fluids and different flow rates, have the relevant dimensionless number values, they are called dynamic resemblances. Reynold "s number is defined by:

$$Rn = (\mathbf{V} \cdot \mathbf{L}) / \nu$$

2.4. Computational Fluid Dynamic (CFD)

Computational Fluid Dynamic (CFD) is a methode in determining the numerical solution of fluid dynamics. CFD is the third approach in the study and development of fluid dynamics fields in addition to theoretical pendants and pure experiments. In the 17th century, the basics of experimental fluid dynamics were introduced in England and France. In the nineteenth century, theoretical dynamics developed the development of fluids. Then throughout the 20th century, the study and practice in fluid dynamics involves the use of pure theory and pure experimentation. This occurs until the early 1960s. In the end 1970 developed a CFD with various limitations. As for some advantages obtained by using CFD among others:

- Minimize time and cost in the design of a product, if the design process is done with experimental tests with high accuracy.
- Have the ability of a study system that can control experiments that are difficult or impossible with experiments.

Have the ability to study under hazardous conditions during or after a critical point (including safety and accident studies). Accuracy will always be controlled in the design process.

2.4.1 Basic Equation of CFD Dynamics

Basically all types of CFDs use the basic equations of fluid dynamics: continuity, momentum and energy. The three basic principles of physics used in the basic principles of CFD are:

- a. The law of mass conservation
- b. Newton's second law
- c. The law of conservation of energy

To get the basic equation of fluid motion, have some philosophy:

- a. Selects the basic physical principles of basic physical laws
- b. Apply the principles of physics in the flow model.

2.4.2 Rans Equation

Time-dependent solutions of the Navier-Stokes equations for high Reynolds-number turbulent flows in complex geometries which is set to resolve all the way to come. Two alternative methods can be employed to render the Navier-Stokes equations tractable so that the turbulent fluctuations do not have to be simulated: Reynolds-averaging (or ensemble-averaging) and filtering. Both methods introduce additional terms in the governing equations that need to be modeled in order to achieve a "closure" for the unknowns.

These equations can be written in Einstein notation in Cartesian coordinate as:

$$\rho \bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j} = \rho \bar{f}_i + \frac{\partial}{\partial x_j} \left[-\bar{p} \delta_{ij} + \mu \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \right) - \overline{\rho u'_i u'_j} \right].$$

The Reynolds-averaged Navier-Stokes (RANS) equations govern the transport of the averaged flow quantities, with the whole range of the scales of turbulence being modeled. The RANS-based modeling approach therefore greatly reduces the required computational effort and resources, and is widely adopted for practical engineering applications. An entire hierarchy of closure models are available in ANSYS FLUENT including Spalart-Allmaras k-epsilon and its variants, k-omega and its variants, and the RSM. The self-sustained (e.g., vortex-shedding, flow instabilities), or self-sustained (e.g., vortex-shedding, flow instabilities)

2.4.3 Fluid Dynamics Theory in CFD

Computational Fluid Dynamics (CFD) is one of the sciences in determining the numerical dynamics of fluid settlement and is the third approach in the development of the field of fluid dynamics other than the experimental and theoretical approach. Here are some advantages of completion with CFD among others method:

- a. The efficiency of time and cost in designing a product, thus can be obtained good results and high accuracy.
- b. Having the ability of a study system that can perform difficult experiments through experiments.
- c. Have the ability to study under hazardous conditions at or after the critical point.
- d. Accuracy will always be in control in the design process

In the design of the work the existing problem needs to be described into the software CFD by describing the model to be analyzed, the properties that exist around the model and also determine the boundary conditions. Then in the solver the existing problem will be calculated by the existing equation. From the calculation results will get the output of the running program CFD.

Computational Fluid Dynamics (CFD) is a system analysis that includes fluid flow, heat transfer, and related phenomena, such as chemical reactions with computer-based simulations. This program is very useful and can be applied in the field of industry and non industry. The CFD Code is composed of numerical logarithms, so it can be used to solve problems in a fluid stream. Code CFd consists of three main elements namely Pre Processor (CFX Bulid), Solver manager and post processor (visualize).

2.5. Speed Length Ratio (SLR)

Based on the consideration of large ship resistance in calm water resistance condition, the most important thing in determining the proper form of hull is based on the comparison between the speed of the ship service (service speed) with the length of the waterline of the ship (length of waterline). Where units are in the knots and the length of the water line in feet.

$$SLR = \frac{Vk}{\sqrt{Lwl}}$$

Where:

SLR = Speed Length Ratio

Vk = Service Speed (knot)

Lwl = Length of Water Line (Feet)

2.5.1 Relationship Between Waves To The Hull Form

In general, ships that flow on the surface of the water will produce transverse waveforms that differ depending on the shape of the stomach. The wave will have a flow velocity (Ck) which is equal to the speed of service (Vk). The magnitude of the wave that arises by itself due to the speed of the ship which has a consequence that is the rise of wave Resistance on the hull of the ship. While the characteristics of the wave. Same as the sine wave where the wavelength (Lw) corresponds to the flow velocity of the wave (Ck).

$$Ck = \frac{1,3}{\sqrt{Lw}}$$

Where :

Ck = Flow Rate (knots)

Lw = Wave Length (Feet)

The magnitude of the SLR for each wave is always equal to 1.3 of the wavelength. For SLRs from ships, how to always depend on the length of the vessel as well as its operating speed. Since the velocity of the flow velocity is equal to the velocity of the vessel, it is an equation between the wavelengths represented by the velocity of the vessel to the length of the waterline (length of waterline) as a function of the SLR

$$\frac{Lw}{Lwl} = \frac{SLR^2}{1,80}$$

Based on experiments ever conducted by Daniel Savitsky get a result as follows:

Table 2. 1 The result of tabulation comparison between wavelength to waterline length.

| SLR | Lw / LWL |
|------|----------|
| 0,94 | 0,50 |
| 1,10 | 0,67 |
| 1,16 | 0,75 |
| 1,34 | 1,00 |
| 1,90 | 2,100 |

In the above table data means that, increasing the speed or SLR, the wavelength will increase until $SLR = 1.34$ and the magnitude of the wavelength will be equal to the water line length (LWL) under $SLR > 1.34$. And can also be interpreted, the wavelength will exceed the length of the water line (LWL). For more details can be seen in the illustration in the picture below

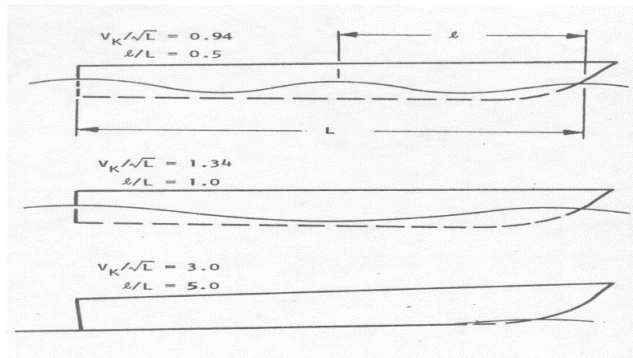


Figure 2. 3 Illustration of wave pattern with ship speed (Daniel Savitski,2003)

2.5.2 Single Hull Form Based on SLR

Based on it's SLR, Single hull Form can be divided into:

a) Displacement Hull

The floating Hull Displacement is entirely due to the buoyancy, the convex form of the waterline, the buttock lines, and the bilge required for the purpose of avoiding the occurrence of flow separation, especially in the ship's bursting to minimize the tensile forces caused by the hull components. Also note that when the vessel is at normal speed with the hull of the ship, the negative pressure on the convex surface is very small and has minimal effect on the performance of the hull. Therefore, the velocity of the vessel on the hull of this type is greater than the speed of the ship design

The maximum limit of the SLR of the Hull displacement is exactly the same as the $SLR = 1.3$ condition. While most ships with displacement hull, at SLR conditions ≥ 1.0 . More details see the picture below:

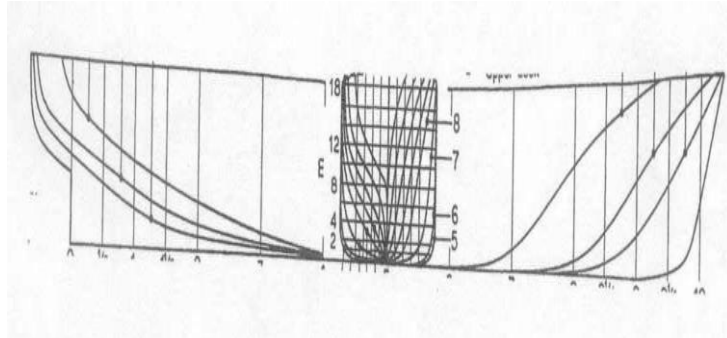


Figure 2. 4 Low – Speed Displacement (Daniel Savitsky,2003)

b) Semi Displacement Hull

For this type of hull, it is designed to avoid the amount of trim angle that occurs in the Hull displacement operating on $SLR \geq 1.3$. Because at this speed the wavelength will be greater than the length of the hull. So the trim angle will increase to reduce it should be designed geometric shape of the hull in accordance with the goal to avoid suction force along the longitudinal buttock lines. So that the buttock lines are designed straight then a part of the transom is immersed which has a width larger than the width of the hull displacement. Such a configuration would result in a positive dynamam pressure, which tends to provide lift force on the ship's velocity, so that it will raise the stomach slowly and will reduce the trim angle. Because not too big a given lift, then this type of hull is called semi-displacement hull or semi-planning.

Semi-displacement hull is recommended to operate under SLR conditions of anata 1.3 and 3.0. For the shape of the semi siplacement hull can be seen in the picture below

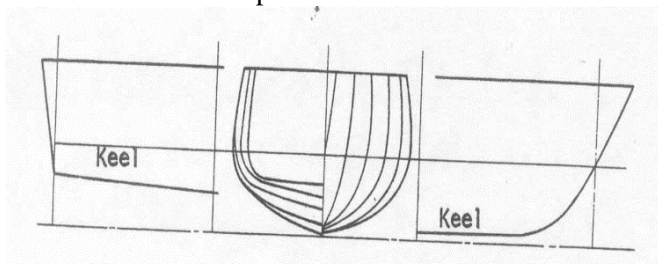


Figure 2. 5 High – Speed Displacement (Daniel Savitsky,2003)

c) Planning Hull

The hull form of this type is designed to increase the magnitude of the positive dynamic pressure which results in the magnitude of the gastric lifting force at high velocity conditions. The consequence obtained when the vessel operates is the decrease in the extent of the wet surface from the vessel condition to the static state. Hard Chine Planning

Hull, recommended to operate on $SLR > 3.0$ condition for the form of hard chine planning hull can be seen in the picture below:

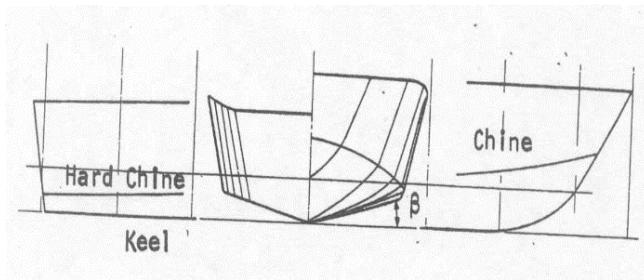


Figure 2. 6 Planning Hull (Daniel Savitsky,2003)

CHAPTER 3 RESEARCH METHODS

This chapter describes the analysis to determine the domain of the event, class and property compiler to define each domain, and things that need to be recognized. The process of determining begins with the method used to look up the facts, to the reason of the determination.

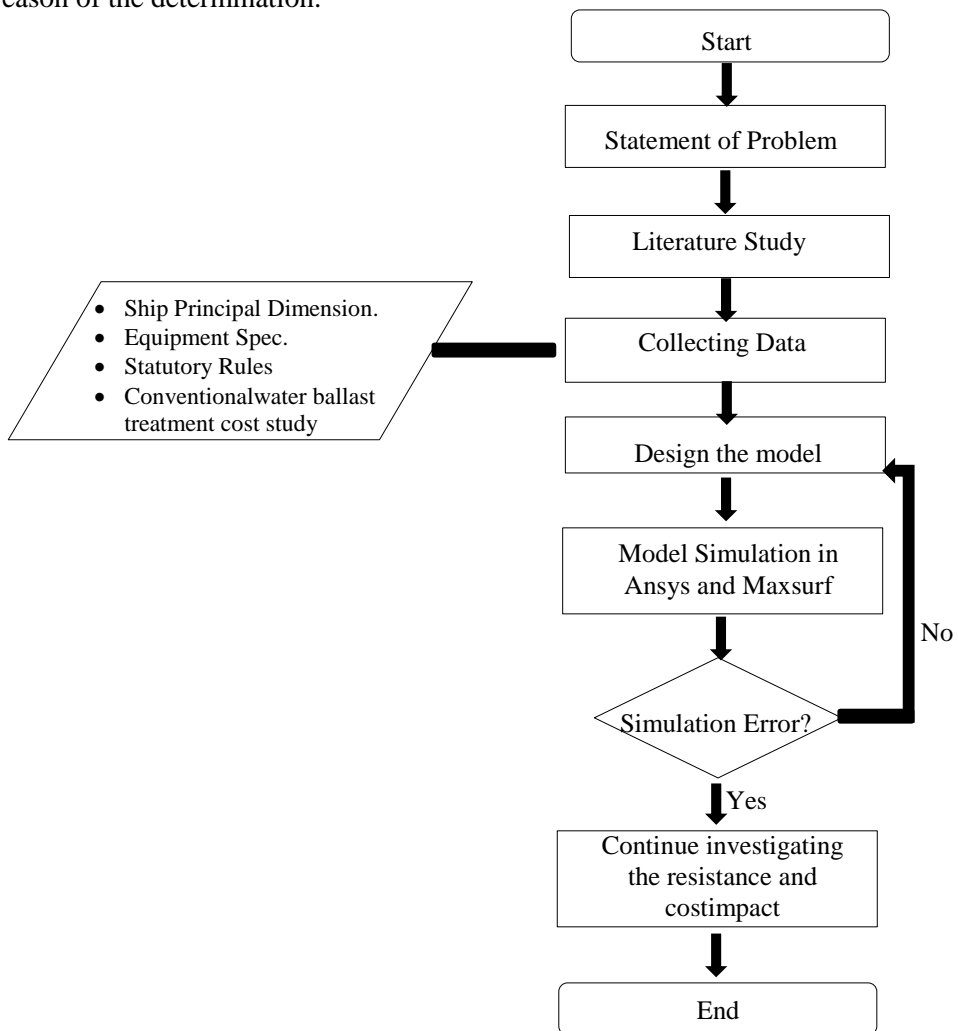


Figure 3. 1 Research Method Flowchart

Figure 3.1 is the flowchart of the work flow of the final task that becomes the reference in this final project work

3.1.Statement of Problem

This stage is an early stage to construct the thesis. In this stage, questions and problems are being prepared specifically in order to determine the specific objectives of this thesis. The content of the thesis is to overcome the statement of the problems mentioned earlier and it will be done by collect some information about the problems. Therefore, the purpose of this thesis can be understood in this stage.

Statement of the problem is done by digging information by doing study studies that have been implemented previously. The Statement of problems obtained by the author is the development of several studies that have been implemented previously and that is how Ballast Water are considered the main factor for the transfer of non-indigenous species of waters around the world. And to solve the issue, the International Maritime Organization (IMO) in 2004 adopted the the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). therefore shipowners and ship operators must select the appropriate BWTS to ensure they comply with IMO and / or USCG standards. Then, new method to solve. A new paradigm of thought developed by Miltiadis Kotinis and Michael G. Parsons to see the ballast condition as a change of buoyancy, not weight gain, to bring the vessel to its safe ballast draft. In this concept, the traditional ballast tanks are replaced by longitudinal, structural ballast trunks that extend beneath the cargo region of the ship below the ballast draft to ensures that the ballast trunks are always filled with “local seawater” and they will not transport nonindigenous aquatic species across the globe.

In this study, by combining some method developed, the problem stated how to implement it to the specific design of ship, and to analyse some impact regarding to the resistance and cost after implementing the system.

3.2.Literature Review

Right after the problems is raised, a literature study is performed. In this stage, literature will be use to connect the problems with existing theories and facts from various sources. Since this thesis is an implementation of many aspects disclipine, various literature topics is required to be constructed into one project. The study of literature is done by reading papers, journals, thesis, media and literature books that relates and able to support this thesis.

3.3.Collecting Data

After literature study which support the thesis has been done, collecting data is being performed. Data is collected by gather information to develop the conceptual design, most of data is available from the engine manufacturer, classification societies, countries regulation and several conventions which provide statutory rules. The required data is dimensional data of the length and width of the ship. At this process the author use maxsurf sample design as a basis ships data. By using maxsurf, the data required about ship all has been provided.

3.4. Model Simulation

The model simulation begins with the creation of a ship model form which will be made as the basis of the analysis. Shipbuilding is done by using Rhinoceros software with the dimensions of the ship that has been specified. After that the first detection analysis is done by using Hullspeed software, then the next stage with ANSYS software

The next process is to import the model on ANSYS ICEM, in ANSYS ICEM will be done again the formation of surface on the model, in order to be analyzed then the model that has been made must have boundary condition and domain. Boundary condition is a condition or type of fluid work area boundary eg inlet side, outlet, simulation object. While the domain shows the type of working fluid geometry that has become the surface (surface) then given the form of tetra-shaped particles (meshing process). Provision of domain volume using ANSYS ICEM software where the smaller the size of the tetra the higher the accuracy of the simulation.

There are three stages in the ANSYS simulation process, namely preprocessor, solution and postprocessor. The preprocessor stage is the stage for creating a geometry model, defining the material properties of mechanical and physical models, and the process of making elements and nodes in the model (meshing). At the solution stage is used to determine the type of settlement of the analysis performed, whether static or dynamic. Completion is made to the model in the form of elements with loading and boundary conditions provided to the model. While in stage postprocessor used to display result of computer iteration analysis terhadap model.

3.5. Resistance and Cost analysis

After every consideration is met the requirement, then the investigating of ship resistance will be conducted. Resistance investigation will be constructed with function calculator in computational fluid dynamic. The result will be compared to the same design of ship with conventional ballast system. So the result will be converted to fuel increase, and will be compared with conventional ballast water treatment maintenance cost.

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CHAPTER 4 ANALYSIS AND DISCUSSION

In this chapter is explained about problem analysis and design of Final Project. Problem analysis discusses the issues raised in this Final Project and the solutions offered. Further discussed also about the design of the system created.

4.1.Ship Dimensional

The type of ship has been determined. To get the data of principal dimension of the ship, Maxsurf software has been selected as source. There were already the existing design provided by maxsurf with bulker type with the length of 154m for its LWL.

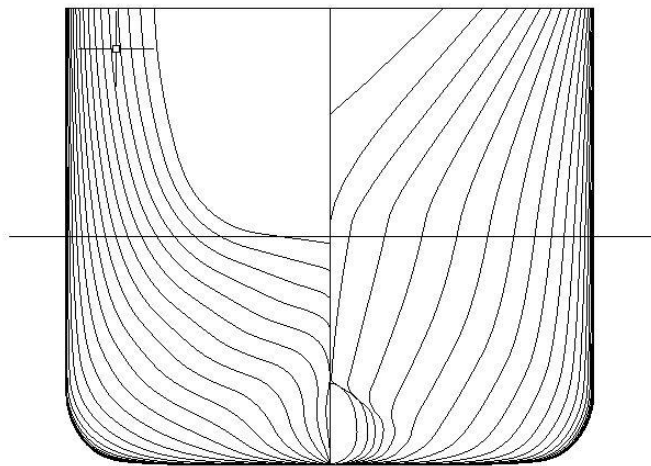


Figure 4. 1 Body Plan of Bulk Carrier

Figure 4.1 shows the body plan of existing model in maxsurf modeler. It then converted to autocad software for redrawing. The complete data is collected from two software and showed in Table 4.1

Table 4. 1 is the complete data of ship dimensionaal

| Specification | explication | Unit |
|------------------------|-------------|----------------|
| LOA | 159.573 | m |
| Displacement | 27690 | t |
| Volume (displaced) | 27014.361 | m ³ |
| Draft Amidships | 10 | m |
| Immersed depth | 10 | m |
| WL Length | 154.113 | m |
| Beam max extents on WL | 23.11 | m |
| Wetted Area | 5428.736 | m ² |
| Max sect. area | 226.781 | m ² |

| | | |
|----------------------------|----------|----------------|
| Waterpl. Area | 3065.735 | m ² |
| Prismatic coeff. (Cp) | 0.773 | |
| Block coeff. (Cb) | 0.758 | |
| Max Sect. area coeff. (Cm) | 0.981 | |
| Waterpl. area coeff. (Cwp) | 0.861 | |

Before processing any further, the drawing of bulk carrier provided by maxsurf, had to be converted to solid 3D drawing with autocad. The cause is many solver software only receive solid state drawing

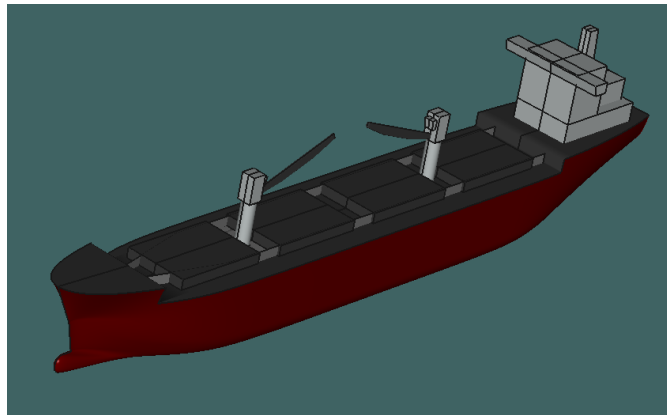


Figure 4. 2 Maxsurf Bulker Sample Design

Figure 4.2 is 3D view of Bulker sample design provided by Maxsurf.

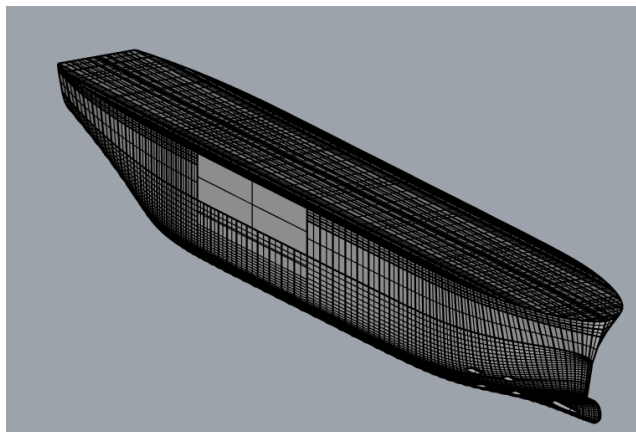


Figure 4. 3 Remodelling of Bulk Carrier Ship in Rhinoceros

After solid state had been made, the model again exported to rhinoceros software for further modelling. In the process of drawing ship model contains the manual element that is by making the surface of the ship so that it can be in accordance

with the planned hull shape of the ship. After the process of drawing the ship model has been completed then the next stage by finding the value of ship resistance

4.2. Resistance Analysis with Hullspeed

to provide supporting data as a comparison for cfd result data, it is necessary to do a resistance analysis using another method. And for that, maxsurf resistance is chosen to help carry out the analysis. In the maxsurf itself there are several methods to analyze the resistance of the ship. and from some of the displacement methods used, one has been selected. And the method is holtrop method. The result is provided in Table 4.2 and Table 4.3

Table 4. 2 Ship's Data from Hull Speed

| | Item | Value | Units | Holtrop |
|----|----------------------------|-------------|-------------------|-----------|
| 1 | LWL | 154.113 | m | 154.113 |
| 2 | Beam | 23.11 | m | 23.11 |
| 3 | Draft | 10 | m | 10 |
| 4 | Displaced volume | 27012.922 | m ³ | 27012.92 |
| 5 | Wetted area | 5351.069 | m ² | 5351.069 |
| 6 | Prismatic coeff. (Cp) | 0.773 | | 0.773 |
| 7 | Waterpl. area coeff. (Cwp) | 0.861 | | 0.861 |
| 8 | 1/2 angle of entrance | 25.2 | deg. | 25.2 |
| 9 | LCG from midships(+ve for' | 0.326 | m | 0.326 |
| 10 | Transom area | 0 | m ² | 0 |
| 11 | Transom wl beam | 0 | m | -- |
| 12 | Transom draft | 0 | m | -- |
| 13 | Max sectional area | 226.781 | m ² | -- |
| 14 | Bulb transverse area | 6.985 | m ² | 6.985 |
| 15 | Bulb height from keel | 1.738 | m | 1.738 |
| 16 | Draft at FP | 10 | m | 10 |
| 17 | Deadrise at 50% LWL | 0 | deg. | -- |
| 18 | Hard chine or Round bilge | Round bilge | | -- |
| 19 | | | | |
| 20 | Frontal Area | 0 | m ² | |
| 21 | Headwind | 0 | kn | |
| 22 | Drag Coefficient | 0 | | |
| 23 | Air density | 0.001 | tonne/ | |
| 24 | Appendage Area | 0 | m ² | |
| 25 | Nominal App. length | 0 | m | |
| 26 | Appendage Factor | 1 | | |
| 27 | | | | |
| 28 | Correlation allow. | 0.0004 | | Calculate |
| 29 | Kinematic viscosity | 0.0000011 | m ² /s | |
| 30 | Water Density | 1.026 | tonne/ | |

Table 4. 3 Resistance Result From Hull Speed

| | Speed (kn) | Froude No. LWL | Froude No. Vol. | Holtrop Resist. (kN) | Holtrop Power (kW) |
|----|------------|----------------|-----------------|----------------------|--------------------|
| 1 | 10.000 | 0.133 | 0.306 | 168.6 | 867.538 |
| 2 | 10.125 | 0.135 | 0.310 | 172.9 | 900.559 |
| 3 | 10.250 | 0.137 | 0.314 | 177.2 | 934.540 |
| 4 | 10.375 | 0.138 | 0.317 | 181.6 | 969.513 |
| 5 | 10.500 | 0.140 | 0.321 | 186.1 | 1005.511 |
| 6 | 10.625 | 0.142 | 0.325 | 190.7 | 1042.567 |
| 7 | 10.750 | 0.143 | 0.329 | 195.4 | 1080.718 |
| 8 | 10.875 | 0.145 | 0.333 | 200.2 | 1120.001 |
| 9 | 11.000 | 0.147 | 0.337 | 205.1 | 1160.457 |
| 10 | 11.125 | 0.148 | 0.340 | 210.0 | 1202.128 |
| 11 | 11.250 | 0.150 | 0.344 | 215.1 | 1245.056 |
| 12 | 11.375 | 0.152 | 0.348 | 220.3 | 1289.289 |
| 13 | 11.500 | 0.153 | 0.352 | 225.6 | 1334.874 |
| 14 | 11.625 | 0.155 | 0.356 | 231.1 | 1381.860 |
| 15 | 11.750 | 0.157 | 0.359 | 236.6 | 1430.302 |
| 16 | 11.875 | 0.158 | 0.363 | 242.3 | 1480.253 |
| 17 | 12.000 | 0.160 | 0.367 | 248.1 | 1531.769 |
| 18 | 12.125 | 0.162 | 0.371 | 254.1 | 1584.911 |
| 19 | 12.250 | 0.163 | 0.375 | 260.2 | 1639.740 |
| 20 | 12.375 | 0.165 | 0.379 | 266.5 | 1696.319 |
| 21 | 12.500 | 0.167 | 0.382 | 272.9 | 1754.716 |
| 22 | 12.625 | 0.168 | 0.386 | 279.5 | 1814.998 |
| 23 | 12.750 | 0.170 | 0.390 | 286.2 | 1877.236 |
| 24 | 12.875 | 0.172 | 0.394 | 293.1 | 1941.506 |
| 25 | 13.000 | 0.173 | 0.398 | 300.2 | 2007.883 |
| 26 | 13.125 | 0.175 | 0.402 | 307.5 | 2076.446 |
| 27 | 13.250 | 0.177 | 0.405 | 315.0 | 2147.278 |
| 28 | 13.375 | 0.178 | 0.409 | 322.7 | 2220.463 |
| 29 | 13.500 | 0.180 | 0.413 | 330.6 | 2296.086 |
| 30 | 13.625 | 0.182 | 0.417 | 338.7 | 2374.234 |
| 31 | 13.750 | 0.183 | 0.421 | 347.1 | 2454.995 |
| 32 | 13.875 | 0.185 | 0.424 | 355.6 | 2538.459 |
| 33 | 14.000 | 0.187 | 0.428 | 364.4 | 2624.717 |
| 34 | 14.125 | 0.188 | 0.432 | 373.5 | 2713.869 |
| 35 | 14.250 | 0.190 | 0.436 | 382.8 | 2806.017 |
| 36 | 14.375 | 0.192 | 0.440 | 392.3 | 2901.275 |

After the process of resistance analysis using Hullspeed is completed then get the value of ship resistance at speed 23 knot with Holtrop method equal to 300.2 kN. The result also shown in graphic mode so that the increasing shape graphic can be known.

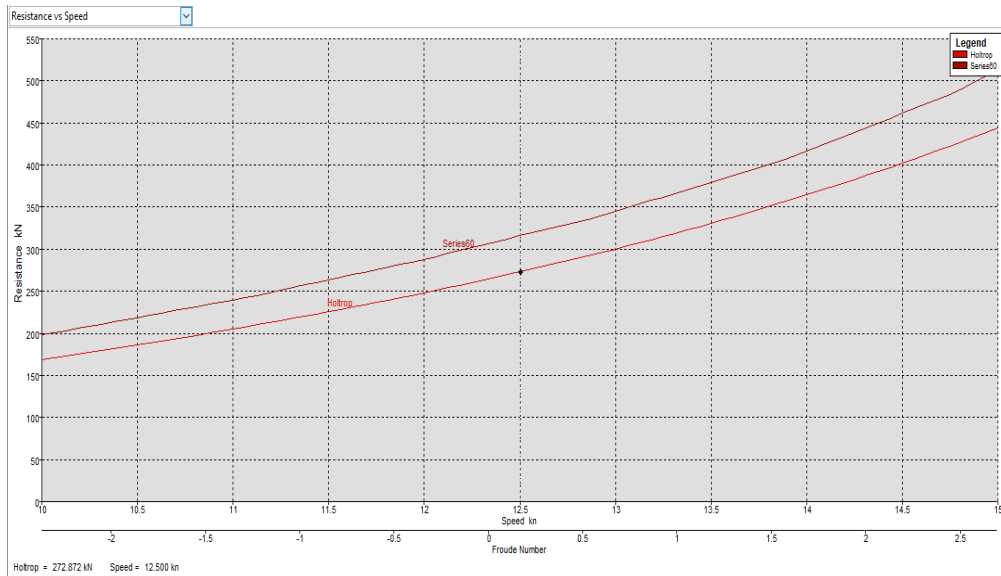


Figure 4. 4 Graphic Diagram of Resistance and Froude Number

Figure 4.4 shows the Graphic of result in analysis of bulker resistance in maxsurf resistance.

4.3. Resistance Analysis with Ansys I

The process of resistance analysis performed using ANSYS consists of several stages. The first stage of ship modeling process, the second stage of the grid meshing process, the third stage of the process pre-processor, the fourth stage of the process solver, and the fifth stage of post processor process. After all the steps are completed it will get the value of the Ship Resistance

4.3.1. Model Ship Drawing

In the process of modeling the ANSYS software using models that have been made in Rhinoceros software. For this analysis it aims to obtain the magnitude of resistance and flow velocity (V_a) that occurs when the ship sails. The first step to be modeled into ANYS software is that the data from rhinoceros is first converted into an igs file. And the subsequent process of surface making is done on the Design Geometry based on the parameters of the curves.

After the shipbuilding process on Design Geometry by way of giving surface, then the next step is the creation of the domain. The term domain is the boundary or scope of the fluid in which the fluid works. In this domain depiction the vessel is placed on a rectangular box of a size larger than the size of the ship's dimensions.

As shown on figure 4.4, The geometry already accepted to the Design Modeller.

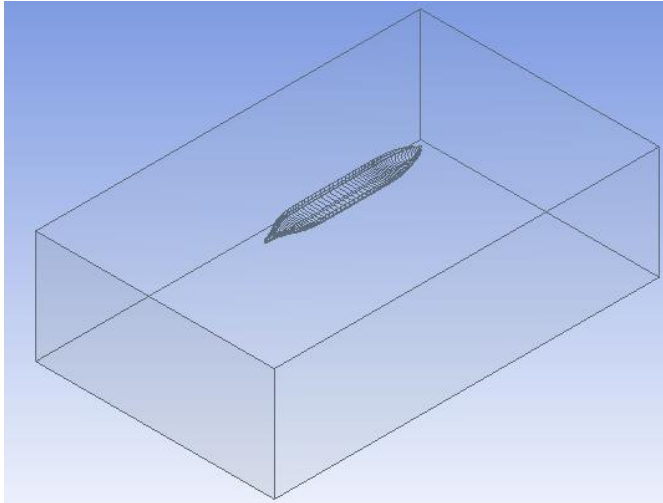


Figure 4. 5 Domain Geometry

After the shipbuilding process on Design Geometry by way of giving surface, then the next step is the creation of the domain. The term domain is the boundary or scope of the fluid in which the fluid works. In this domain depiction the vessel is placed on a rectangular box of a size larger than the size of the ship's dimensions.

The next stage before entering the meshing process is to create three part domains as boundary conditions that will be analyzed such as inlet, outlet, bottom, starboard, portside, and also ship.

4.3.2. Grid (Meshing)

In the meshing process is a process where there are lines that resemble the form of a net, with the meshing process requires very small size / fine because it will get accurate and maximum results. And on the part that is not too important or detailed does not require the meshing process with a small size, simply use a relatively large or rough size.

In the current simulation meshing process with small size or need detail include part of the next ship is by inlet, outlet, bottom, top, starboard, and portside.

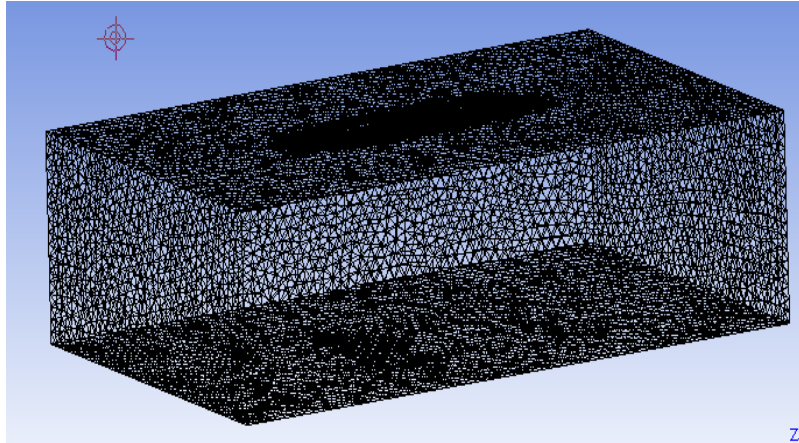


Figure 4. 6 Domain in Mesh

4.3.3. Pre Process

In the pre CFX process is an advanced step of the CFX build that serves as inputting input before it is simulated. And the domain to be used is domain stationer where the fluid is working water and air.

In the domain domain processor area which includes the domain is the model of the ship itself, so that the flow that works when passing through this domain will experience the movement of translation.

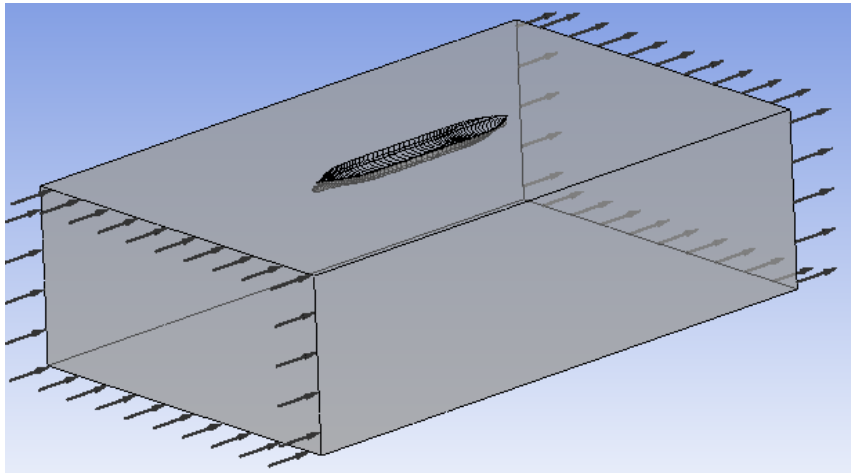


Figure 4. 7 Domain Stationer

a. Boundary

Boundary is a boundary condition created to know the characteristics of the object and the fluid to be close to the actual conditions. The boundary conditions formed include inlet as fluid inlet, outlet as fluid outlet and wall (boundary wall) used as boundary on ship model, opening on top, symmetry on portside and starboard and wall on bottom

b. Inlet

In the simulation method is used single fluid method because the condition is considered there is only one type of fluid that enter into the simulation of sea water and air. The given speed parameters varied when the vessel has entered the maximum speed of 13 knots.

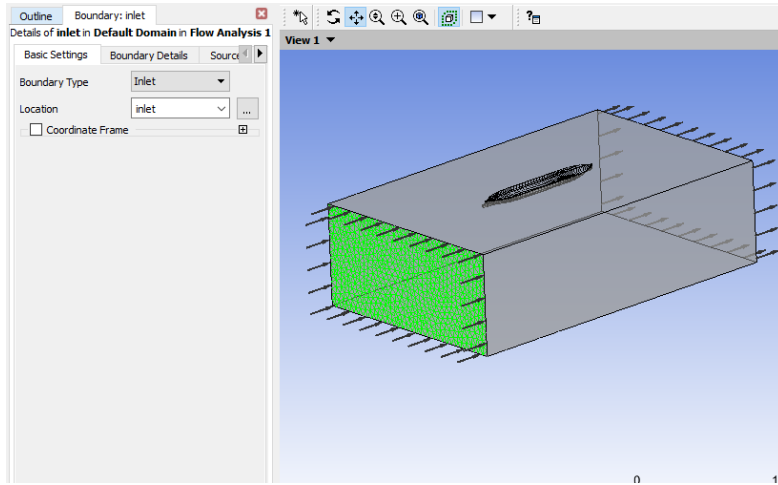


Figure 4. 8 Boundary Inlet

c. Outlet

In this part of the process is a part of the stationary domain with the parameters used is the static pressure with Atm expression downpres that is relative to the pressure fluid

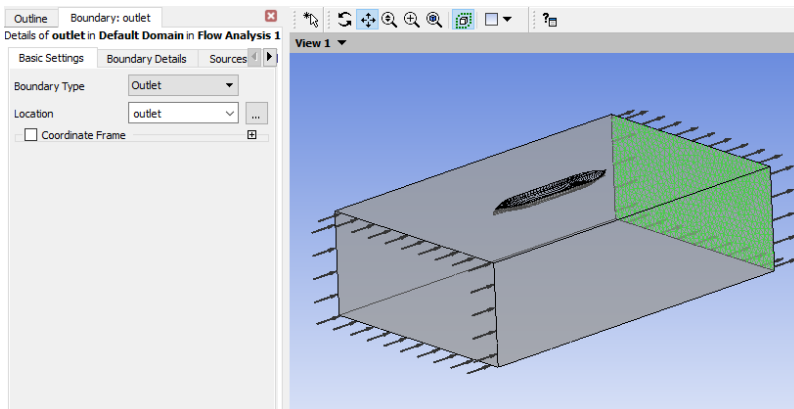


Figure 4. 9 Boundary Outlet

d. Ship

In the process of this analysis the ship is used as a boundary wall with no slip parameters with the sense that there is no friction on the model when passed the flow of fluid.

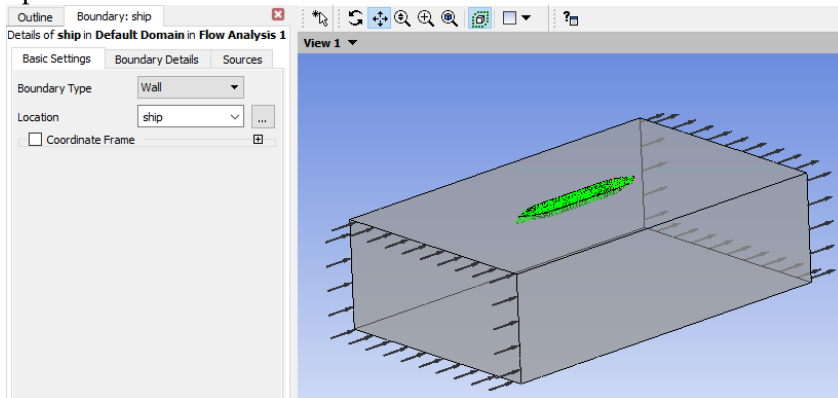


Figure 4. 10 Boundary Wall of Ship

e. Wall Surround

In the process of this analysis starboard and portside used as boundary symmetry. And in the top part made a part of opening which means that the fluid flow that works on the experiment is considered will not bounce again into, while the bottom is used as a boundary wall because it is likened to the floor or base.

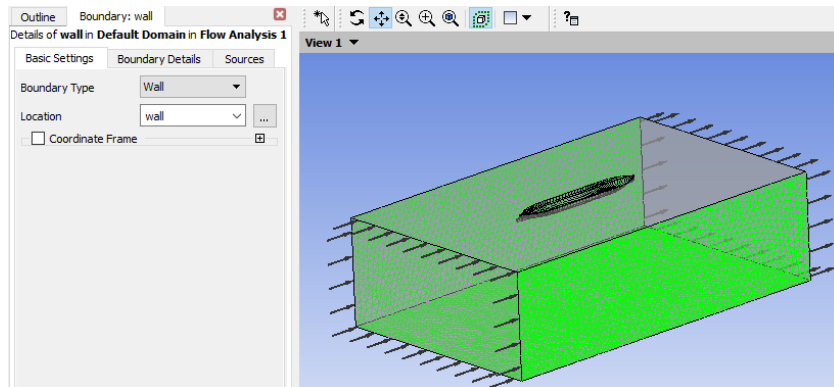


Figure 4. 11 Boundary Wall Surround

4.3.4. Solver

In this CFD solver process serves as to perform data processing with computer numeric calculation of all parameters - parameters that have been determined at the time of pre processors.

At this stage is done charging data parameters to be used for the analysis process, charging the data is used to obtain convergence, ie the suitability between input simulation or guess given with the calculation results obtained. The smaller the difference in convergence then the results will be obtained more accurate.

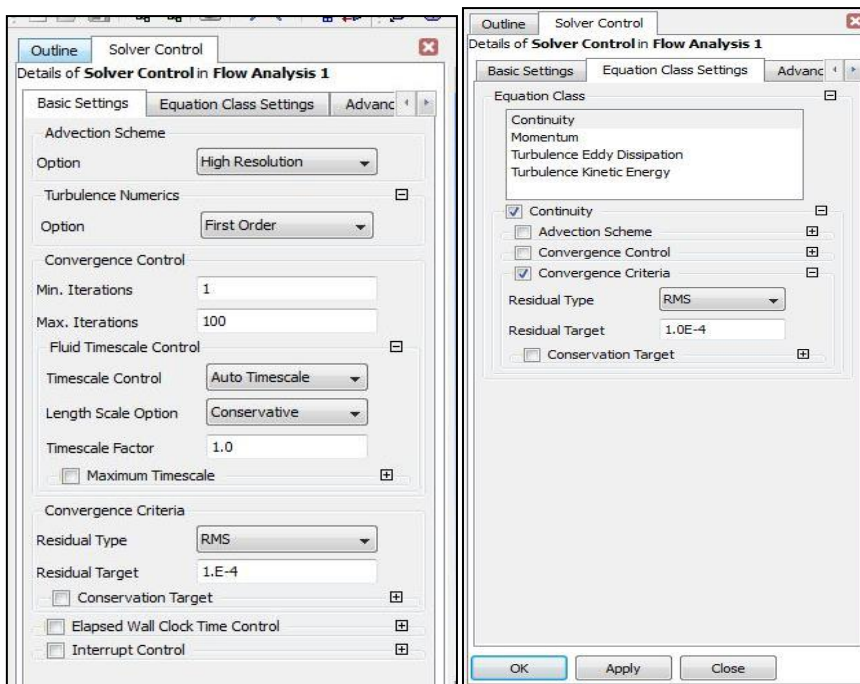


Figure 4. 12 Parameter Data Solver

4.3.5. Post Processor

In the post processor process step aims to find out the results of data processing that has been done in this solver stage. The results obtained can be either numerical data or visual data. So the value of data that has been obtained is used as a validation process

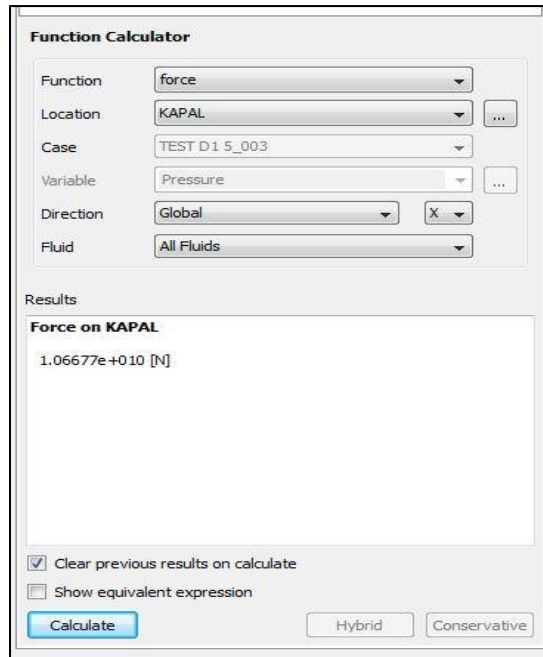


Figure 4. 13 Function Calculator

The validation process that will be analyzed is to use numerical data from the result of a superb analysis. The magnitude of the resistance value is pinned as the vessel travels at the fluid flow (force) and also the value of the ave water velocity. All these values can be seen in the fuction calculator,

While for the process of visual result is can use isosurface water volume friction, countour water supercritical velocity, and streamline water velocity. Then it will be seen as follows.

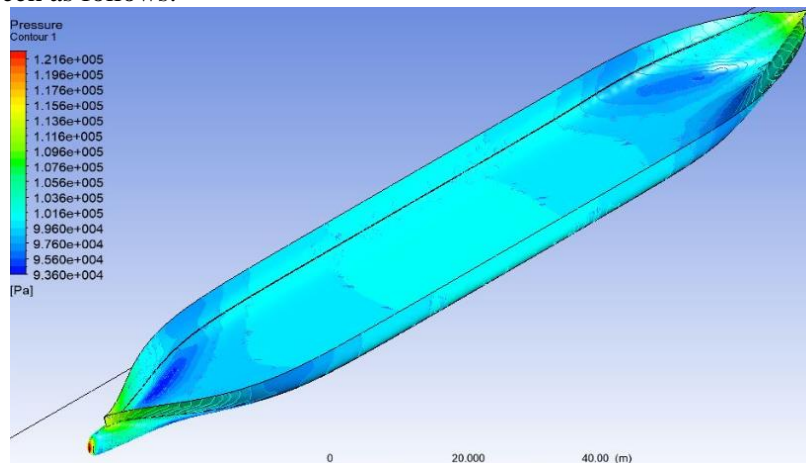


Figure 4. 14 Countour Pressure

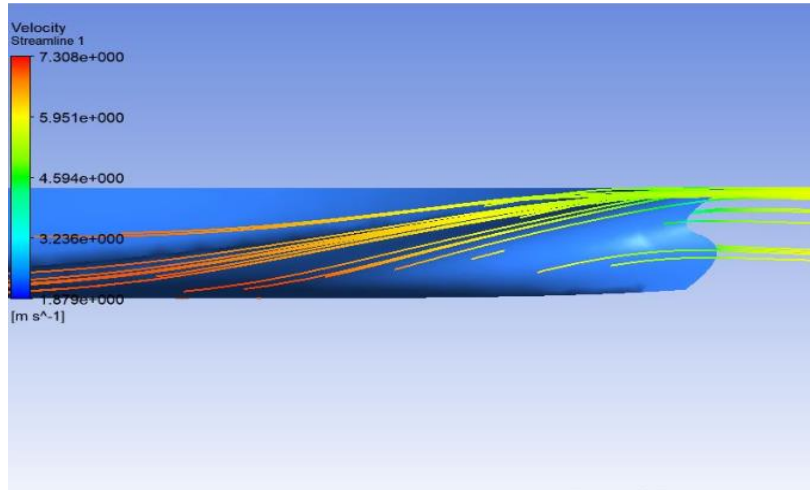


Figure 4. 15 Streamline at Afterpeak

From the results of analysis that has been done, the value of resistance (force) and velocity of fluid flow (V_a) received by ship. Here is the value of the prisoner of the ship that does not use Ballast Free System

Table 4.3 Solver Result

| no | Ship | RT at 13 knot (kN) |
|----|-----------|--------------------|
| 1 | bare hull | 298 |

4.4. Validation of Resistance Result

After obtaining the resistance analysis result from two methods, the result of each method can be compared. And with the error analysis formula, can be known to what extent the simulation to make error than the calculation. In this case, the hullspeed simulation result is considered a calculation because its function as a resistivity counter is based on existing formulas. And thus, analysis with cfd is considered as a simulation result because it functions as a model simulator

Table 4. 4 Resistance Result from Ansys and Hullspeed

| no | ship | RT at 13 knot (kN) |
|-------|-----------|--------------------|
| 1 | Ansys | 287.168 |
| 2 | Hullspeed | 300 |
| Error | | 4.277% |

Table 4.4 shows an error in the results of the resistance analysis using ansys. However, errors can be ignored and the results of data are acceptable because the error results do not exceed five percent

4.5. Modelling of Ballast Free Ship

At this stage, the ballast tunnel will be added to the ship model as a ballast water flow path. This tunnel is modeled by considering the need for ballast water on the vessel. calculations show that the ship requires 4200 m³ of water for its ballast needs. Tunnel modeled with longitudinal pipe shape and dimensions tailored to the needs of the ballast water required.

To analyze the various effects of resistance , then 3 models have been made. Model made in rhinoceros software by combining with ship model that has been in solid. That way the domain form needed for the simulation can be made. model is then tested again on ansys with a speed of 13 knots. the models are:

a. Model with Big inlet and Big Outlet

The first model created was a tunnel with inlets and outlets of the same size as a tunnel. This model rather difficult to built because the impact to the hull. The bigger the tunnel, the bigger the hole will tear hull skin. because of its influence on the bulbous bow, which makes the tunnel flow on the tunnel near the midship to be connected with the inlet from the center tunnel.

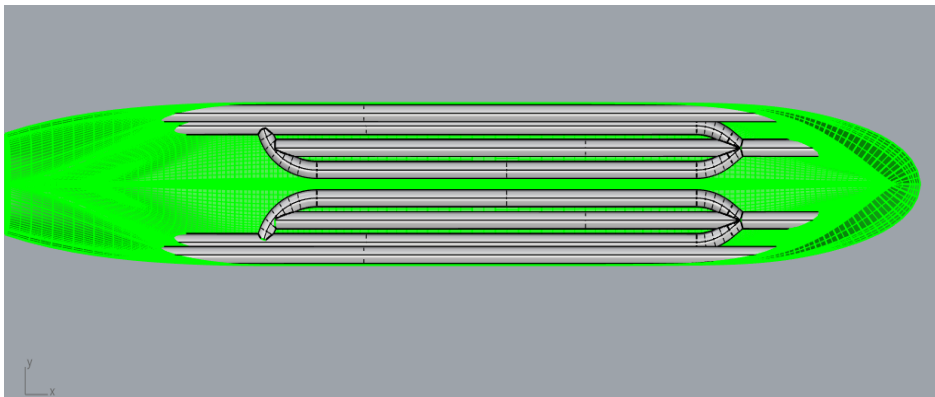


Figure 4. 16 Model A

- b. For the second model, inlet and outlet wil be reduced to smaller hole. But in the middle of tunnel, the pipe will be gave sudden enlargement, and sudden constraction to ensure that the water will fill ballast water need. the second model is made without branch to know the difference of tunnel model with branch. tunnel model with branch will be made on the next model. this model is also designed to reduce the size of the valve on the inlet and outlet. In the first model, the inlet and outlet should wear large diameter valves following the inlet and outlet diameter. but by reducing the inlet and outlet diameter, the required valve size will decrease. thus it will benefit the cost and supply part because the larger the valve, the harder it will be to manufacture and will be more expensive.

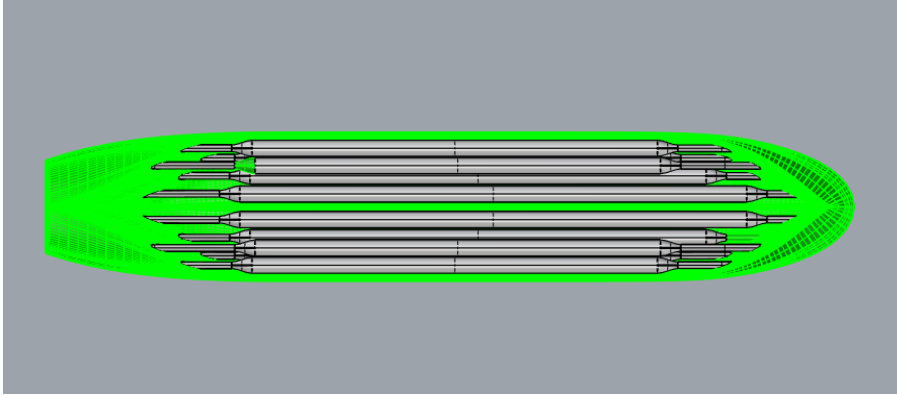


Figure 4.17 Model B

- c. The third model also follows the design of the second model is to shrink the diameter of the inlet and outlet. However, the third and second models differ in their inlet streams. By reducing the number of inlets, the inlet stream is made branched off into the main tunnel. That way, in addition to the size of the valve used will shrink, the amount of valve required is also reduced..

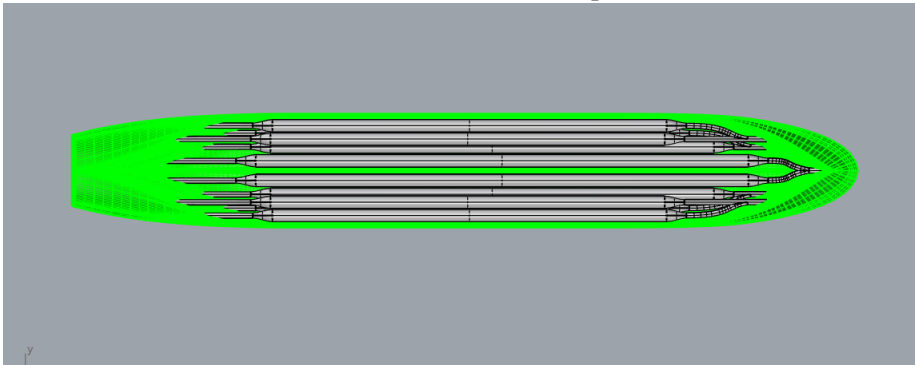


Figure 4.18 Model C

4.6. Analysis Result

To obtain the results of the analysis, the three models need to be simulated with the same procedure as the previous simulation. In this way we will get comparison data of simulation result from three models.

The first data obtained from the simulation class is streamline velocity to determine the speed of water flow in each tunnel. That way, the time it takes for local water to change the flow can be known.

The second data is pressure contour. With pressure contour, pressure in each tunnel will be known. although this data has no effect on resistance analysis results, but this data can be helpful in further research.

And the last result is the result of Total Resistance. Like the previous simulation this result is obtained by using the function calculator on the post processor feature. The third result is then compared to find out which model produces the

smallest total resistance. The model with the smallest total resistance will be selected for comparison with the ship parent. ship parent is a regular ship without a ballast free system and uses conventional ballast water treatment

The result shows different flow rate and pressure contour resistance results. Post process result given below:

4.6.1. Velocity Comparison

As mentioned before, the comparison results in the streamline velocity will show the rate of flow of water in the tunnel. Furthermore, it will be explained through the simulated image of the three models.

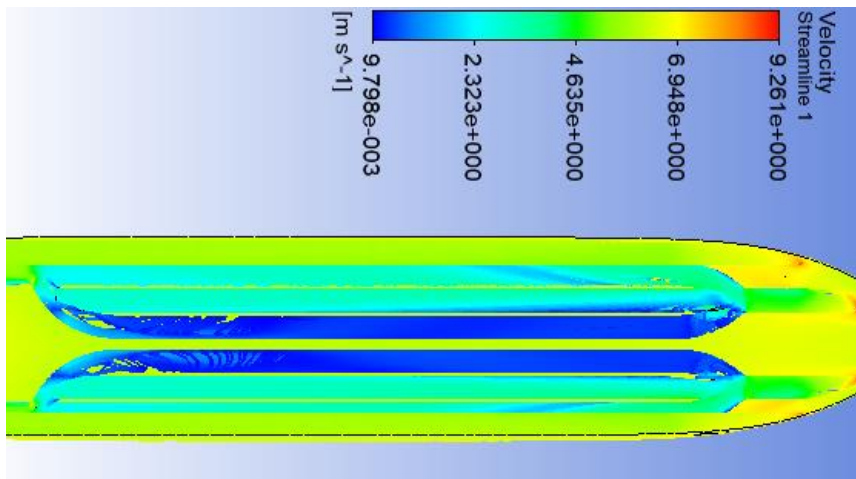


Figure 4. 19 Velocity Inside the Tunnel A

Figure 4.19 shows the streamline velocity in the first model. From the figure, it can be seen that the water flow rate is uneven in the three tunnels. Tunnel with the position near the center girder produces the lowest speed. This is the effect of trapping the flow in the tunnel as a result of the flow from the other tunnel.

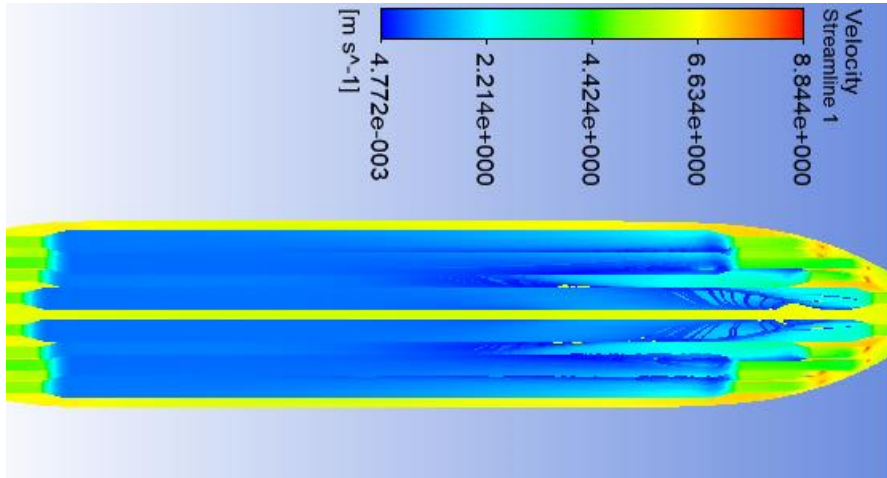


Figure 4. 20 Velocity Inside the Tunnel B

Figure 4.20 shows the streamline velocity on the second model. the picture shows the existence of turbulence after the flow out of the sudden enlargement. And since turbulence is not discussed in this analysis, the resulting turbulence can be ignored. In addition, the resulting speed is evenly distributed across all tunnels of the second model. The flow slows down through a sudden enlargement. This is because of the sudden contraction at the outlet. flow velocity on tunnel model 2 is slower than the first tunnel model

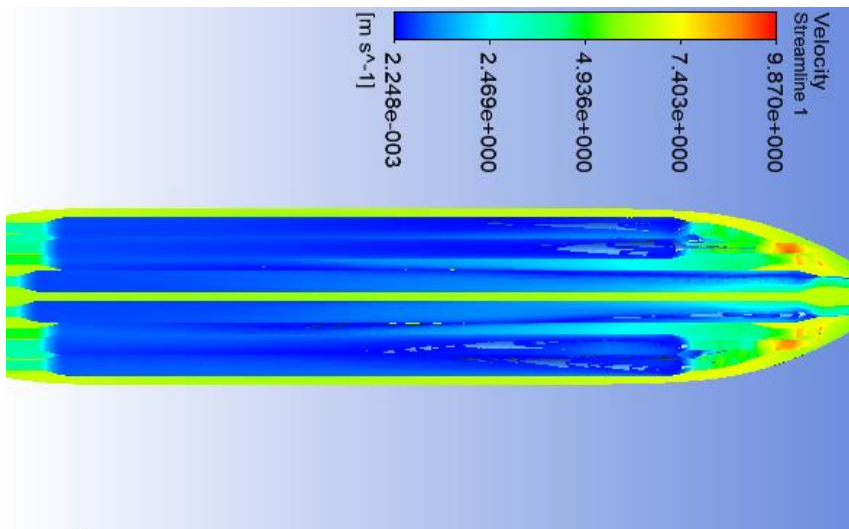


Figure 4. 21 Velocity Inside the Tunnel C

Figure 4.21 shows the streamline velocity on the third model. the image shows results that are not much different from the tunnel of the second model. flow velocity on the third model tunnel is even slower than the second or the first tunnel model

After knowing the third result then the comparison of velocity and flushing time will be implemented. The result can be seen in Table 4.5

Table 4. 5 Complete Flush Time Comparison

| no | ship | Vs (knot) | Vwater (m/s) | CFT (Hour) | CFT (seconds) |
|----|--------------|-----------|--------------|-------------|---------------|
| 1 | ship model A | 13 | 0.09798 | 0.340205484 | 1224.739743 |
| 2 | ship model B | 13 | 4.424 | 0.007534659 | 27.12477396 |
| 3 | ship model C | 13 | 4.936 | 0.006753106 | 24.31118314 |

4.6.2. Resistance Comparison

The next result to be compared is the result of resistance analysis. Resistance analysis is done with function calculator after simulation done. To complement the resistance graphic, the simulation of the three models is performed at five different speeds between 10 to 14 knots. The result can be shown in the Table 4.6, 4.7, 4.8, and Figure 4.22

Table 4. 6 Total Resistance of Model A

| BFS Model A | | | |
|-------------|-----------|----------|---------|
| no | Vs (Knot) | Vs (m/s) | RT |
| 1 | 14 | 7.196 | 368.154 |
| 2 | 13 | 6.682 | 322.309 |
| 3 | 12 | 6.168 | 275.211 |
| 4 | 11 | 5.654 | 232.345 |
| 5 | 10 | 5.14 | 194.001 |

Table 4. 7 Total Resistance of Model B

| BFS Model B | | | |
|-------------|-----------|----------|---------|
| no | Vs (Knot) | Vs (m/s) | RT (KN) |
| 1 | 14 | 7.196 | 255.27 |
| 2 | 13 | 6.682 | 222.884 |
| 3 | 12 | 6.168 | 191.106 |
| 4 | 11 | 5.654 | 162.324 |
| 5 | 10 | 5.14 | 135.763 |

Table 4. 8 Total Resistance of Model C

| BFS Model C | | | |
|-------------|-----------|----------|---------|
| no | Vs (Knot) | Vs (m/s) | RT (KN) |
| 1 | 14 | 7.196 | 288.611 |
| 2 | 13 | 6.682 | 251.833 |
| 3 | 12 | 6.168 | 215.484 |
| 4 | 11 | 5.654 | 179.993 |
| 5 | 10 | 5.14 | 144.902 |

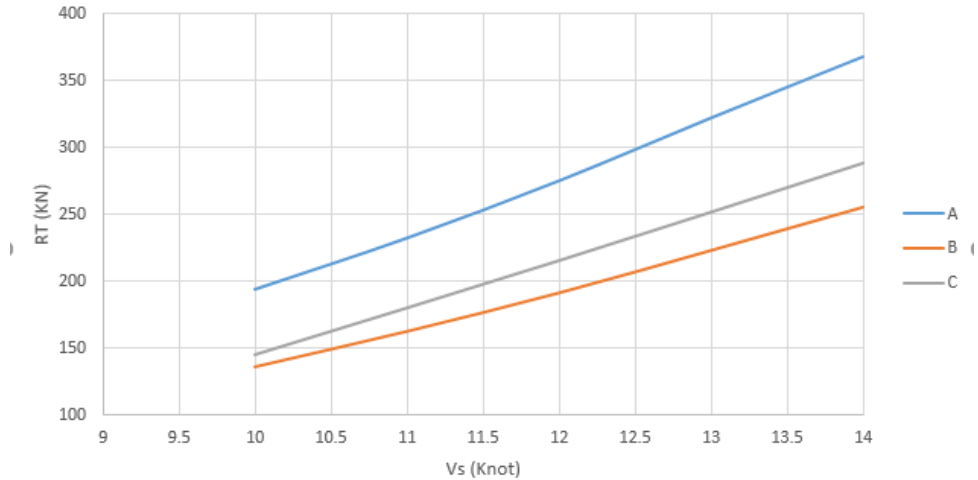


Figure 4. 22 Graphic of Total Resistance

Figure 4.22 is graphic represent the result in resistance analysis from three models. From the above results, it can be concluded that model B has a smaller total resistance than the other two models. Thus, the model chosen for the next capital cost comparison is model B

4.7. Cost Analysis

In the Cost Analysis sub chapter, Cost impact due to integrated ballast free system will be analyzed. The analysis is devoted to the analysis of changes in capital expenditure and operational expenditures before and after applying the ballast free system. The only searched changes relate to the ballast system on board. And in this analysis, all unrelated capital expenditures and operational expenditures will be considered equal or unchanged.

4.7.1. Capital Expenditure (Capex)

Capex (Capital Expenditure or) is the business expenses incurred to create acquisition benefits in the future of assets that will have a useful life beyond the tax year. eg expenses for assets such as buildings, machinery, equipment or upgrades of existing facilities so that their value as an asset increases.

And in this analysis, the capex is devoted to the costs required in the construction of a ballast free system, as well as some additional expenses related to changes in inner ship building.

capex here is divided into 2 parts. The first is the costs incurred to build a ballast free system and additional construction. This cost will be a plus on the calculation of capex. And the second is the estimated cost of ballast water treatment procurement covering the cost of purchase and installation costs. This cost will be a minus value as it is considered to be eliminated. table 4.9 gives the cost value of the estimate of each part.

Table 4. 9 Capex of BFS

| | |
|--|------------------|
| Additional hull steel cost (Rp) | + 1.610.000.000 |
| Gates Valve (Rp) (20 @ 280.000.000 each) | + 5.600.000.000 |
| Additional welding cost (Rp) | + 120.000.000 |
| Elimination of ballast tank Valve(Rp) | - 172.620.000 |
| Elimination of BWTS Installation Cost (Rp) | - 258.930.000 |
| Elimination of ballast treatment system (\$) | - 12.083.400.000 |

4.7.2. Operational Expendiure (Opex)

Operating expenditure is the planned allocation in the budget to conduct the company's operations normally. In other words, operating expenditure (operating expenses) is used to maintain asset sustainability and ensure the company's planned activities take place well. Because of its daily cost, the operating costs do not cover income taxes, depreciation, and financing costs (interest on loans). In this thesis, operational expenditure is specialized in the additional costs required to operate the ship due to the integration of the ballast free system.

like in capex analysis, opex here is divided into 2 parts. The first is the cost charged to the operation of the ballast free system which in this case is a diesel engine fuel, and the additional cost for annual maintenance. This cost will be a plus on opex calculations. And the second is the estimated annual maintenance cost of ballast water treatment. This cost will be a minus value as it is considered to be eliminated. Table 4.10 gives the estimated cost value of each section.

Table 4. 10

| | |
|--------------------------------------|----------------|
| Additional heavy fuel oil cost (Rp) | +6.877.726.800 |
| Additional Annual Maintenance (Rp) | + 150.000.000 |
| Elimination of BWTS annual cost (Rp) | - 158.235.000 |

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CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1. Concluions

After planning and simulation of all models and have obtained the results of bulk carrier vessel resistance analysis with ballast free system, it can be concluded that:

1. The concept of a ballast free system is integrated on a bulk carrier vessel with 159 m LOA by adding a pipe tunnel based on the needs of the ballast water. Tunnel made into 3 models (varied with inlet and outlet difference of 2.5 meters and 1 meter) longitudinal with 2.5 m diameter which then divided into 3 models to compare. And by adding tunnel, the double bottom height increases from 1.6 meters to 3 meters.
2. Analysis with ansys software on bulk carrier vessel with ballast free system at 13 knot speed shows model a yielding resistance of 322.309 kn, and model b yields resistance of 222,884 kn, and in model c yields resistance of 251.883 kn. While the estimated time for CFT (Complete Flushing Time) in model a requires 0.340205484 hours, model b requires 27.12477396 seconds, and model c takes 24.31118314 seconds. The result of comparison of ship resistance analysis in ansys cfx software with hullspeed shows a difference of 12,832 kn. Error validation of both simulation methods of 4.27%. This result is acceptable because its value is below 5%.
3. Based on the results of comparison between bulk carrier vessels with conventional ballast water treatment systems and bulk carrier vessels with ballast free systems, changes in capital expenditure (capex) and also in operating expenditure (opex). The results showed that bulk carrier vessels with ballast free systems could cut capital expenditure of Rp 5,184,950,000,-. While in operating expenditure, vessels with ballast free system indicate an additional charge of Rp 6,869,491,800,- per year.

Table 5. 1 Net Capital Cost

| | |
|-------------------------------------|-----------------|
| Net capital cost change (Rp) | - 5.184.950.000 |
| Net operating cost change per annum | + 6.869.491.800 |

5.2. Recommendation

Based on the analysis and the whole process that has been done by the writer in conducting resistance analysis on bulk carrier vessel with ballast free system, need suggestion so that the next research get better result again. And suggestions recommended by the author are as follows:

1. Due to construction changes in double bottom part, it is necessary to have construction design analysis for ship with ballast free system. With a special design for double bottom construction, the ship with this ballast free system, will be able to transport cargo with more capacity.
2. in order to obtain more perfect resistance analysis results, it needs to do towing test for ship design with ballast free system. this is because environmental conditions can be better conditioned in towing test.
3. it is necessary to model tunnel system with a more varied form. by varying the tunnel shape, there is a possibility that the resistance of the vessel will decrease or even the cargo capacity will increase.

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ATTACHMENT

Ship Engine Calculation

| <u>Ship's Data</u> | | | | | |
|--------------------|---|----------|----|---------|-----|
| Lpp | = | 147.9485 | m | 485.395 | ft |
| Ldisp | = | 151.03 | m | 495.508 | ft |
| Lwl | = | 154.11 | m | 505.620 | ft |
| B | = | 23.11 | m | 75.820 | ft |
| H | = | 14.30 | m | 46.916 | ft |
| T | = | 10.00 | m | 32.808 | ft |
| Vs | = | 13.00 | kt | 6.688 | m/s |
| Cb Lpp | = | 0.76 | | | |
| Cm | = | 0.98 | | | |
| Cp | = | 0.77 | | | |
| Cb Lwl | = | 0.76 | | | |

SHIP'S POWER CALCULATION

Power 1 kW = 1.341 HP

Effective Ship's Power

EHP = $R_T \times V$ (m/s)

| No. | Speed | | | Ship's power (kW) | Ship's Power (HP) |
|-----|--------------|------|---------|-------------------|-------------------|
| | Ship | Knot | m/s | | |
| 1 | Bare hull 6 | 13 | 6.68772 | 1647.286 | 2209.010 |
| 2 | Bare hull 10 | 13 | 6.68772 | 2400.624 | 3219.237 |
| 3 | Model A | 13 | 6.68772 | 2694.390 | 3613.178 |
| 4 | Model B | 13 | 6.68772 | 1863.232 | 2498.594 |
| 5 | Model C | 13 | 6.68772 | 2105.236 | 2823.121 |

Power of Ships Propeller

$$\begin{aligned} \text{DHP} &= \text{EHP}/P_c \\ \text{Hull Efficiency} & \\ \eta_H &= (1 - t) / (1 - w) \\ \text{Wake Friction} & \\ w &= 0,5 \times C_{bpp} - 0,05 \\ &= 0.329 \\ \text{Thrust Deduction} & \\ t &= k * w \\ &= 0.000 \end{aligned} \quad \begin{aligned} \text{where} \\ k = 0,7 - 0,9 \\ k = 0.8 \end{aligned}$$

$$\begin{aligned} \text{Hull Efficiency:} \\ \eta_H &= 1.490313 \\ \text{Relative Rotative Efficiency} \\ \eta_{rr} &= 1,0 \sim 1,1 \\ &= 1.05 \\ \text{Propeller Efficiency} \\ \eta_o &= 40\% \sim 70\% \\ &= 50\% \\ \text{Propulsive Efficiency} \\ P_c &= \eta_H \times \eta_{rr} \times \eta_o \\ &= 0.7824143 \\ \text{DHP} &= \text{EHP}/P_c \end{aligned}$$

| No. | Speed | | | Shaft Power (kW) | Shaft Power (HP) |
|-----|--------------|------|---------|------------------|------------------|
| | Ship | Knot | m/s | | |
| 1 | Bare hull 6 | 13 | 6.68772 | 2105.388 | 2823.325 |
| 2 | Bare hull 10 | 13 | 6.68772 | 3068.226 | 4114.491 |
| 3 | Model A | 13 | 6.68772 | 3443.688 | 4617.985 |
| 4 | Model B | 13 | 6.68772 | 2381.388 | 3193.442 |
| 5 | Model C | 13 | 6.68772 | 2690.692 | 3608.218 |

Shaft Horse Power

$$\eta_B \eta_S = 98\% \quad \text{SHP} = \text{DHP} / \eta_B \eta_S$$

| No. | Speed | | | Shaft Power(kW) | Shaft Power (HP) |
|-----|--------------|------|---------|-----------------|------------------|
| | Ship | Knot | m/s | | |
| 1 | Bare hull 6 | 13 | 6.68772 | 2148.355 | 2880.944 |
| 2 | Bare hull 10 | 13 | 6.68772 | 3130.843 | 4198.460 |
| 3 | Model A | 13 | 6.68772 | 3513.967 | 4712.230 |
| 4 | Model B | 13 | 6.68772 | 2429.988 | 3258.614 |
| 5 | Model C | 13 | 6.68772 | 2745.604 | 3681.855 |

For the vessel whose engine room is located at the rear will experience losses of 2%, but on the ship whose engine room on the midship of the ship experienced losses of 3%. In this planning, the engine room is located at the back, so the losses that occur only 2%

Man Engine

$$\text{BHP}_{\text{SCR}} = \text{Gearbox Efficiency}$$

$$\text{BHP}_{\text{MCR}} = \text{Engine Margin}$$

$$\eta_G = 98\% \quad \text{BHP}_{\text{SCR}} = \text{SHP} / \eta_G$$

| No. | Speed | | | BHP _{SCR} (kW) | BHP _{SCR} (HP) |
|-----|--------------|------|---------|-------------------------|-------------------------|
| | Ship | Knot | m/s | | |
| 1 | Bare hull 6 | 13 | 6.68772 | 2192.199 | 2939.739 |
| 2 | Bare hull 10 | 13 | 6.68772 | 3194.738 | 4284.143 |
| 3 | Model A | 13 | 6.68772 | 3585.681 | 4808.398 |
| 4 | Model B | 13 | 6.68772 | 2479.580 | 3325.116 |
| 5 | Model C | 13 | 6.68772 | 2801.637 | 3756.995 |

$$\text{EM} = 85\% \quad \text{BHP}_{\text{MCR}} = \text{BHP}_{\text{SCR}} / \text{EM}$$

| No. | Speed | | | BHP _{MCR} (kW) | BHP _{MCR} (HP) |
|-----|--------------|------|---------|-------------------------|-------------------------|
| | Ship | Knot | m/s | | |
| 1 | Bare hull 6 | 13 | 6.68772 | 2579.058 | 3458.517 |
| 2 | Bare hull 10 | 13 | 6.68772 | 3758.515 | 5040.169 |
| 3 | Model A | 13 | 6.68772 | 4218.448 | 5656.938 |
| 4 | Model B | 13 | 6.68772 | 2917.152 | 3911.901 |
| 5 | Model C | 13 | 6.68772 | 3296.043 | 4419.994 |

ATTACHMENT

Ceas Wizard Result

| | | | |
|--------------------------|----------------------------------|-------|----------|
| Engine type | 5G40ME-C9.5 PL-HPT with scrubber | | |
| Input parameters | | | |
| SMCR power | kW | 5500 | |
| SMCR speed | r/min | 125 | |
| Turbocharger type | High eff. | | |
| NOx emission compliance | Tier II | | |
| Propeller type | Fixed pitch propeller | | |
| Cooling system | Central | | |
| Hydraulic power supply | Mechanical | | |
| Hydraulic control system | Unified | | |
| Constants | | | |
| LCV for fuel oil | [kJ/kg] | 42700 | |
| Steam pressure | [bar] | 7 | |
| ISO | Air | 25 | Water 25 |

| Load | Power | Speed | SFOC | | Exh.gas amount | Exh.gas temp |
|-------|-------|-------|-------|--|----------------|--------------|
| %SMCR | kW | r/min | g/kWh | | kg/s | °C |
| 100 | 5500 | 125 | 176 | | 11.9 | 255 |
| 95 | 5225 | 122.9 | 174.7 | | 11.3 | 244 |
| 90 | 4950 | 120.7 | 173.6 | | 10.8 | 235 |
| 85 | 4675 | 118.4 | 171.5 | | 10.3 | 229 |
| 80 | 4400 | 116 | 169.6 | | 9.9 | 225 |
| 75 | 4125 | 113.6 | 168.7 | | 9.4 | 224 |
| 70 | 3850 | 111 | 167.8 | | 9 | 224 |
| 65 | 3575 | 108.3 | 167.3 | | 8.5 | 225 |
| 60 | 3300 | 105.4 | 167.9 | | 8 | 228 |
| 55 | 3025 | 102.4 | 168.6 | | 7.4 | 232 |
| 50 | 2750 | 99.2 | 169.5 | | 6.9 | 238 |
| 45 | 2475 | 95.8 | 170.6 | | 6.2 | 246 |
| 40 | 2200 | 92.1 | 171.7 | | 5.6 | 255 |
| 35 | 1925 | 88.1 | 173.1 | | 4.9 | 264 |
| 30 | 1650 | 83.7 | 174.1 | | 5.1 | 221 |
| 25 | 1375 | 78.7 | 176.1 | | 4.3 | 227 |
| 20 | 1100 | 73.1 | 178.1 | | 3.7 | 223 |
| 15 | 825 | 66.4 | 182.1 | | 3.1 | 207 |
| 10 | 550 | 58 | 192.1 | | 2.6 | 169 |

| Tropical | Air | 45 | Water | 36 | | |
|----------|-------|-------|-------|----|----------------|--------------|
| Load | Power | Speed | SFOC | | Exh.gas amount | Exh.gas temp |
| %SMCR | kW | r/min | g/kWh | | kg/s | °C |
| 100 | 5500 | 125 | 177.8 | | 11 | 289 |
| 95 | 5225 | 122.9 | 176.5 | | 10.5 | 277 |
| 90 | 4950 | 120.7 | 175.4 | | 10 | 267 |
| 85 | 4675 | 118.4 | 173.3 | | 9.6 | 261 |
| 80 | 4400 | 116 | 171.4 | | 9.2 | 257 |
| 75 | 4125 | 113.6 | 170.5 | | 8.7 | 256 |
| 70 | 3850 | 111 | 169.6 | | 8.3 | 256 |
| 65 | 3575 | 108.3 | 169.1 | | 7.9 | 257 |
| 60 | 3300 | 105.4 | 169.7 | | 7.4 | 260 |
| 55 | 3025 | 102.4 | 170.4 | | 6.9 | 265 |
| 50 | 2750 | 99.2 | 171.3 | | 6.3 | 271 |
| 45 | 2475 | 95.8 | 172.4 | | 5.8 | 279 |
| 40 | 2200 | 92.1 | 173.6 | | 5.2 | 289 |
| 35 | 1925 | 88.1 | 174.9 | | 4.6 | 298 |
| 30 | 1650 | 83.7 | 175.9 | | 4.7 | 253 |
| 25 | 1375 | 78.7 | 177.9 | | 4 | 259 |
| 20 | 1100 | 73.1 | 179.9 | | 3.4 | 255 |
| 15 | 825 | 66.4 | 184 | | 2.8 | 238 |
| 10 | 550 | 58 | 194.1 | | 2.4 | 198 |

| Specified | Air | 10 | Water | 10 | | |
|-----------|-------|-------|-------|----|----------------|--------------|
| Load | Power | Speed | SFOC | | Exh.gas amount | Exh.gas temp |
| %SMCR | kW | r/min | g/kWh | | kg/s | °C |
| 100 | 5500 | 125 | 173.8 | | 12.4 | 229 |
| 95 | 5225 | 122.9 | 172.6 | | 11.8 | 219 |
| 90 | 4950 | 120.7 | 171.5 | | 11.2 | 210 |
| 85 | 4675 | 118.4 | 169.4 | | 10.8 | 204 |
| 80 | 4400 | 116 | 167.6 | | 10.3 | 201 |
| 75 | 4125 | 113.6 | 166.7 | | 9.8 | 200 |
| 70 | 3850 | 111 | 165.8 | | 9.3 | 199 |
| 65 | 3575 | 108.3 | 165.3 | | 8.8 | 201 |
| 60 | 3300 | 105.4 | 165.9 | | 8.3 | 203 |
| 55 | 3025 | 102.4 | 166.6 | | 7.7 | 207 |
| 50 | 2750 | 99.2 | 167.5 | | 7.1 | 213 |
| 45 | 2475 | 95.8 | 168.5 | | 6.5 | 220 |
| 40 | 2200 | 92.1 | 169.7 | | 5.8 | 229 |
| 35 | 1925 | 88.1 | 171 | | 5.1 | 237 |
| 30 | 1650 | 83.7 | 172 | | 5.3 | 197 |
| 25 | 1375 | 78.7 | 173.9 | | 4.5 | 202 |

ATTACHMENT

Ship Comparison Result

| | Typical bulk carrier | Ballast-Free bulk carrier | Comments |
|--|----------------------|---------------------------|---|
| Endurance (miles) | 11000 | | |
| Service speed | 13 knot | | |
| Installed engine Nominal MCR (kw) | 5500 | | |
| Maximum payload (tons) | 20000 | | |
| Cargo carried per annum (tons) | 236,291 | | |
| Required service in ballast condition (kw) | 3458.5 | 3912 | |
| Specific fuel consumption (g/(kw*hour)) | 167.3 | 168.7 | |
| Hull steel weight (tons) | 4920 | 5564 | |
| Annual heavy fuel cost | 41,107,067.400 | 47,984,794.200 | Assuming a fuel price (IFO380) of 6,790,000,-/ton. |
| Hull steel cost | 12,300,000,000 | 13,910,000,000 | Assuming a steel price 2,500,000,-/ton. |
| Changes in capital cost | | | |
| Additional hull steel cost | + 1,610,000,000 | | |
| Gates Valve (20 @ 280,000,000 each) | + 5,600,000,000 | | Typical price for a 40" gate plus ff |
| Elimination of ballast tank Valve | - 172,620,000 | | 14 @ \$1000 each |
| Elimination of BWTS Installation Cost | - 258,930,000 | | Elimination of Installation of Filtration and UV |
| Elimination of BWTS annual cost | - 158,235,000 | | Annual operational and Maintenance Cost |
| Additional welding cost | + 120,000,000 | | Additional welding due to raise of inner bottom (material + |
| Elimination of ballast treatment system | - 12,083,400,000 | | Elimination of filtration and UV equipment. |
| Changes in operating cost | | | |
| Net capital cost change | -5,184,950,000 | | |
| Net operating cost change per annum | +6,869,491,800 | | |

Preliminary
Overview of
Global
Ballast Water
Treatment
Market

ATTACHMENT

Voyage Planning

Voyage Planning

| No | Departure | Destination | Distance | | Vs |
|----|-----------|-------------|----------|--------|----|
| | | | Nm | Km | |
| 1 | Jakarta | Perth | 1763 | 3268.6 | 13 |
| 2 | Perth | Jakarta | 1763 | 3268.6 | 13 |

Remarks : 1 nm = 1.854 km

Source : sea distance.org

Speed Planning

Jakarta - Perth

| Start | Manouver max 5 mile VS1 = 30-40% Vs | Sailing (Main Distance) VS2 = 100%Vs | Weather Manouvering (30% Dist) VS3 = 60-70% Vs | Manouver max 5 mile VS1 = 30-40% Vs | Berthing |
|----------|--|---|---|--|----------|
| Distance | 5 | 1224.1 | 528.9 | 5 | Berthing |
| V | 5.2 | 13 | 9.1 | 5.2 | Berthing |
| Time | 0.962 | 94.162 | 58.121 | 0.962 | Berthing |

| | | |
|--------------|---------|----|
| Moving Time | 154.205 | hr |
| Loading Time | 24 | hr |
| Total Time | 178.205 | hr |


Perth - Jakarta

| Start | Manouver max 5 mile VS1 = 30-40% Vs | Sailing (Main Distance) VS2 = 100%Vs | Weather Manouvering (30% Dist) VS3 = 60-70% Vs | Manouver max 5 mile VS1 = 30-40% Vs | Berthing |
|----------|--|---|---|--|----------|
| Distance | 5 | 1224.1 | 528.9 | 5 | Berthing |
| V | 5.2 | 13 | 9.1 | 5.2 | Berthing |
| Time | 0.962 | 94.162 | 58.121 | 0.962 | Berthing |

Moving Time 154.205 hr
 Loading Time 24 hr
 Total Time 178.205 hr

Secure | <https://sea-distances.org>

SEA-DISTANCES.ORG Ports Distances Voyage Calculator Advertise Contact us



Port of Departure: Country: Indonesia, Port: Jakarta

Port of Arrival: Country: Indonesia, Port: Belawan

Vessel speed, knots: 10

Calculate

Result

Direct way

Distance: 861 nautical miles

Vessel speed: 10 knots

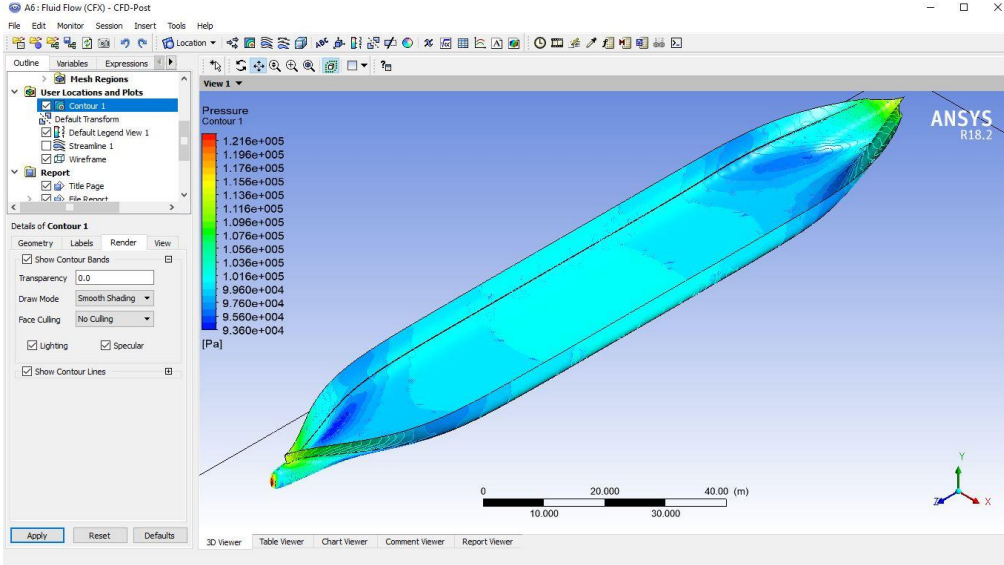
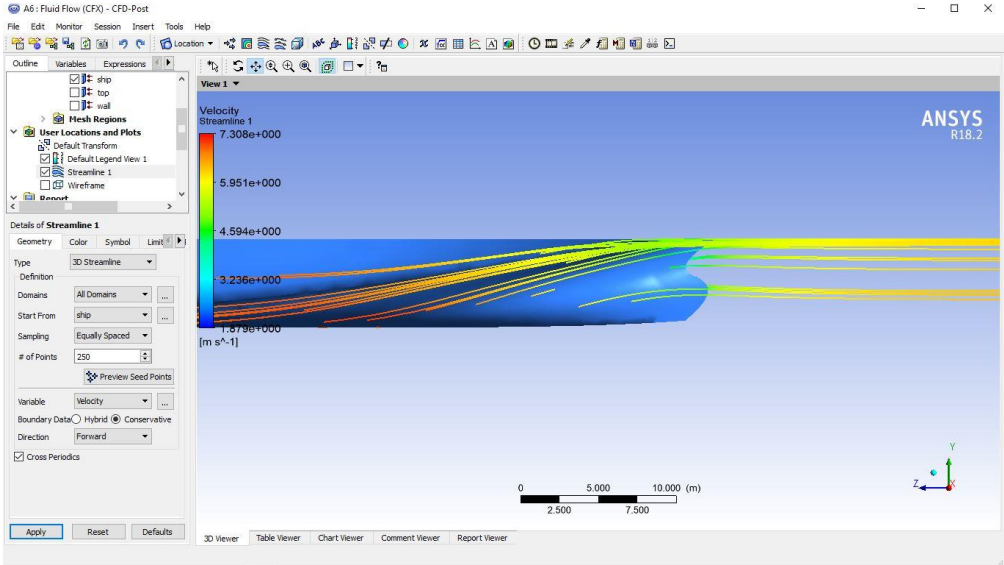
time: 3 days 14 hours

SUMMARY

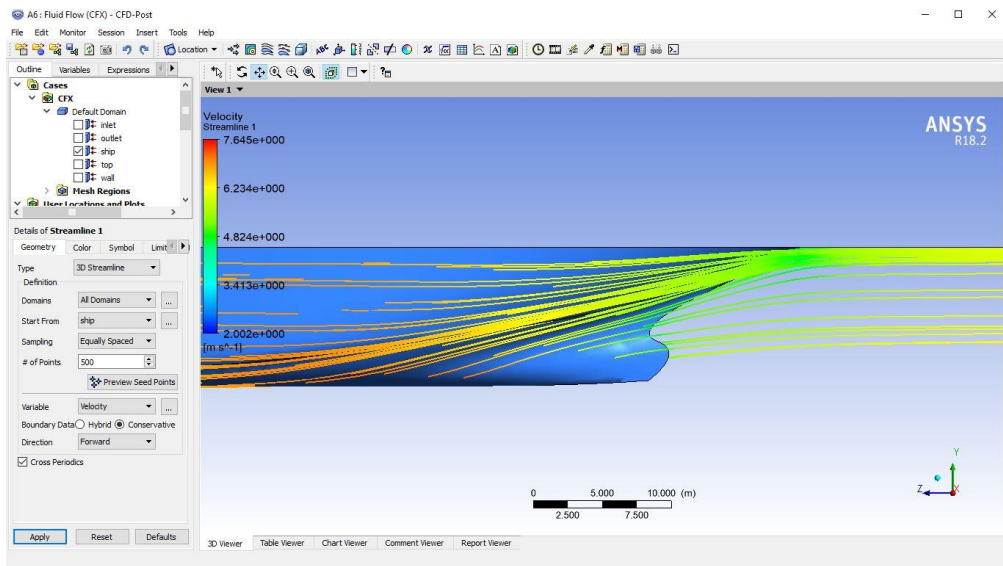
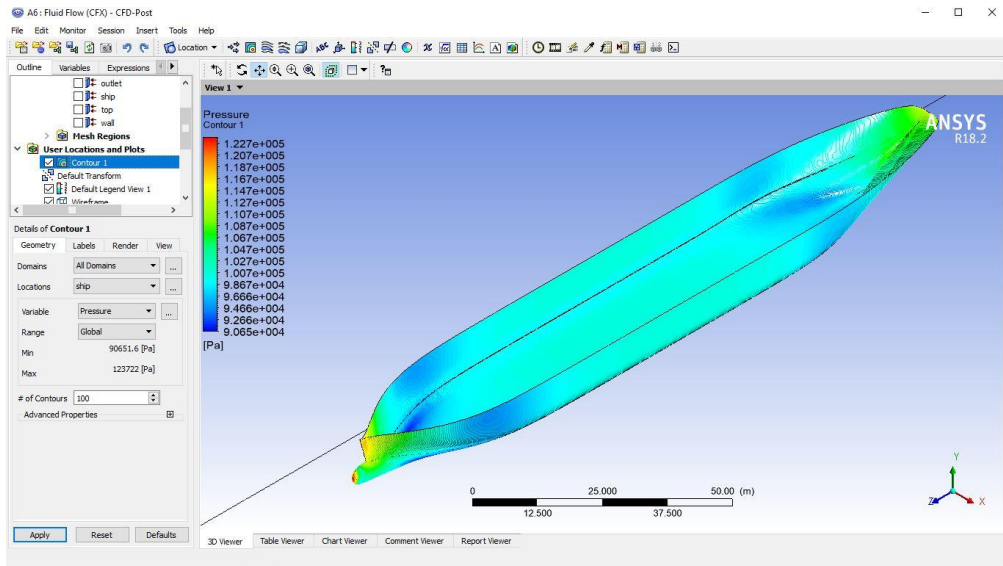
| | | |
|-----------------------------|---------|-----|
| Total Voyage | 308.411 | hr |
| Total Voyage+Loading/Unload | 356 | hr |
| | 14.9 | day |

ATTACHMENT

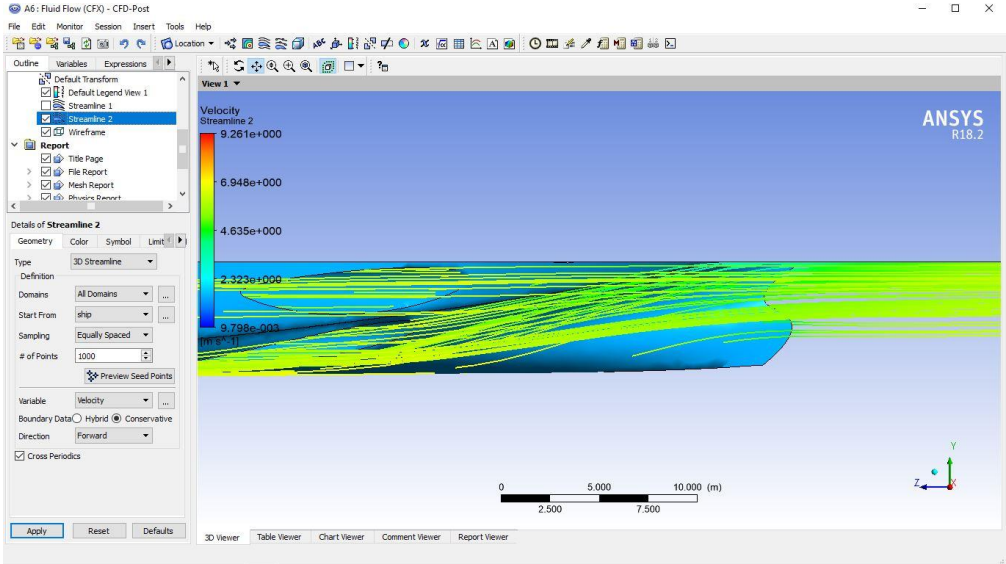
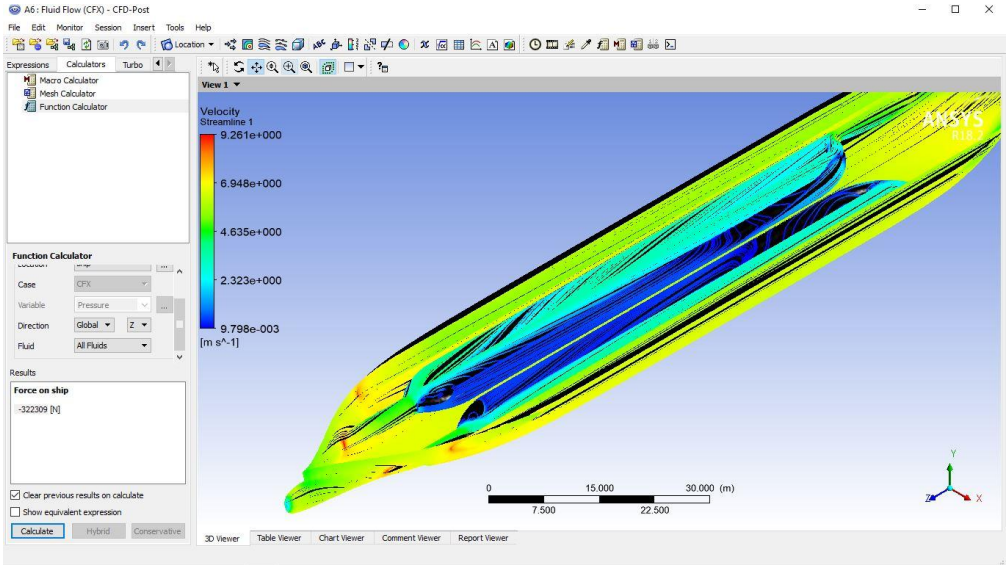
Low Draught Condition

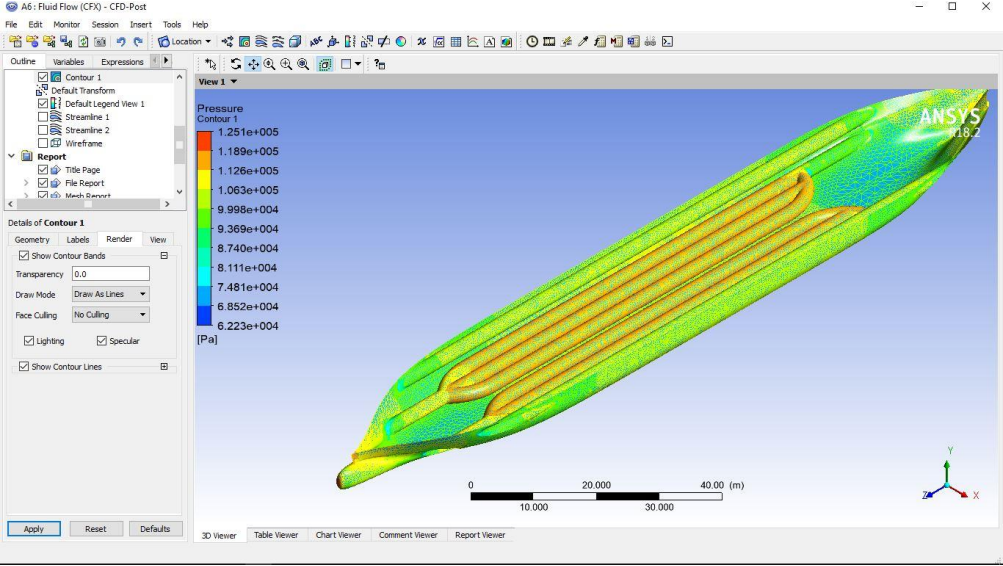


Full Draught Condition

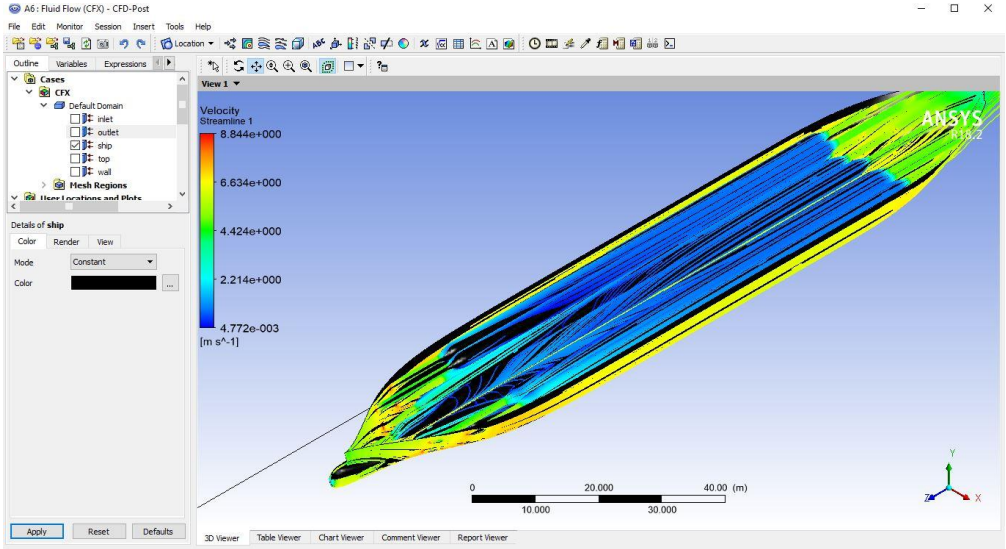
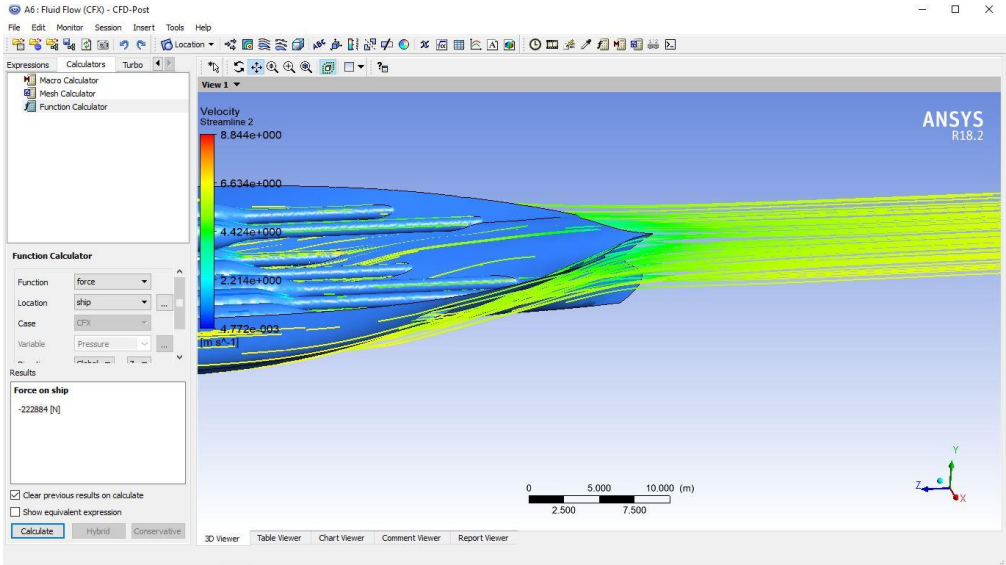


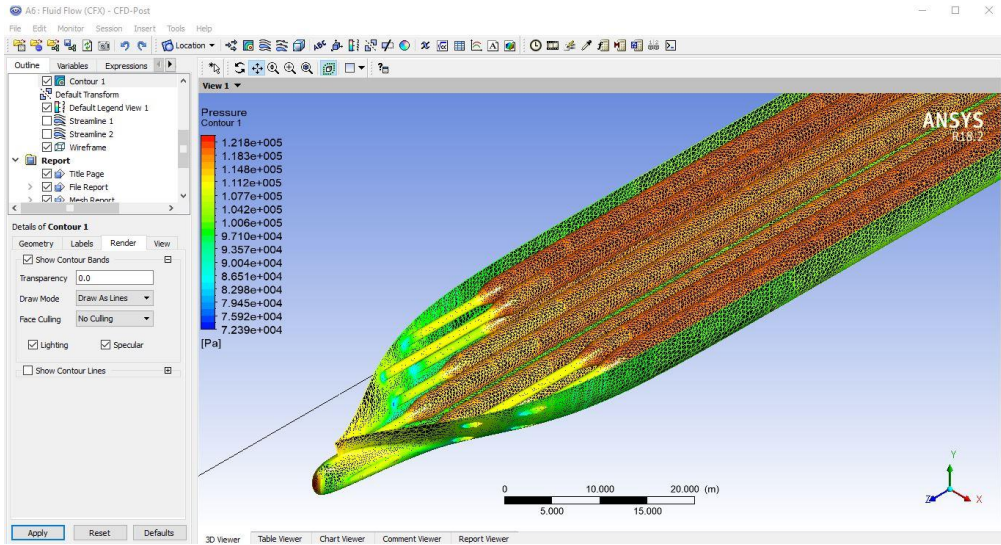
Model A



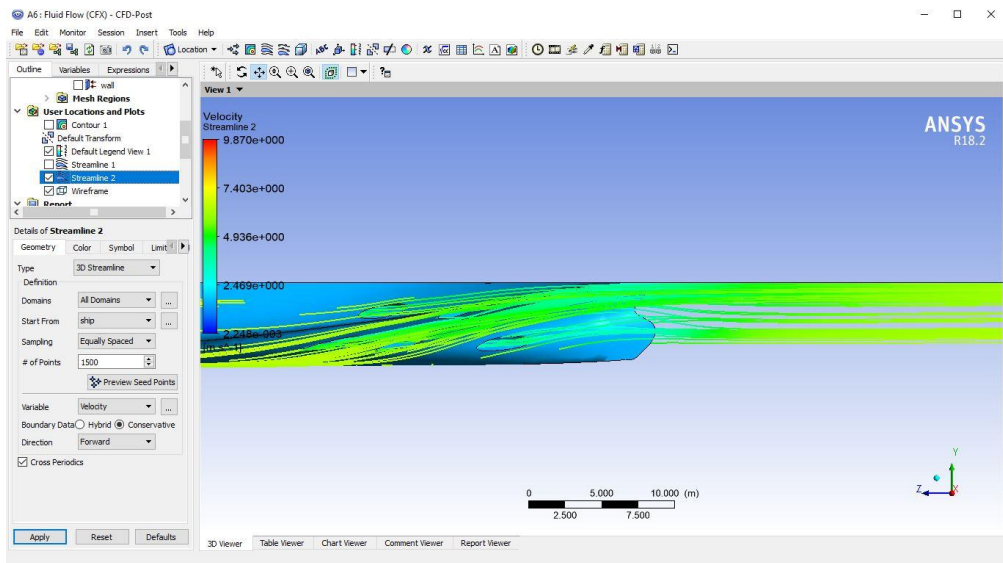
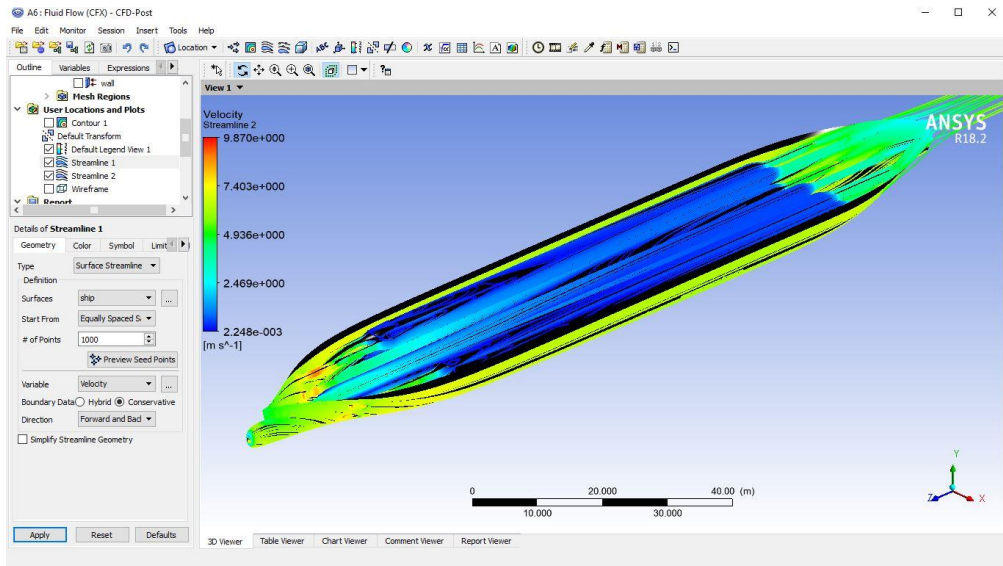


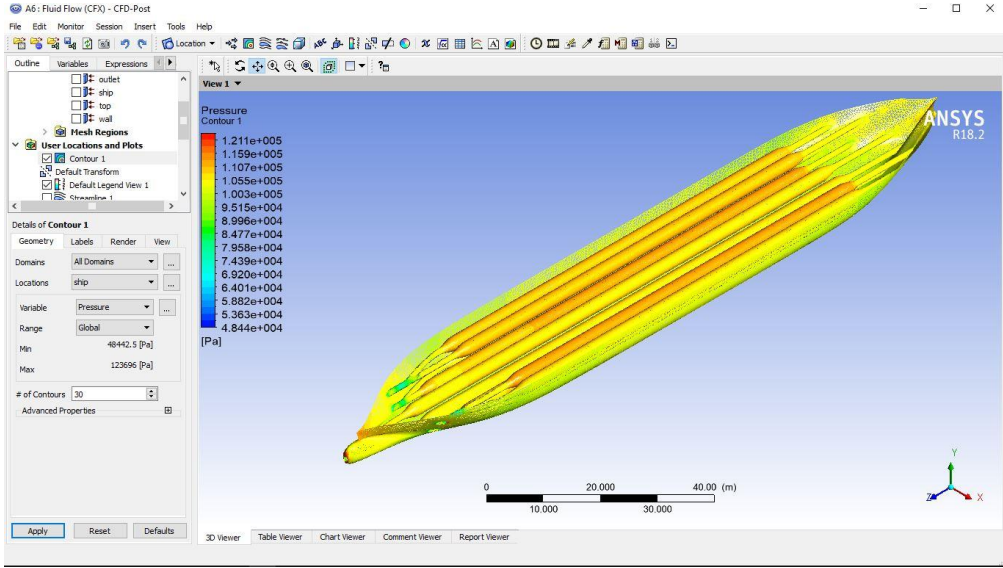
Model B





Model C





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