BACHELOR THESIS & COLLOQUIUM – ME184841

PERFORMANCE ANALYSIS OF SHELL AND TUBE AS A PREHEATER FUEL FOR BIODIESEL

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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2019

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ANALISA KINERJA DARI SHELL AND TUBE SEBAGAI PEMANAS BAHAN BAKAR PADA BIODIESEL

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APROVAL SHEET

PERFORMANCE ANALYSIS OF SHELL AND TUBE AS A PREHEATER FUEL FOR BIODIESEL

BACHELOR THESIS

Submitted to Comply One of The Requirements to Acquire a Bachelor of
Engineering Degree in Double Degree of Marine Engineering Program
Department of Marine Engineering - Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Department of Marine Studies
Hochschule Wismar, University of Applied Sciences

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SURABAYA
JULI, 2019

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APPROVAL FORM

PERFORMANCE ANALYSIS IF SHELL AND TUBE AS PREHEATER FUEL FOR BIODIESEL

BACHELOR THESIS

Submitted as one of Requirements to obtain Bachelor Degree in Engineering
on
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Institut Teknologi Sepuluh Nopember

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DECLARATION OF HONOR

With signed below, I declare that:

This thesis has been written and developed independently without any plagiarism act. All contents and ideas drawn directly from internal and external sources are indicated such as cited sources, literatures, and other professional sources.

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Surabaya, July 3, 2019

Hafid Rafi Noviantoro

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Abstract

Diesel engines are widley used by ships because of great torque, high combustion efficiency, and high durability. Although diesel engine efficienly consuming fuel, the fuel reserves from fossil are decreasing. Therefore alternative fuel is needed. Biodiesel is one solution to solve insufficien fuel in the future. Biodiesel may come from vegetable or animal. Most common biodiesel come from vegetable such as, palm oil, jatropha oil, soybean oil, etc. In this research biodiesel preheated before enters the engine due to high viscoity. Instead using electric heater, waste heat from cooling water engine used to heated the fuel until 70ºC. Diesel engine used in this reasearch is Mitsubushi 4D30. The heat from cooling water transfered using shell and tube heat exchanger. This research manually calculating to find size and simulating the shell and tube heat exchanger used CFD simulation. The result obtained with size of tube outside diameter 0.375 inch, shell outside diameter 2.25 inch and length of heat exchanger is 270 mm, show that heat from cooling water engine able to heated biodiesel from 30 ºC untill 70 ºC.

Keywords: Biodiesel, Heat Exchanger, Shell and Tube, Waste Heat Recovery, CFD Simulation

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Analisa Kinerja dari Shell and Tube Sebagai Pemanas Bahan Bakar Pada Biodiesel

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Abstrak

Mesin diesel banyak digunakan oleh kapal karena torsi besar, efisiensi pembakaran tinggi, dan daya tahan tinggi. Meskipun mesin diesel secara efisien mengkonsumsi bahan bakar, cadangan bahan bakar dari fosil menurun. Oleh karena itu diperlukan bahan bakar alternatif. Biodiesel adalah salah satu solusi untuk mengatasi kekurangan bahan bakar di masa depan. Biodiesel dapat berasal dari sayuran atau hewan. Biodiesel yang paling umum berasal dari sayuran seperti, minyak kelapa sawit, minyak jarak, minyak kedelai, dll. Dalam penelitian ini biodiesel dipanaskan terlebih dahulu sebelum memasuki mesin karena viskositas yang tinggi. Alih-alih menggunakan pemanas listrik, buang panas dari mesin air pendingin yang digunakan untuk memanaskan bahan bakar hingga 70ºC. Mesin diesel yang digunakan dalam penelitian ini adalah Mitsubushi 4D30. Panas dari air pendingin dialirkan menggunakan penukar panas shell and tube. Penelitian ini menghitung secara manual untuk menemukan ukuran dan mensimulasikan penukar panas shell and tube menggunakan simulasi CFD. Hasil yang diperoleh dengan ukuran diameter *tube* 0.375 inch, diameter *shell* 2.25 inch, dan panjang 270 mm, panas dari mesin air pendingin mampu memanaskan biodiesel dari 30 ºC hingga 70 ºC.

Kata Kunci: CFD Simulasi, Biodiesel, Heat Exchanger, Shell and Tube, Waste Heat Recovery

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PREFACE

Praise and deep gratitude, the author prays to the presence of Allah Subhanahu Wa Ta'ala, who has given His grace, mercy, guidance and His blessings, this Bachelor Thesis can be completed properly on time. Greetings and salvation may always be devoted to the Prophet Muhammad Shallallahu 'Alaihi wa Sallam.

This Bachelor Thesis with the title of **Performance Analysis of Shell and Tube as A Preheater Fuel for Biodiesel** is submitted to Comply One of The Requirements to acquire a Bachelor of Engineering Degree in Double Degree of Marine Engineering Program in Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya.

This Bachelor thesis and the success of undergraduate study program can be completed because help and support from various parties. Therefore, the authors express gratitude to the parties below, namely:

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The author realizes that the research done in this Bachelor Thesis is far from being perfection, so criticism and suggestions are very open to making better work and providing usefulness.

The author hopes that this final work can be useful for the author and for all readers in the future.

Surabaya, July 2019

Author

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CHAPTER I
INTRODUCTION

1.1 Background

Fuel engine has huge roll consumed more than 60% of fossil fuel. Fossil fuel resources is very limited, because based on theory not more than 30 years fossil fuel can be used (Semin, 2015), it makes energy management must be carried out optimally to ensure stability energy for now as well as for the future. But in fact, management energy not done optimally. Things that can be done to manage energy optimally such as using alternative energy like electric vehicle instead of internal combustion engine. Besides using alternative energy, savings and optimizing energy such as utilize waste heat from engine and conversion to biofuels. The major consumer of fossil fuel was internal combustion engine, however only 30% - 40% energy of combustion engine in the engine chamber was transformed into useful mechanical work (Hoang, 2018). The rest of energy was released as a heat to the environmental through exhaust gas and cooling water were approximately 25% - 35%. Recovering and utilizing waste heat not only reduced the toxic pollution but also increase the heat efficiency of internal combustion engines by using technology such as using turbocharger and variable valve timing or other advance combustion chamber (Aladeyleh, 2015).

An engine produced waste energy while running by combustion process, which wasted in vain into environment. In the time of engine run through sources of waste heat such as exhaust gas, cooling water, lube oil, and turbocharger. Heat that has best quality is the value not only about amount of the heat (Bhawan & Puram, 2015). In the moment engine run, there are four waste heat from the angina e such as exhaust gas, cooling water, lube oil and turbocharger. Temperature of cooling water not only the one that important to waste heat, but also mass flow rate of cooling water (Janak Rathavi, 2012). In the diesel engine can produce temperature of high temperature freshwater reaches 70-80°C. As seen in the figure 1, heat loss in diesel engine for cooling water is 25%-35% of total heat loss (Shuaijun Wang, 2018).

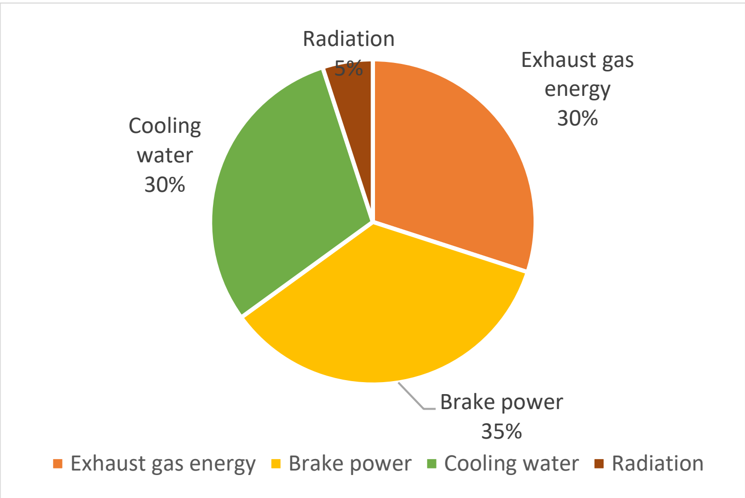

Figure 1. 1 Heat Loss Energy in Diesel Engergy

Waste heat is energy, which is generated in a process by way of fuel combustion or chemical reaction, and then “dumped” into the environment in the time of engine run through sources of waste heat such as exhaust gas, cooling water, lube oil, and turbocharger. Quality of heat is not about the amount but about its value. The idea to recover the heat from the engine are depends on the temperature of waste heat gases and the economics involved (Bhawan & Puram, 2015).

Device that use to recover waste heat which is heat exchanger. Heat exchanger is a device used to transfer heat from one fluid into another fluids. The fluids can be single or two phase and, depending on the exchanger type. Heat exchanger may be separated or in direct contact. There are four basic flow configurations such as counter flow, concurrent flow, crossflow and hybrids. One of energy sources of heat exchanger is heat from cooling water that can be used as preheated bio diesel (Thulukkanam, 2013).

Bio diesel is an alternative fuel obtained from varies sources of vegetables oils, animal fat, or waste frying oil to give the corresponding fatty acid methyl ester. The potential for biodiesel oil production in Indonesia from 6 types of biodiesel raw materials includes jatropha curcas, 557842 thousand barrels of biodiesel oil. Followed by oil palm 438876, algae 258867 thousand barrels, coconut 238455 thousand barrels, used cooking oil 45515 thousand barrels, and rubber 3989.7 thousand barrels. With biodiesel supplements, Indonesia will be able to overcome the energy crisis until 210 (Kuncahyo, et al., 2013). Bio diesel present some physicochemical or properties differences with diesel oil such as higher density, viscosity, water content, acid value and lower of flash point that can give effect to the performance and condition of engine such as atomization of combustion, injector chocking, filter gumming, stuck in piston ring and engine deposit. To avoid this happening some improvement should be taking such as preheat. Therefore, in this study will utilize waste heat from water cooling using heat exchanger to preheat bio diesel with simulation model using software engineering (Khalid, 2014).

1.2 Research Problems

Based on background mentioned above, it can be concluded some problems of this thesis are:

1. Determine what the right size shell and tube application in preheater process for biodiesel fuel?
2. Analyze how the performance of shell and tube application in preheater process for biodiesel fuel?

1.3 Research Objectives

Based on problems mention above, the objectives of this thesis are:

1. To know the right size shell and tube heat exchanger application in preheater process for biodiesel fuel
2. To know the effect of shell and tube application in preheater process for biodiesel fuel.

1.4 Research Limitations

This thesis can be focused and organized, with limitations on problem which are:

1. This thesis only focusing on waste heat from engine cooling water.
2. Type of heat exchanger used is shell and tube.
3. Calculation method used in this research is Kern Method
4. Type of fuel is using biodiesel B20 from Pertamina
5. Design modelling and flow simulating use 3D modelling and CFD Software Student License.
6. This thesis only analyzes the temperature and heat transfer coefficient of fluid flow.
7. This thesis the simulation ignores disturbance of environmental factors (Adiabatic).

1.5 Research Benefits

This thesis is expected to give benefits for the various kinds of parties. The benefits that can be obtained are:

1. Provide the right size of shell and tube based on desire temperature.
2. Provide information about effect different tube layout
3. Reducing in energy consumption for auxiliary device such as boiler or electric heater.
4. as reference for similiar research about shell and tube as a heater.

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CHAPTER II
LITERATURE STUDY

2.1. Biodiesel

Diesel engines have different ignition, emission and injection characteristic; therefore, the use of biodiesel is restricted. The treatment of biodiesel is needed to make biodiesel usable for diesel engine (Mohod, 2014). The high viscosity, density of vegetable oil interferes with injection process and leads poor fuel atomization. The viscosity of fuels has important effects on fuel droplet formation, atomization, evaporation and fuel-air mixing process, thus influencing the exhaust emission and performance parameters of the engine (Khalid, 2014).

Palm oil biodiesel has a better efficient than biodiesel produced from another vegetable oils. The lower of energy content of biodiesel make diesel engine consumed more fuel then regular diesel oil. The lowering of power can be to 5-10%, it depends on type of biodiesel, engine speeds and loads (M, et al., 2018). Semin in 2018 has done research about performance biodiesel using cotton seed oil with mixture B20 and B30 with the result performance increase compared to regular diesel oil. However, the consumption is higher (Semin, et al., 2018). Preheating process is needed for the vegetable oils. It will make viscosity reduce and making the biodiesel more likely to petroleum diesel. By reducing Viscosity make the biodiesel suitable for diesel engine because high viscosity causing fuel flow and ignition problems (McCarthy, et al., 2011).

Figure 2. 1 Jars of Biodiesels

The bio diesel is B20 which contain 80% diesel fuel and 20% CPO. The more contain of CPO then makes the density and the kinematic viscosity of the biodiesel getting high. High viscosity will make results in reduced flow rates for equal injection pressure and reduced atomization. In other condition, fuels with high viscosity has larger droplets on injection which can make poor combustion, increased exhaust smoke and emissions (R. Mohod, 2014). Preheating process involves heating of biodiesel before injection it into combustion cylinder. Biodiesel can be preheated at different temperature of 27.5°C, 40°C, 50°C, and 60°C. Heat exchanger can be used to preheat the biodiesel.

2.2. Waste Heat Recovery

Intake Waste heat is heat which is produced due to chemical reaction or fuel combustion which expelled into the environmental. This heat could still be reused for some useful and economic purpose, in this study waste heat from the cooling water will be used to preheat fuel. The amount of heat is not significant quality otherwise is its value. The way to recover the heat is relay on the temperature of the waste heat (Bhawan & Puram, 2015).

Technology of heat recovery could be reducing the operating cost while increasing energy productivity. This technology also many are already good and proven developed. Waste heat can be recovered either directly (without using a heat exchanger-e.g., recirculation) or, more commonly, indirectly (using heat exchanger). Direct heat recovery is often the cheaper option, but its use is limited by location and combination considerations. In indirect heat recovery, the two fluid streams are separated by a heat transfer surface, which can be categorized as either a passive or active heat exchanger. Passive heat exchanger requires no external energy input, while active heat exchanger do (Shewa Bhawan, 2015).

Theres are some factors that influence to waste heat recovery such as:

1. Heat quantity is how much energy useful from waste heat. Waste heat quantity are including temperature and mass flow rate of the stream.
2. Heat quality / waste heat temperature is factor that determine whether temperature of waste heat can be useful.
3. Waste stream composition is the composition of heat stream that will influence thermal conductivity and heat capacity. This composition will impact the effectiveness of heat exchanger.
4. Minimum allowed temperature is the minimum limit of temperature that permissible. It is also connected to corrosion of the material. The method that usually used is designing heat exchangers with exhaust temperature above dew point temperature.

2.3. Heat Transfer

Heat transfer is a process transfer of heat due to difference of temperature. Heat will be move from high temperature to the lower temperature. These objects could be two solids, a solid with gas or liquid. There are three process of heat can transfer such as: (Kakac, 2012)

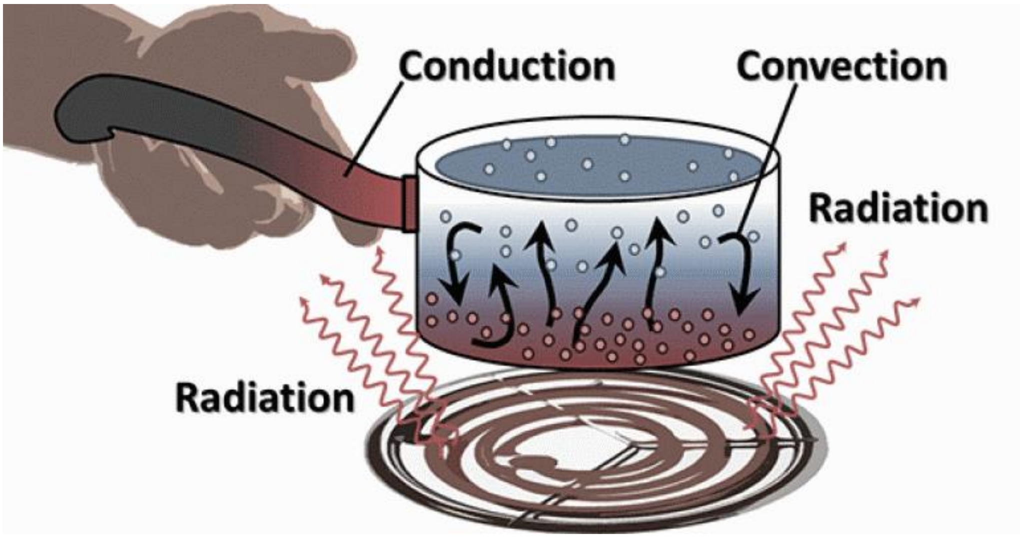

Figure 2. 2 Ilustration of Conduction, Convection and Radiation

2.3.1. Conduction

Conduction is a heat transfer process that occurs in a solid or fluid because there is different temperature between one surface with another surface. Equation of conduction also known as Fourier Law and write. Conduction is the transfer of heat through a conductive substance without the displacement of parts of the substance. Heat transfer by conduction generally occurs in solids. A substance can deliver heat called a conductor, like various metals. While a bad heat-carrying substance is called an insulator, in general non-metallic objects. An example of conduction is heating an iron rod on a flame. If one of the iron ends is heated, then the other end is held, then the longer the end that is held is getting hotter. This indicates that heat or heat moves from the heated iron tip to the iron tip held. (Kakac, 2012)

2.3.2. Convection

The movement of heat between solid surface which move or flow and also involving conduction. Heat transfer rate of convection referring to Newton`s Law of Cooling which can be write as follows. heat transfer through an intermediate substance that is accompanied by the transfer of parts of that substance. In general, the conductor used is in the form of liquid and gas. Heat moves because of the flow of substances that are heated due to differences in density (density). The mass of the heated part is smaller than the density of the part of the substance that is not heated. An example of convection is heating the water in the pan to boiling. Daily events related to heat convection are the occurrence of land winds and heat winds. (Kakac, 2012)

2.3.3. Radiation

The movement of heat between solid surface which move or flow and also involving conduction. Heat transfer rate of convection referring to Newton`s Law of Cooling which can be write as follows. Heat transfer without the need for intermediate substances. Heat emission only occurs in gas or vacuum, for example the delivery of solar heat to the earth through a vacuum. A tool used to determine the presence of heat emission called a thermoscope. Differential thermoscopes are used to investigate the nature of the emission of various surfaces. An example of radiation is the transfer of heat from sunlight to earth. Heat radiation can also occur in an electric incandescent lamp that is lit and a fire that is on. When we are around a fire that is burning, our body feels warm because of the heat radiation emitted by the campfire. (Kakac, 2012)

2.4 Heat Exchanger

The Heat exchanger is a device which used for transfer of internal thermal energy between two or more fluids at different temperature. Commonly the fluids in heat exchanger are separated by a heat transfer surface, and ideally, they do not mix. Heat transfer in heat exchanger involving convection between different fluids and conduction along the surface which separated between fluids. Common examples of heat exchangers familiar day to day use are automobile radiators, condensers, evaporators, air preheaters, and oil coolers. (Thulukkanam, 2013)

Heat transfer rate between two fluids depend on different temperature along the heat exchanger. In analysis of heat exchanger, commonly using Logarithmic Mean Temperature Difference (LMTD) which mean difference temperature between two fluids that come in into the heat exchanger. There are many variations of heat exchanger, in general heat exchangers have been divided by construction, transfer processes, degrees of surface compactness, flow arrangements, pass arrangements, phase of the process fluids, and heat transfer mechanism. (Thulukkanam, 2013)

2.5.1. Construction

According to geometry construction details, heat exchangers are classified as follows: (Thulukkanam, 2013)

2.4..1 Tubular heat exchanger

Tubular heat exchanger made from a circular tube, which the fluid flow inside the tube and the other fluid flow outside the tube. Designing tubular heat exchanger more flexible because this type of heat exchanger possible to change amount of tube, length of tube, and height of tube. Tubular heat exchanger has different type such as: (Thulukkanam, 2013). Tubular Heat Exchanger is a heat exchanger where in the construction design there is a tube component as a flow container from one fluid. In general, the fluid flowing in the tube is a high pressure fluid. So the tube material must be able to withstand high compressive loads starting from low carbon steel, Admiralty, copper, copper-nickel, stainless steel, Hastelloy, Inconel or titanium. With dimensions generally 0.625 to 1.5 inches. Tubular Heat Exchanger has several types, namely: shell and tube heat exchanger, double pipe heat exchanger and Spiral Tube Heat Exchanger.

a. Double pipe heat exchanger

One type of heat exchanger is a double pipe arrangement. This type is the simplest heat exchanger, because this pipe has a small diameter which has a large pipe installed in the middle with a packing gland system so that between the pipes formed annulus like a place of empty space that is used as the main medium carrying heat. Here small pipes are stored in the main room or core space protected by large pipes and insulation.

The double pipe heat exchanger consists of two standard metal pipes which are welded in both ends into one or connected with a sealing box. One fluid flows inside the pipe, while the second fluid flows inside the annulus between the outer pipe and the inner pipe. This type of heat exchanger can be used at small fluid flow rates and high operating pressures. Heat transfer that occurs in fluid is a convection process, while the conduction process occurs on the pipe wall. Heat flows from high temperature fluid to low temperature fluid. Double pipe heat exchanger is a heat exchanger that is used when flow rates from liquids and hot tasks are small (less than 500 kW).

b. Shell and tube heat exchanger

Shell and tube heat exchanger are the most common type of heat exchanger used in the process industries, in conventional and nuclear power stations condensers, steam generators in presurized water reactor power plants, and feed water, and they proposed for many alternative energy applications, including, ocean, thermal, ang geothermal.

The basic components in shell and tube heat exchanger are tube which inside in thel shell with varying amounts. Beside shell and tube there is baffle inside the shell. It make the fluid flow more turbulence and will increase the heat transfer cofficient in the heat exchanger.

c. Spiral tube heat exchanger

This type of heat exchanger uses tube pipes which are designed to form a spiral inside the shell side. Heat transfer in this type is very efficient, but on the side it is almost impossible to clean the inside of the tube when it is dirty.

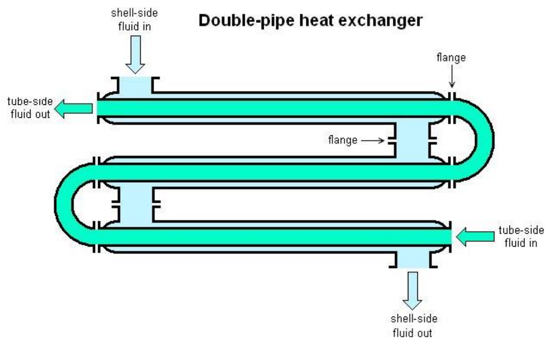

Figure 2. 3 Double Pipe Heat Exchanger

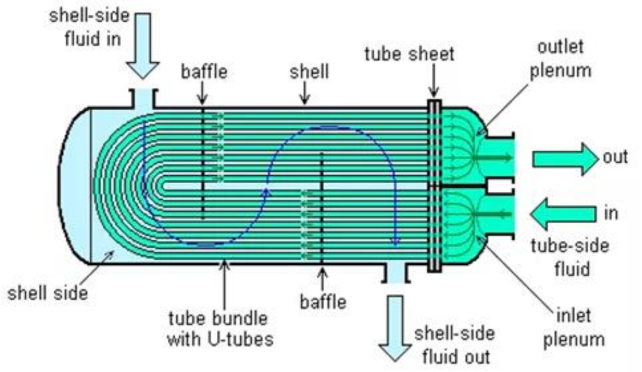

Figure 2. 4 Shell and Tube Heat Exchanger

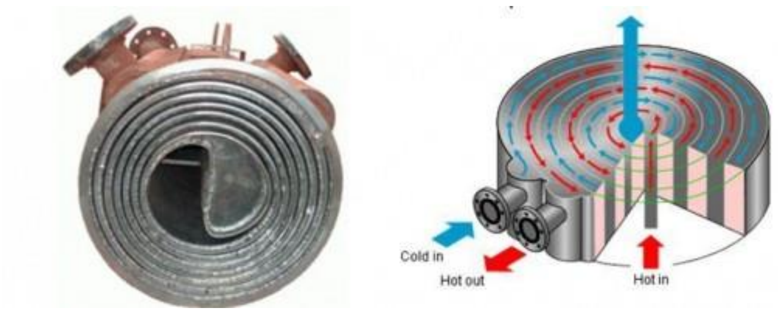

Figure 2. 5 Spiral Tube Heat Exchanger

2.4..2 Plate heat exchanger

Plate heat exchanger is made from metal plate to transfer the heat between two fluids. Plate heat exchanger are less widely used than tubular heat exchangers. This type of heat exchanger can transfer heat for combination fluids or combination (Thulukkanam, 2013).

Ordinary plate heat exchangers are made of thin plates. This plate can be either a smooth plate or corrugated plate, and can also be flat or spiral placed in a heat exchanger. The heat exchanger cannot withstand high pressure fluid, high temperature or high temperature or pressure differences. Plate heat exchangers can be classified as gasketed, welded or brazed depending on the required leakage in the heat exchanger. Plate heat exchangers can also be spiral plates, lamellae and platecoils. There are three principal groups of plate heat exchanger can be classified as follows:

a. Gasketed plate heat exchanger

This type of heat exchanger is commonly used as an alternative to shell and tube for exchange of liquid-liquid heat with low to medium pressure. This tool consists of a plate section with four channels of inlet and outlet, as well as the frame.

b. Spiral plate heat exchanger

The spiral plate (SPHE) heat exchanger is used as an alternative to Shell and Tube when the working fluid used contains solid particles such as slurry or suspension.

c. Lamella heat exchanger

can provide optimum results in the heating and cooling process in terms of control, efficiency, and product quality.

Figure 2. 6 Plate Heat Exchanger

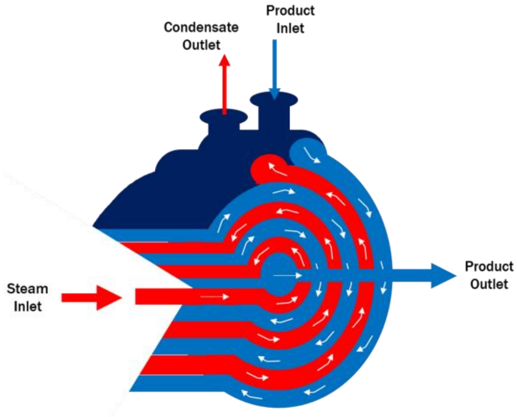

Figure 2. 7 Spiral Plate Heat Exchanger

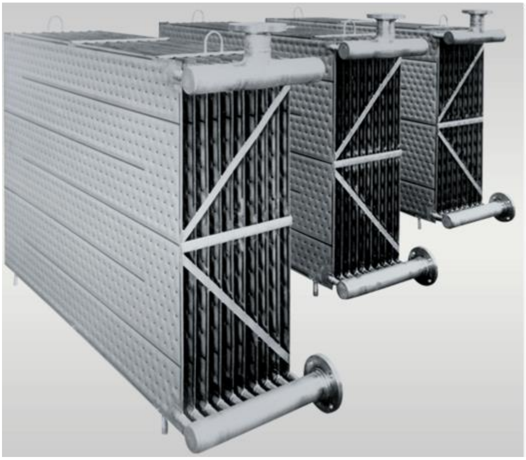

Figure 2. 8 Lamella Heat Exchanger

2.4..3 Extended surface exchanger

Extended surface exchanger using fins which attached to the primary surface. The purpose by using fins to increase heat transfer rate if the heat transfer coefficient is low and need a large heat transfer area. There are two common example of extended surface exchangers: (Thulukkanam, 2013)

a. Plate fin heat exchanger

b. Tube fin heat exchanger

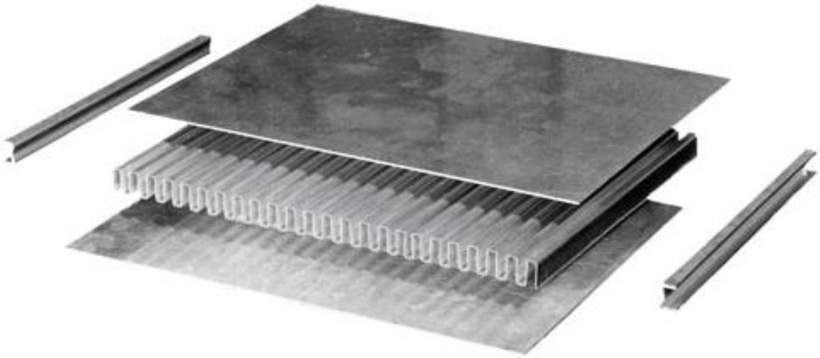

Figure 2. 9 Extended Surface Exchanger

Figure 2. 10 Tube Fin Heat Exchanger

2.5.1. Transfer Process

According to the process of heat exchanger classified as indirect contact type and direct contact type. Indirect contact is heat transfer process between two fluids separated by impervious wall. This type of heat exchanger can be classified into direct transfer type, storage type, and fluidized exchangers. The principle of heat transfer in HE this type occurs by using a wall layer that separates the two fluids with different temperatures. so that during the heat transfer process, there is no direct contact between the fluids used as heating and cooling media.

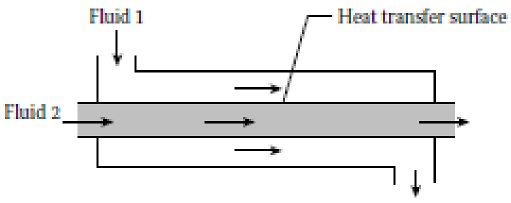

Figure 2. 11 Indirect Contact Heat Transfer Process

While direct contact is heat transfer process between two fluids without any separation or impervious wall. Direct contact often used in the mass heat transfer. There are some types of direct contact heat exchanger include immiscible fluid exchanger, gas-liquid exchangers, and liquid-vapor exchanger (Thulukkanam, 2013).

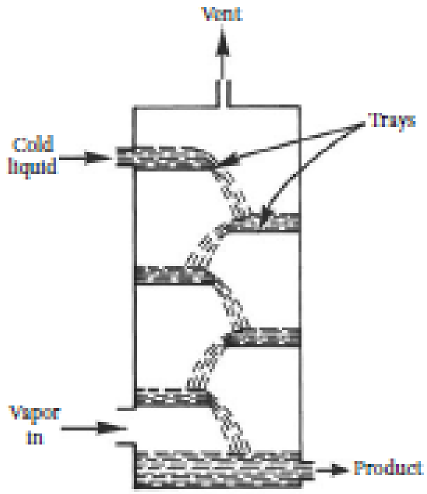

Figure 2. 12 Direct Contact Heat Transfer Process

2.5.1. Flow Arrangement

The basic flow arrangement can be classified into 3 types which are Parallel flow, Counter flow, and Cross flow. The selection of which flow arrangement is dependent upon required exchanger effectiveness, fluid flow, allowable thermal stresses, temperature levels, and other design criteria. The meaning of parallel flow where the fluids in heat exchanger flow in the same direction.

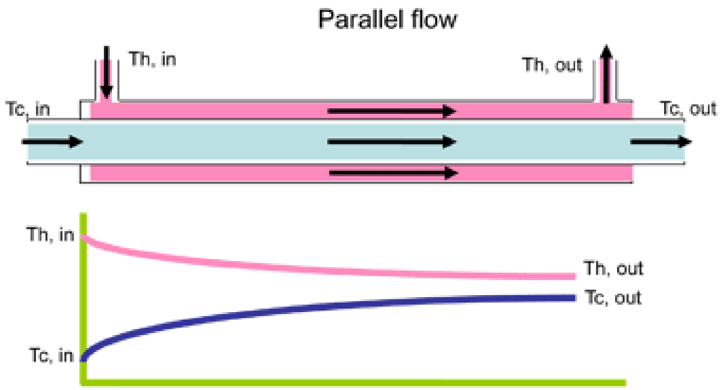

Figure 2. 13 Parallel Flow

While counter flow has the opposite direction between fluids.

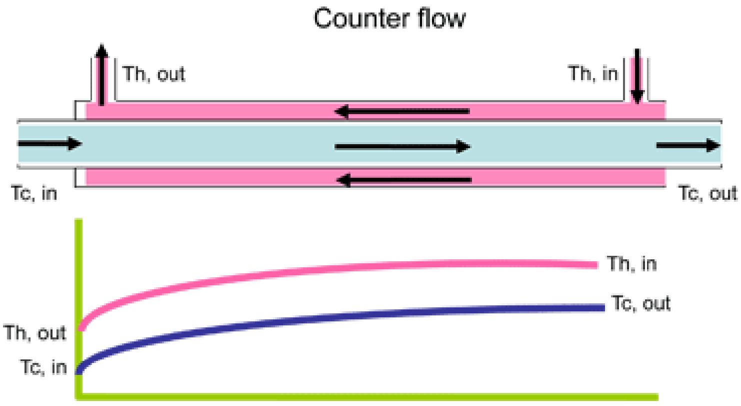

Figure 2. 14 Counter Flow

Cross flow where two fluids flow in heat exchanger has perpendicular or cross flow. (Thulukkanam, 2013)

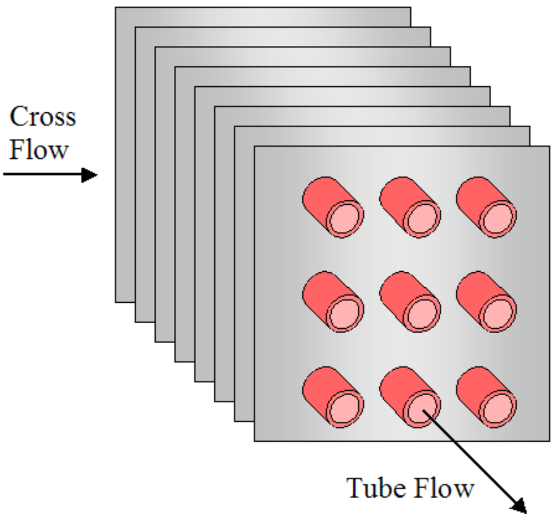

Figure 2. 15 Cross Flow

2.5 Shell and Tube Selection

In this final project, shell and tube is used to transfer the heat from one liquid into another. This type of heat exchanger has flexibility for any requirements, reliable for many services and can be worked in high pressures. Standards used for selection shell and tube is TEMA (Tubular Exchanger Manufacturers Association). Theres are some that must be considered in the selection of shell and tube such as, shell type, tube arrangement, baffle spacing and flow direction.

2.5.1. Shell Types

Theres are various type for shell based on TEMA standard as shown in figure. The most common used for shell type is E-shell. This type of shell has simplicity at design and low cost. There is only one inlet and on outlet on other side of shell, it is also known as single pass (Kakac, 2012).

Figure 2. 16 Logo of TEMA

A pure counterflow can increase effective temperature difference. The type of shell that can achieved is F-shell. Different with E-shell, in this type of shell has two passes with longitudinal baffle. The pressure drop in this type is much higher than E-shell (Kakac, 2012).

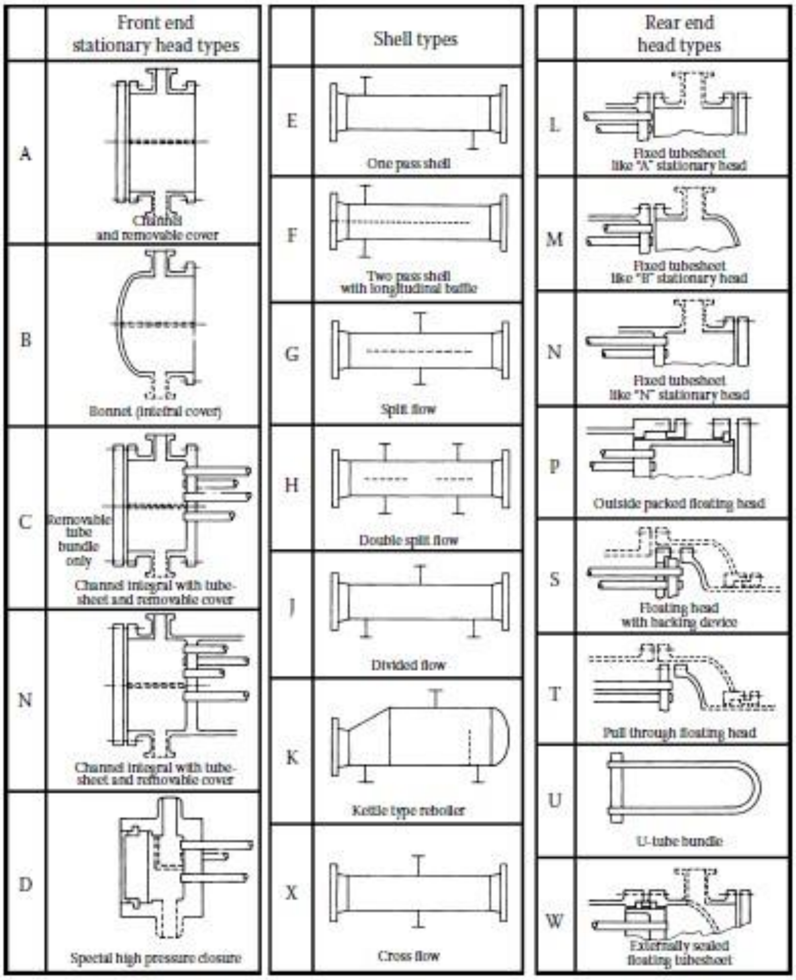

Figure 2. 17 Standard Shell Type by TEMA

2.5.2 Tube Arrangement

Tubes are fabricated from varietty of material such as, aluminum bronze, steel, copper, brass, muntz metal, and steinless steel. Size of outside diameter of tube is the actual outside diameter in inches. The thickness for tube is very strict tolerance. BWG (Brimingham Wire Gage) is provide wall thickness of the tube (Kern, 1983).

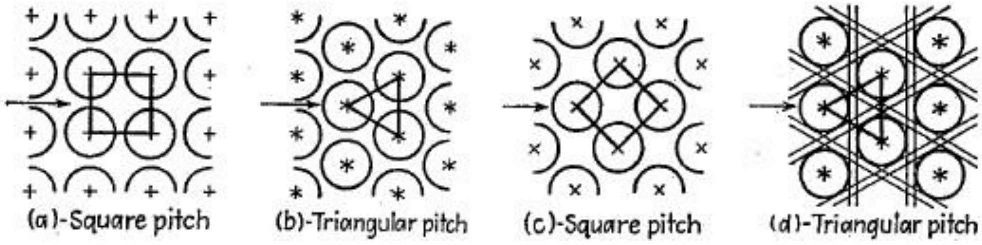

Figure 2. 18 Tube Layout Arrangement

Arrangement of tube cannot drill too close. It will make the structure of tube is weak. There must be a clearance or ligament. The pitch of tube has two type which, square pattern and triangular pattern as shown in figure. The square pitch has avantages easy to clean than triangular pitch and lower of pressure drop. In this final project square pitch is chosen due to characteristics of lquid flow in shell side. Tube pitch, Pt, is usually chosen with pitch ratio, Pt/do, between 1.25 and 1.5 (Kern, 1983).

2.5.3 Baffle Types and Geometry

Baffle in shell and tube heat exchanger has two main functions which include, to support the tubes to make structure rigid and make heat transfer is high (Kakac, 2012). Baffle will maintain turbulent flow to make higher heat transfer coefficient. This causes considerable turbulence even only small quantity of liquid flows through the shell (Kern, 1983).

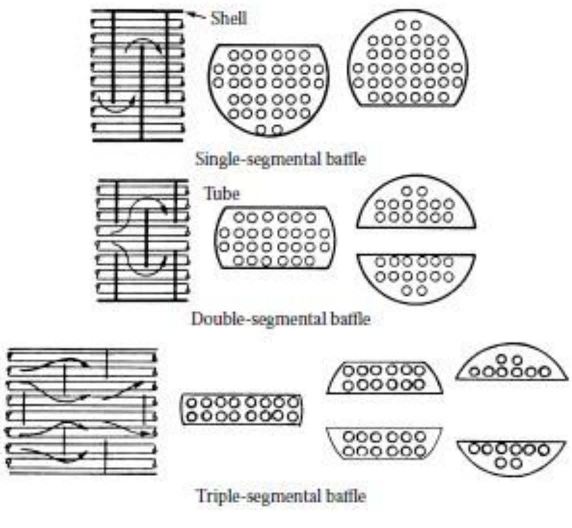

Figure 2. 19 Baffle Type and Geometry

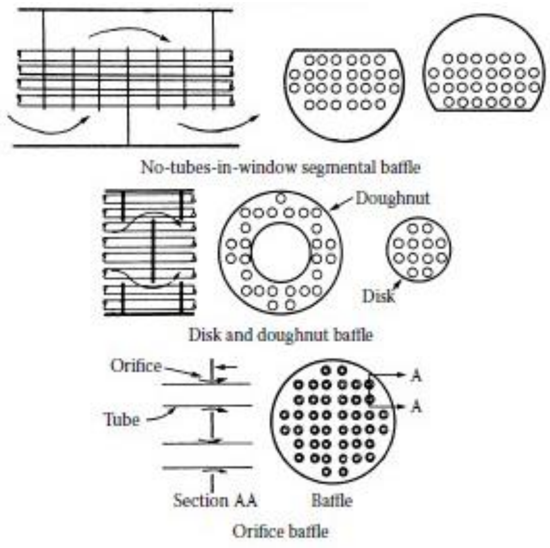

Figure 2. 20 Baffle Type and Geometry

Theres are variety type of baffle as shown in figure. The most common type used is single segmental and double segmental. The baffle spacing need to consider properly. The baffle spacing is usually somewhere 0.4 and 0.6 of the shell diameters and for segmental baffle cut of are generally 75% of the inside diameter of shell (Kakac, 2012).

There are number of alternatives for selecting heat exchanger. The most important criteria of fluids to be handled, operating pressures and temperatures, heat duty and cost. Operation conditions for heat exchanger are various in wide range, and spectrum of demand to design, all of this must be considered to selecting heat exchanger. There are some points must be considered: (Thulukkanam, 2013)

- Material of construction
- Operating pressure and temperature, temperature program, and temperature driving force
- Flow rates
- Flow arrangements
- Performance parameters
- Fouling tendencies
- Types and phases of fluids
- Maintenance, inspection, cleaning, extension, and repair possibilities

2.6 Shell and Tube Calculation

There is some calculation needed to determine the heat exchanger:

a. Heat duty

The equation to determine heat that can be transferred from hot fluid to cool fluid in the heat exchanger: (Kakac, 2012)

$$\mathrm{Q} = \mathrm{mh.Cp.}\Delta T \quad (1)$$

b. Logarithmic Mean Temperature Difference (LMTD)

Difference temperature between two fluids that come in into the heat exchanger, the equation can be write: (Kakac, 2012)

$$LMTD = \frac{\Delta th - \Delta tc}{ln\frac{\Delta th}{\Delta tc}} \quad (2)$$

b. Flow area

Flow area is area which flow by each fluid. This can be calculated by following this equation: (Kakac, 2012)

- Hot fluid

$$\mathrm{as} = \frac{\mathrm{IDs.C.B}}{144\ \mathrm{Pt}} \quad (3)$$

- Cold fluid

$$\mathrm{at} = \frac{\mathrm{Nt.At}}{144\ \mathrm{n}} \quad (4)$$

c. Mass flow rate

Mass flow rate can be calculated by bay following this equation: (Kakac, 2012)

- Hot fluid

$$\mathrm{Gs} = \frac{\mathrm{ms}}{\mathrm{as}} \quad (5)$$

- Cold fluid

$$\mathrm{Gt} = \frac{\mathrm{mt}}{\mathrm{at}} \quad (6)$$

d. Reynold number

Reynold number can be found by following this equation: (Kakac, 2012)

- Hot fluid

$$\text{Res} = \frac{De.GS}{\mu} \quad (7)$$

- Cold fluid

$$\text{Ret} = \frac{IDt.Gt}{\mu} \quad (8)$$

e. Heat transfer coefficient
Heat transfer coefficient can be calculated by following this equation: (Kakac, 2012)

$$\frac{hi}{Øt} = \partial\text{H x}\frac{K}{IDt}Pr^{\frac{1}{3}} \quad (9)$$

f. Temperature on tube wall
Temperature on tube wall can be calculated by following this equation: (Kakac, 2012)

$$\text{tw} = \text{tc} + \frac{h/_{\varphi}S}{\frac{hio}{_{\varphi}t} + \frac{ho}{_{\varphi}S}}(\text{Tc} - \text{tc}) \quad (10)$$

g. Viscosity fluid ratio
Viscosity fluid ration can be calculated by following this equation: (Kakac, 2012)

$$_{\varphi}\text{s} = \frac{\mu}{\mu w} \quad (11)$$

h. Pressure drops
Pressure drop is the maximum reduction in pressure allowed in a heat exchanger when a fluid passes through it. The pressure drop will be greater if the value of the fouling factor increases. (Kakac, 2012)

$$\Delta\text{Ps} = \frac{f.Gs^2(N+1)}{5{,}22\ x\ 10^{10}.Dc.SG\ Øs} \quad (12)$$

2.7 Computational Fluid Dynamics

Computational fluid dynamics (CFD) is a subsidiary method of fluid mechanics used numerical analysis and data structures to solve and analyze any problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. The goal of the field of computational fluid dynamics is to understand the physical event that occur in the flow of fluids around and within designated objects. These events are related to the action and interaction of phenomena such as dissipation, diffusion, convection, shock waves, slip surface, boundary layers, and turbulence.

In the simulation process, there are three steps that must be done, there are pre-processing, solving and post-processing.

1. Pre-Processor

Pre-processor is the initial stage in Computational Fluid Dynamic (CFD) which is the stage of data input that includes the determination of domain and boundary condition. At this stage, meshing is also done, where the analyzed object is divided into the number of specific grids.

2. Processor

The next step is the processor stage. At this stage, is done the process of calculating data that has been entered using iterative related equations until the results obtained can reach the smallest error value.

3. Post Processor

The last step is the post processor stage, the results of the calculations at the processor stage will be displayed in pictures, graphs and animations.

Regardless of what the numerical errors are called, if their effects are not thoroughly understood and controlled, they can lead to serious difficulties, producing answers that represent little, if any, physical reality.

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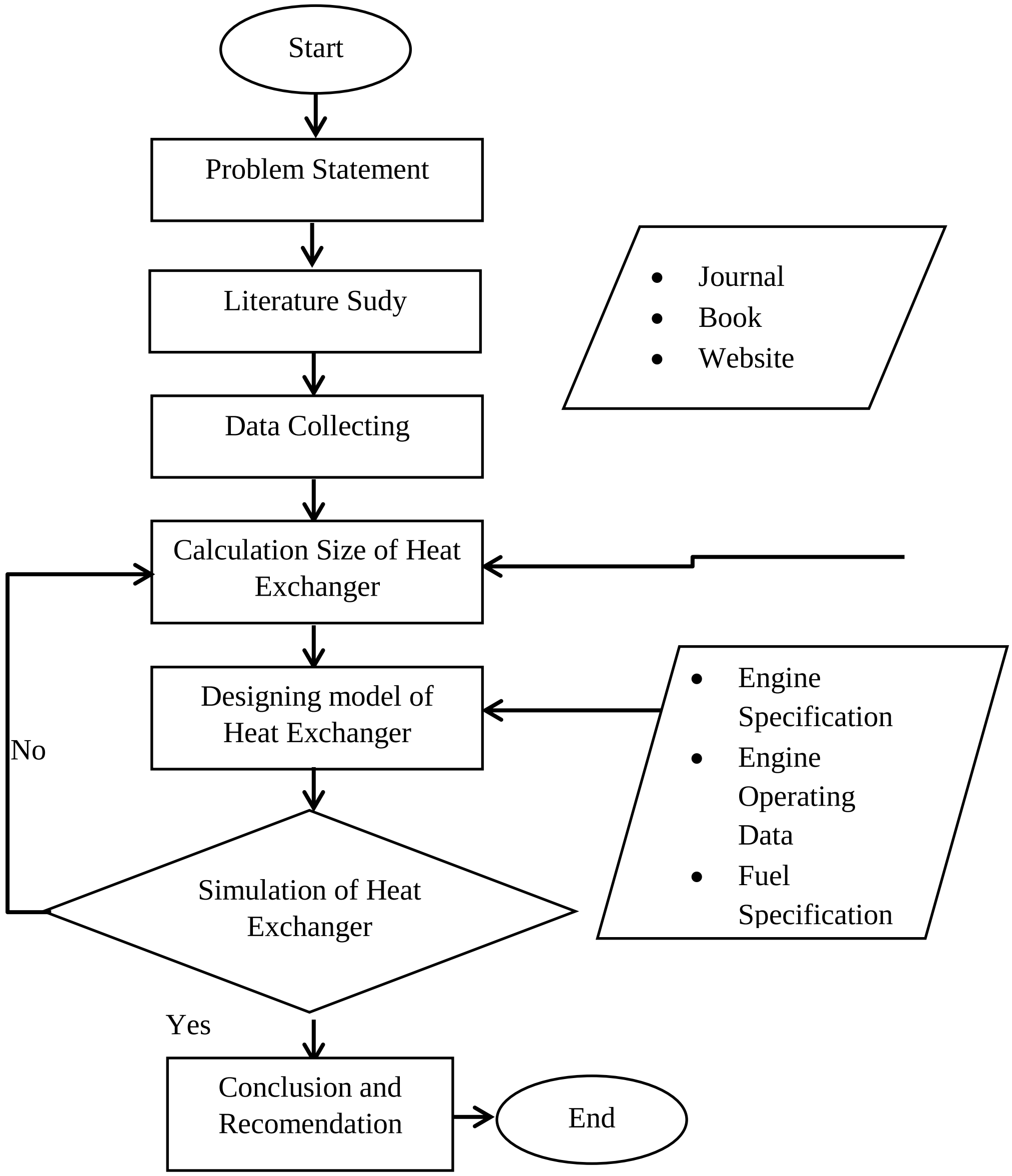
CHAPTER III
METHODOLOGY

Methodology represents of the stages from start to finish the thesis. The methodology of this thesis cover all the activity that supports the completion of this thesis. The stages of this methodology are as follows as flowchart below**.**



Explanation of the stages of this methodology flowchart is as follows:

3.1 Problem Statement

This final project will start determining the problem that related with the topics. The problems will be discussed are how to utilize waste heat from diesel engine to preheat biodiesel and how characteristics biodiesel such as viscosity and density after preheating.

3.2 Literature Review

Literature review will help author in conducting final project by studying theories regarding problems in chapter 1. The theories used in this research sources from books, journals, and trusted website. This research mostly refers to the literature about biodiesel specifically B20 characteristics such as viscosity and density. The other literatures also learn about designing heat exchanger or preheater, in this case heat exchanger will be used is shell and tube. The literature review about heat exchanger also include calculation the of heat exchanger such as LMTD, heat duty, mass flow, etc.

3.3 Collecting Data

Data that will be used in this research are engine specification, engine operating data, and fuel characteristic. In this study, biodiesel was heated by using cooling water from a small diesel engine. Engine that will be used in this study is Mitsubishi 4D30. The technical parameters were briefly featured as Table 3.1.

Description	Unit	Parameter
Maximum Power, Nc	PS	90
Revolution, n	rpm	3500
Bore, D	mm	100
Stroke, S	mm	105
Maximum Torque @1800rpm	kgfm	22
Minimum engine speed without load	rpm	600-650
Maximum engine speed without load	rpm	3800-3850
Displacement	cc	3298

Table 3. 1 Mitsubishi 4D30 Engine Specification

Another data will support this research is operating data of the engine as boundary condition such as water-cooling and B20 temperature, mass flow rate of B20 and water cooling and amount of cooling water. For mass flow rate of water were reduce from 2560 kg/h to 3 kg/h due to high difference mass flow rate than biodiesel mass flow rate. The data were briefly featured as table 3.2.

Description	Unit	Parameter
Temperature of B20	°C	30
Temperature of Water	°C	83
B20 Mass Flow Rate	Kg/h	1.5
Water Mass Flow Rate	Kg/h	3

Table 3. 2 Boundry Condition

Biodiesel to be analyzed for the characteristics after preheating is B20 from Pertamina with the characteristics before preheat show in table 3.3 below.

No.	Characteristics	Unit	Limitation		ATSM Method
			Min	Max	
1.	Cetane Number		45		D 613
2.	Density @ 15°C	kg/m³	815		D 1298/D 4052
3.	Viscosity @ 40°C	mm²/sec	2.0	4.5	D 445
4.	Flash Point	°C	52		D 93
5.	Pour Point	°C		18	D 97
6.	Water Content	mg/kg		500	D 6304
7.	Ash Content	%		0.01	D 482
8.	Carbon Residue	%		0.1	D 4530/D 189

Table 3. 3 Pertamina Biodiesel Specification

3.4 Calculation

Calculation stage has purpose to determine size of shell and tube heat exchanger. To get the right size of shell and tube there's are several steps to calculate, such as preliminary design and rating the shell and tube. Method used in this calculation is Kern Method. The complete result can be seen in the attachment B.

3.4.1. Heat Duty

Calculate the heat duty to know heat transfer rate. This heat transfer rate determined by

$$Q = (mCp)(\Delta Tc)$$

3.4.2. Hot Water Outlet Temperature

Outlet temperature of hot side can be known by

$$T_{h2} = T_{h1} - \frac{Q}{mCp}$$

3.4.3. Mean Temperature Difference

Counter current flow in heat exchanger is needed to calculate LMTD from given four inlet/outlet temperatures.

$$\Delta Tm = \frac{(T_{h1-}T_{c2}) - (T_{h2} - T_{c1})}{ln\frac{T_{h1-}T_{c2}}{T_{h2} - T_{c1}}}$$

3.4.4. Shell Side Heat Transfer Coefficient

There’s some step before calculating the shell side heat transfer coefficient such as area, flow rate, diameter and Nusselt number.

$$A_s = \frac{(D\ CB)}{Pt}$$

$$G = \frac{m}{A_s}$$

$$D = \frac{4(Pt^2 - \frac{\pi do^2}{4})}{\pi\ do}$$

Due to turbulent in shell side, McAdam´s correlation used to get Nusselt number

$$Nu = 0.36\left(\frac{D\ Gs}{\mu}\right)^{0.55}\left(\frac{Cp\ \mu}{k}\right)^{0.33}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

Shell side heat transfer coefficient calculated as

$$h_o = \frac{Nu\ k}{D}$$

3.4.5. Tube Side Heat Transfer Coefficient

There’s some step before calculating the tube side heat transfer coefficient such as area, flow rate, diameter and Nusselt number.

$$A_t = \frac{\pi\ di^2}{4}$$

$$A_{tp} = \frac{Nt\ A_t}{Number\ of\ passes}$$

$$G = \frac{m}{A_{tp}}$$

$$u_t = \frac{G}{\rho}$$

$$Re = \frac{u\,\rho\,di}{\mu}$$

Fluid on the tube side is turbulent, to calculate Nusselt number using the Petukhov-Kirillov correlation,

$$Nu = \frac{\left(\frac{f}{2}\right) Re\ Pr}{1{,}07 + 12.7(\frac{f}{2})^{1/2}\ (Pr^{\frac{2}{3}} - 1)}$$

where $f = (1.58 \ln Re - 3.28)^{-2}$

Tube side heat transfer coefficient calculated as

$$h_i = \frac{Nu\ k}{di}$$

3.4.6. Overall Heat Transfer Coefficient

The overall heat transfer coefficient can be determined using equation:

$$U = \frac{1}{\frac{d_o}{d_i h_i} + \frac{d_o \ln\left(\frac{d_o}{d_i}\right)}{2k} + \frac{1}{h_o}}$$

3.4.7. Heat Transfer Area

Determine the heat transfer area can be known by following heat transfer rate equation.

$$A = \frac{Q}{U\ F\ \Delta T_m}$$

3.4.8. Length of Heat Exchanger

After heat transfer area is known, the length of heat exchanger can be determining using equation:

$$L = \frac{A}{N\,\pi\,D_o}$$

3.4.9. Shell Side Pressure Drop

The pressure drop in shell side can be calculated using equation:

$$\Delta Ps = \frac{f\,Gs^2(Nb+1)\,Ds}{2\rho\,D\,\emptyset s}$$

3.5.0. Tube Side Pressure Drop

The pressure drop in tube side can be calculated using equation:

$$\Delta Pt = \left(4f\,\frac{L\,Np}{di} + 4Np\right)\frac{\rho\,u^2}{2}$$

3.5 Shell and Tube Modeling

Modelling stage is where the real dimensional data from calculation drawn using 3D modelling software. In this modeling used Solidworks 2018. Theres are several parts of shell and tube to be draw before assemble them.

3.5.1. Drawing parts

In the modeling of shell and tube theres are parts must be draw separately such as shell, baffle, tube and shell cover. The first part to draw is shell with dimension below:

Shell Side			
Parameter	Notation	Dimension	Unit
Pitch	Pt	0,593701	in.
Clearence	C	0,271654	in.
Baffle spacing	B	2,65748	in.
Outside diameter	Do	2,25	in.

Table 3. 4 Shell Dimension

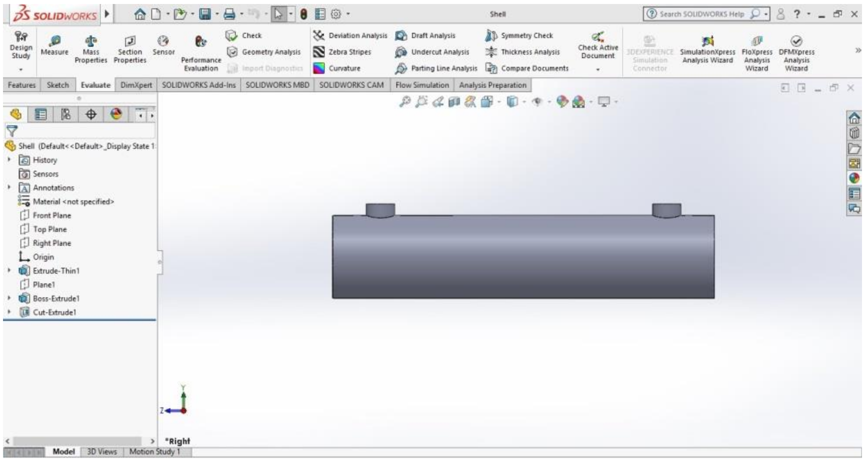


Figure 3. 1 Shell from Right Side

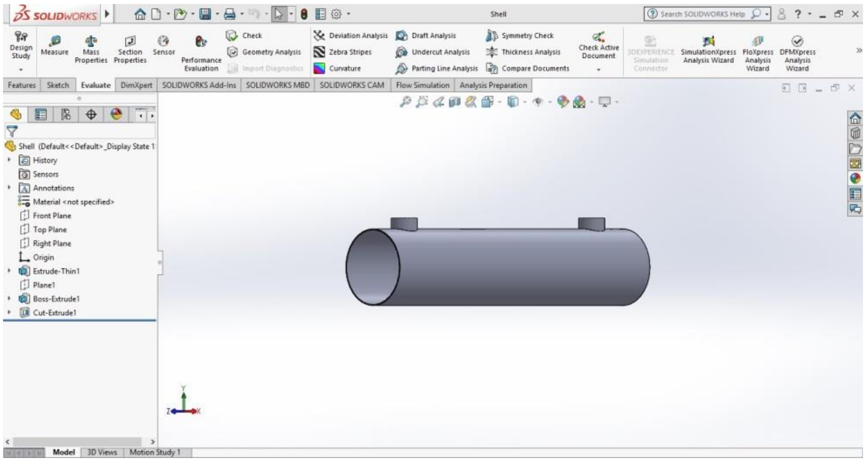


Figure 3. 2 Shell from Front Side

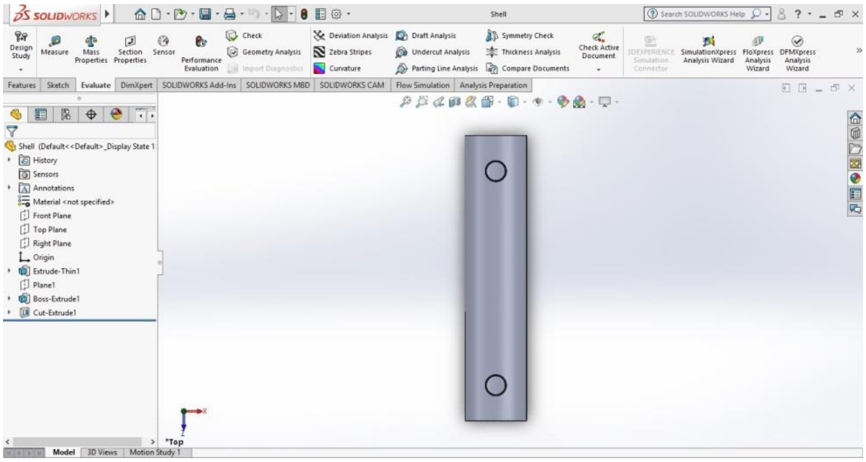


Figure 3. 3 Shell from Top Side

After drawing shell, next part is tube with drawing dimension below:

Tube Side			
Parameter	Notation	Dimension	Unit
Outside diameter	do	0,375	in.
Inside diameter	di	0,319	in.
Flow area	a´	0,0731	$in.^2$
Number of tubes	Nt	9	
Lenght	L	270	mm

Table 3. 5 Tube Dimension

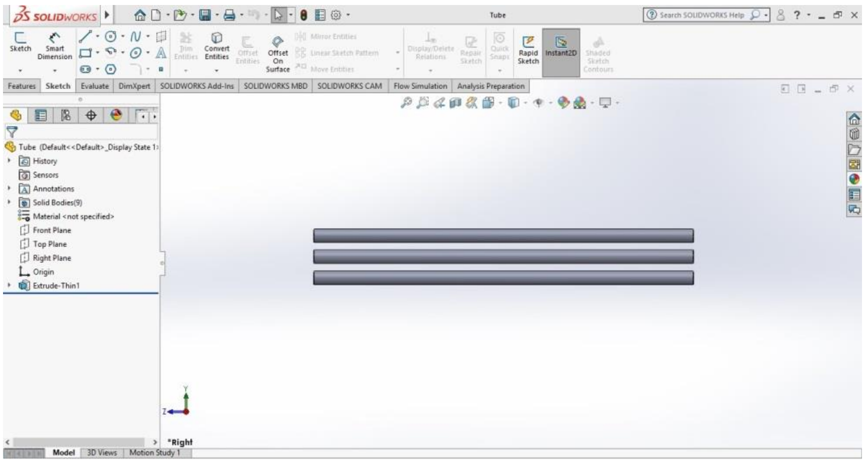


Figure 3. 4 Tubes from Right Side

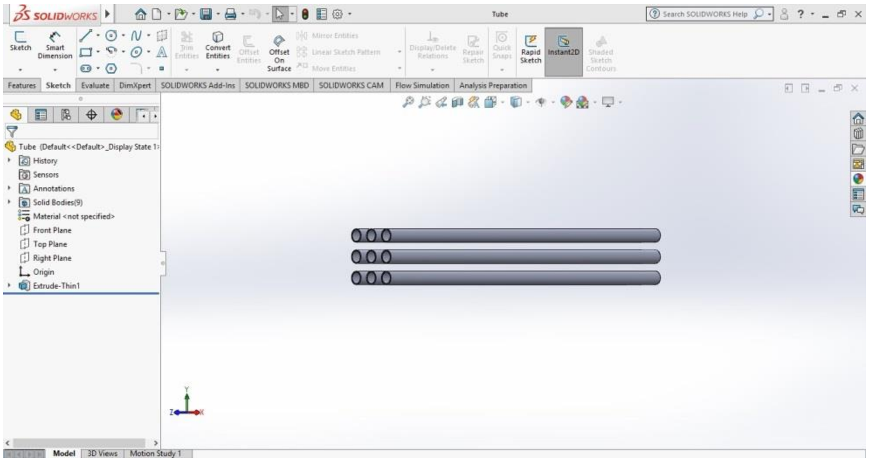


Figure 3. 5 Tubes from Front Side

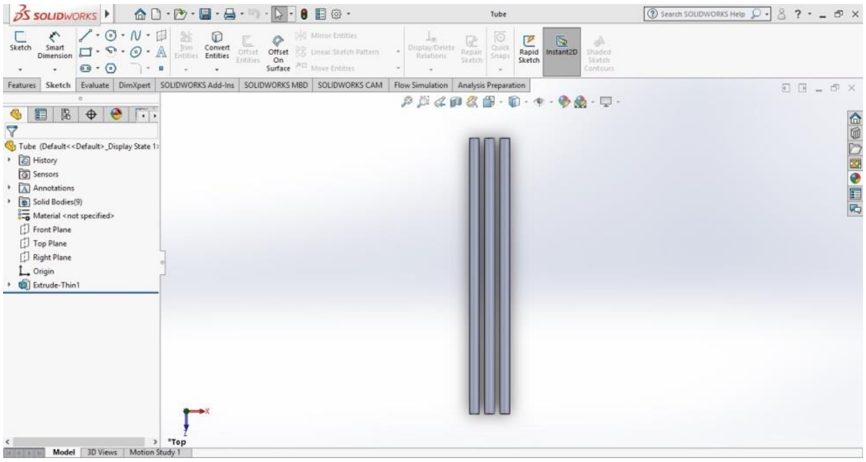


Figure 3. 6 Tubes from Top Side

The last part of shell and tube to draw is baffle with dimension below:

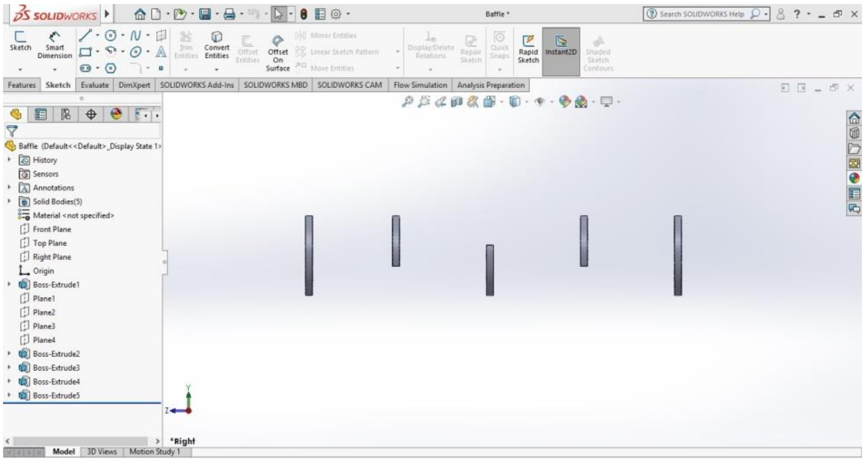


Figure 3. 7 Baffle from Right Side

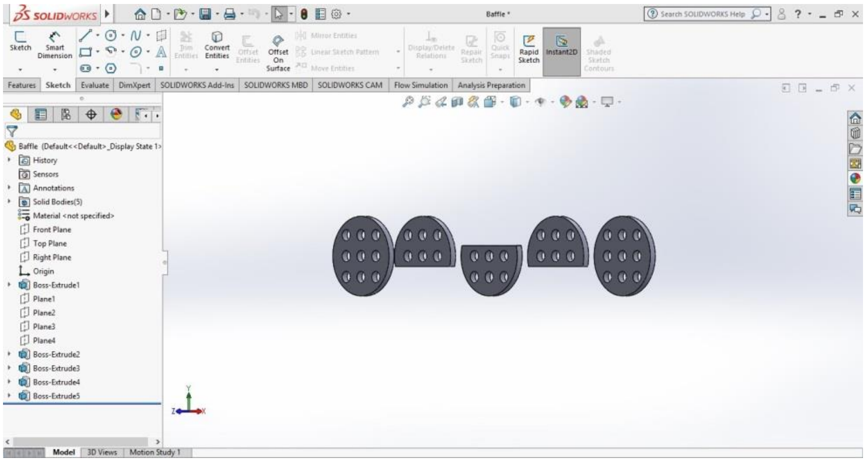


Figure 3. 8 Baffles from Front Side

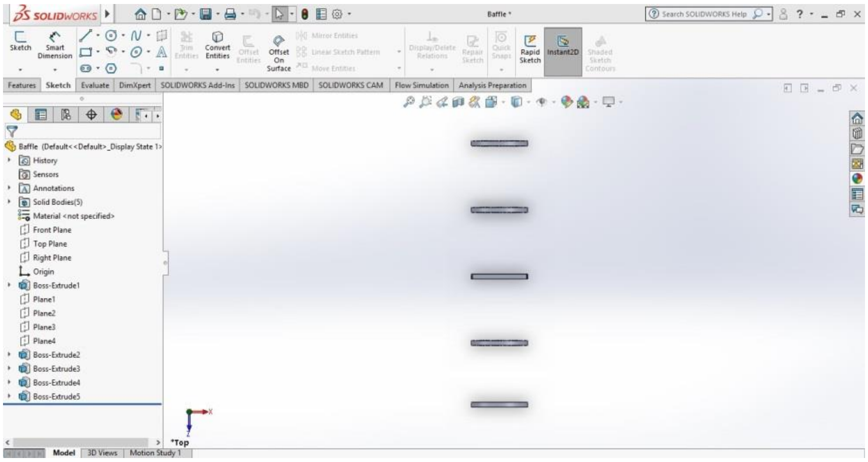


Figure 3. 9 Baffles from Top Side

3.5.2. Assembling Parts

After drawing parts of shell and tube is done, the next step is assembling them. The assembly process still used same software for drawing parts.

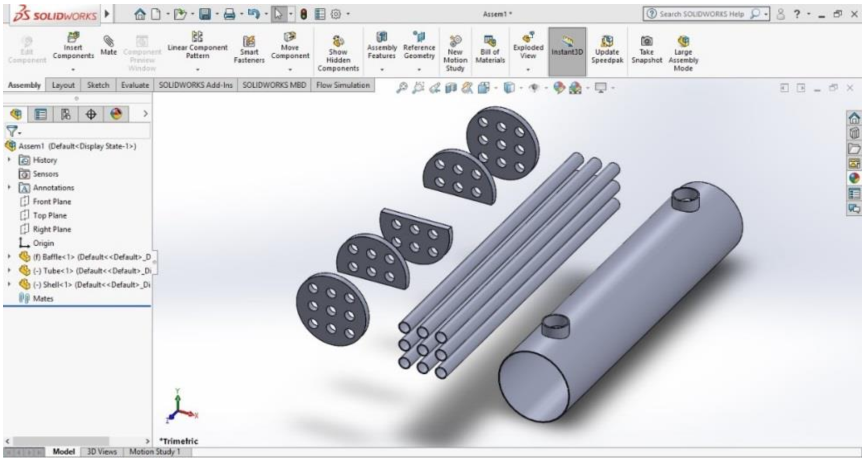


Figure 3. 10 Parts Assembly

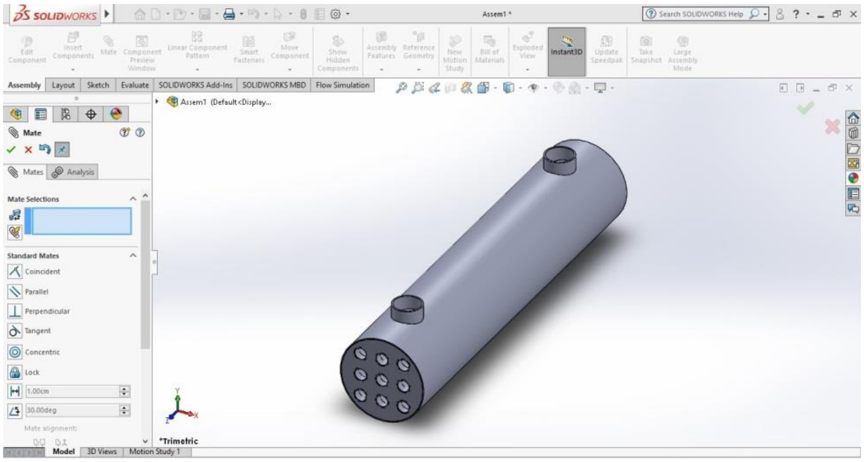


Figure 3. 11 Parts Finished Assembly

3.6 Simulation of Shell and Tube

Fluid flow simulation used Solidworks 18 Student License. Same as the modeling stage, in this stage author simulating the fluid flow inside shell side and tube side.

First thing in computational fluid dynamics simulation is choose the analysis system of its software. Here choosed flow simulation for complete the simulation.

3.6.1. Import Geometry

Import geometry to solidworks flow simulation and input certain things such as fluid types, solid material. After that, named all inlet and outlet surface for supporting simulation process in set up stage. Picture of geometry below:

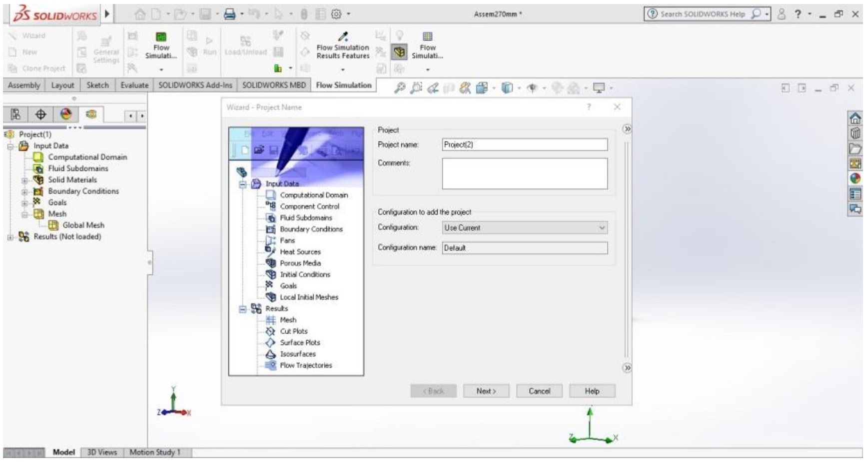


Figure 3. 12 Main Panel Flow Simulation

3.6.2. Input the Boundary

After as geometry already in flow simulation panel and all of the inlet and outlet already closed using lids, in this stage is input the boundry as follows:

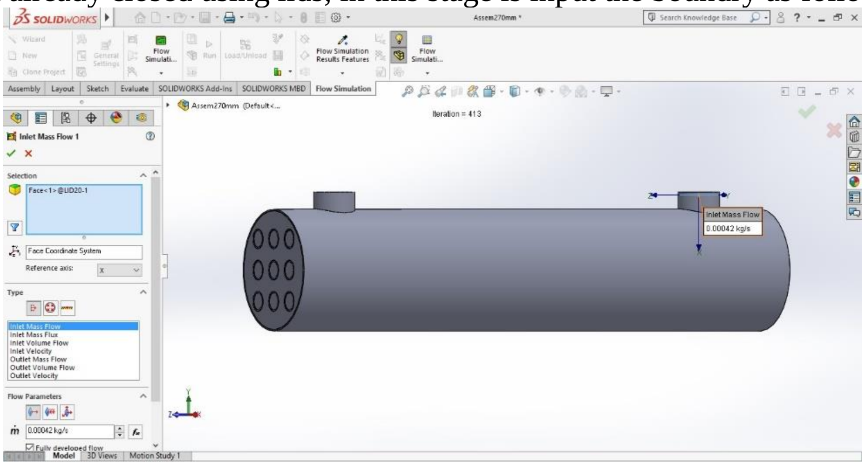


Figure 3. 13 Input Shell Boundry

3.6.3. Meshing Process and Run

After import all model to workbench, it needs to build a good enough mesh process. Here picture of meshing process in Solidworks Fluid Simulation:

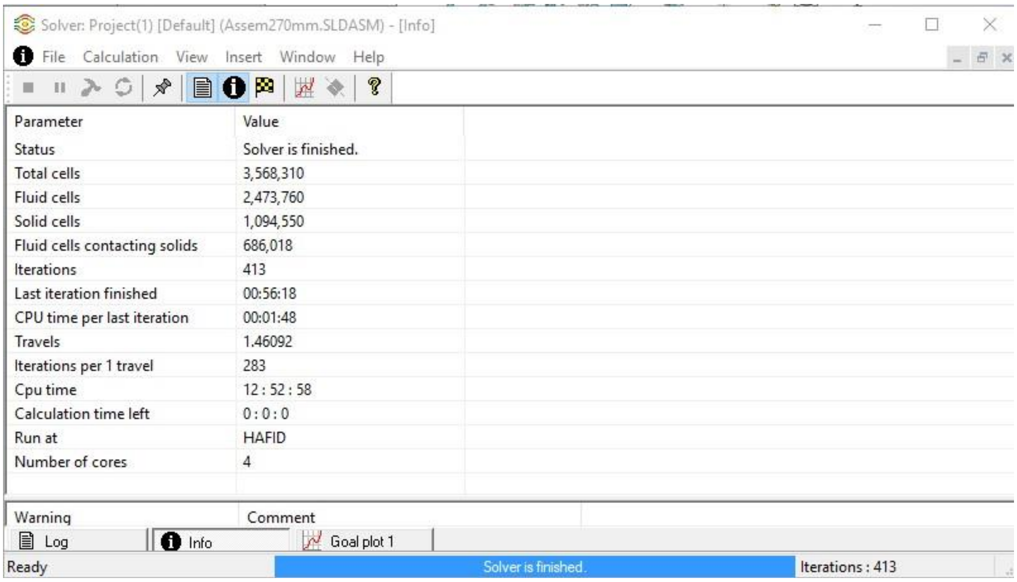


Figure 3. 14 Solver Finished Calculation

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CHAPTER IV
DISCUSION AND RESULT

After running all solution with enough iteration or reach convergent calculation. The result can be shown in work window of Solidworks Flow Simulation main panel. Here the result of simulation.

4.1. Flow Simulation Result

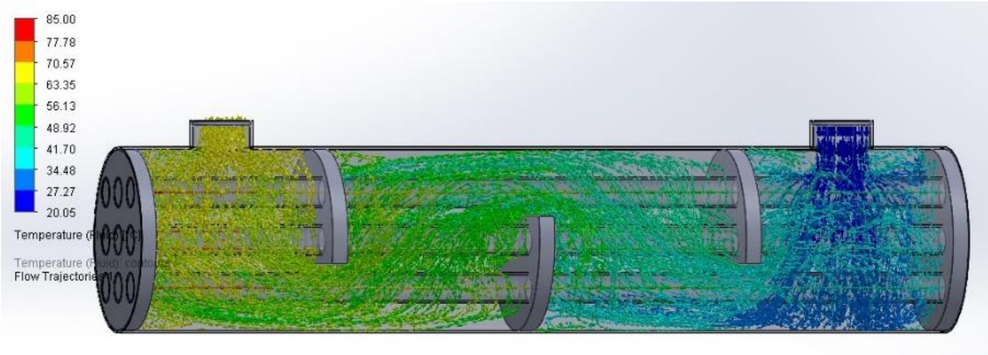

Figure 4. 1 Simulation Result of Flow Fluid Temperature

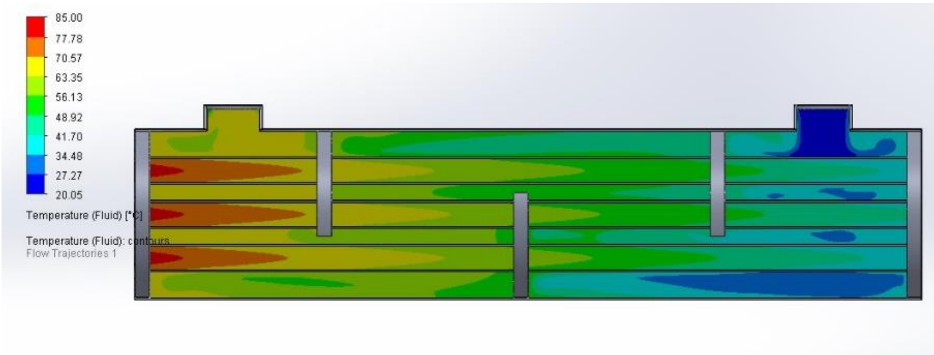

Figure 4. 2 Cut Plane Fluid Temperature

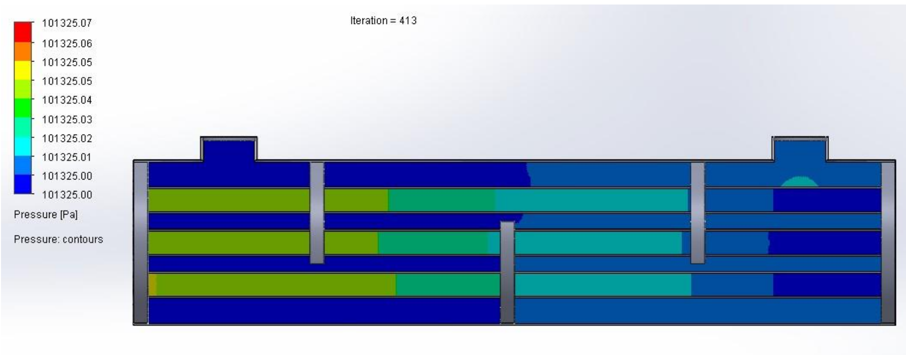

Figure 4. 3 Cut Plane Pressure

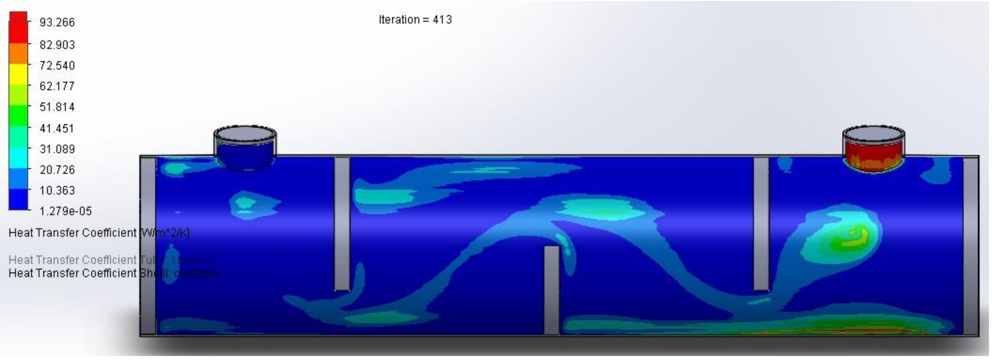

Figure 4. 4 Surface Plane Heat Transfer Coefficient of Shell

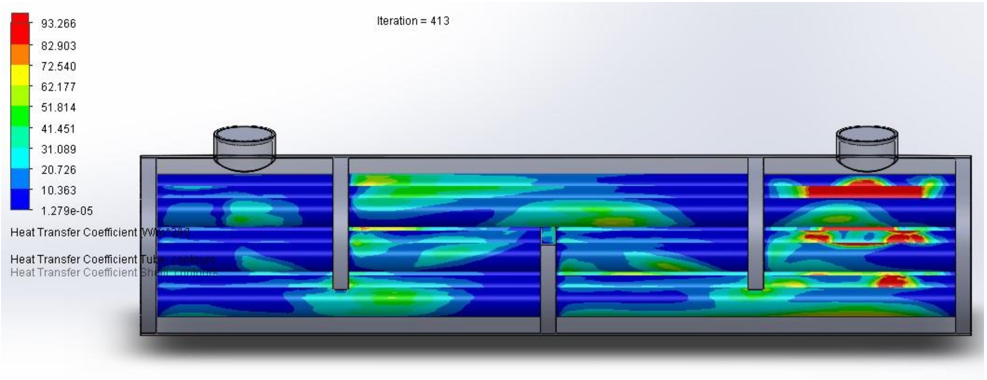

Figure 4. 5 Surface Plane Heat Transfer Coefficient of Tube

4.2. Fluid Temperature

On post processing simulation, can be obtained calculation results of simulation for fluid temperature.

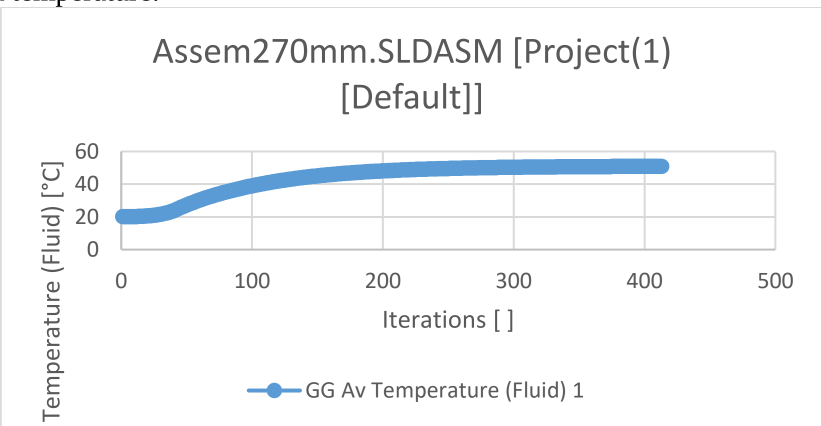

Figure 4. 6 Avarage Fluid Temperature

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av.Temperature (Fluid) 1	[°C]	50.85	50.54	49.95	50.85

Table 4. 1 Avarage Fluid Temperature

From figure 4.2 clearly shown that the temperature in the shell side, which is biodiesel success going up from 30°C untill desire temperature 70°C. The temperature of cooling water flow inside the tube going down until 60°C.

4.3. Fluid Pressure

From the result, can be obtained calculation results of simulation for fluid pressure

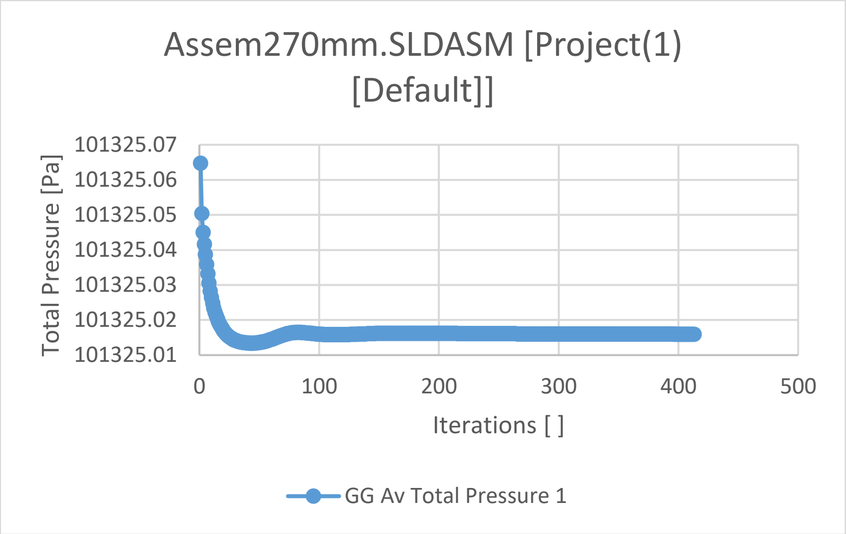

Figure 4. 7 Avarage Total Pressure

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
GG Av Total Pressure 1	[Pa]	101325.016	101325.016	101325.016	101325.0161

Table 4. 2 Avarage Total Pressure

From figure 4.3, it can be seen that pressure in shell is quite same between inlet and outlet. Pressure in the tube side is going down make the pressure down than the inlet. The average for shell and tube is about 101325 Pa.

4.4. Heat Transfer Coefficient

From the result, can be obtained that calculation results of simulation for average heat transfer coefficient.

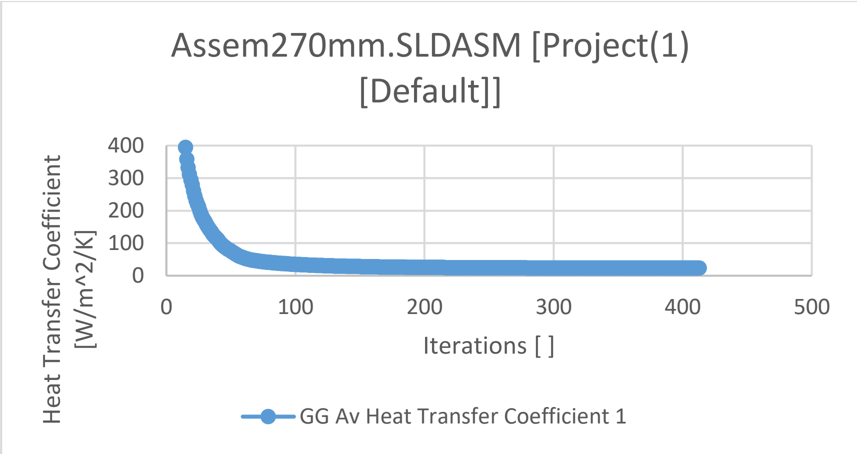

Figure 4. 8 Avarage Heat Transfer Coefficient

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
GG Av Heat Transfer Coefficient 1	[W/m^2/K]	23.50	23.70	23.50	24.09

The figure show that the average heat transfer coefficient is 23.70 W/m².K. this result not very different with calculation result which is 20.20 W/m².K.

CHAPTER V
CONCLUSION AND SUGGESTION

5.1. Research Conclusion

Based on the results of calculations and simulation that have been done by the author related to the performance analysis

1. From the result of calculation shell and tube have heat duty 36 W, shell heat transfer coefficient 21.24 W/m².K, tube heat transfer coefficient 426 W/m².K, overall heat transfer coefficient 20.06 W/m².K, heat transfer area 0.072 m². The results of calculation are not very different than result of simulation, which in simulation shows that the average heat transfer coefficient is 23.00 W/m².K.
2. After the calculation is complete, has been found the right size of heat exchanger as; tube outside diameter 0.375 inch. Shell outside diameter 2.25 inch and length of heat exchanger is 270 mm.

5.2 Suggestion

Based on the analysis and whole process that has been done by the author in conducting the analysis of shell and tube performance as preahetar for biodiesel fuel, there are several things need to be considered in conducting shell and tube flow analysis; to improve result, another condition need to be simulate, such as baffle spacing variation, tube diameter variation, operating engine condition. Calculation for finn on the baffle need to be calculated properly since there are no formula to calculate yet. As comparable result another sophisticated software can be used.

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ATTACHMENTS

ATTACHMENT A NOMENCLATURE

A	heat transfer area, m^2
B	baffle spacing, m
C	clearance netween tubes, m
Cp	specific heat at constant pressure, J/kg.K
Ds	shell diameter inside, m
do	tube outside diameter, m
di	tube inside diameter, m
F	friction factor
G	mass velocity, $kg/m^2.s$
hi	tube side heat transfer coefficient, $W/m^2.K$
ho	shell side heat transfer coefficient, $W/m^2.K$
k	thermal conductivity, W/m.K
L	effective tube length, m
m	mass flow rate, kg/s
Nt	number of tubes
Pt	pitch size, m
Q	heat duty of heat exchanger, W
Tc	cold fluid temperature, °C
Th	hot fluid temperature, °C
Uc	overall heat transfer coefficient, $W/m^2.K$
Δp	total pressure drop, Pa
ΔTm	log mean temperature differences, °C
μ	dynamic viscosity, kg/ms
ρ	fluid density, kg/m^3

ATTACHMENT B CALCULATION

AUTHOR BIOGRAPHY

The Author's name is Hafid Rafi Noviantoro, was born in Jakarta, November 1st, 1994 as a first son and has two sisters. He started his formal education in An-Nur elementary school, Bani Saleh junior high school, and PB. Soedirman 1 Bekasi as senior high school. In 2015, author proceed to pursue bachelor's degree at Department of Marine Engineering (Double Degree Program with Hochschule Wismar, Germany), Faculty of Marine Engineering, Institut Teknologi Sepuluh Nopember Surabaya specializes in marine power plant. During collage, author did many activities in campus organizations such as: Society Petroleum Engineer as a staff, Petrolida Event as a Gala Dinner staff, and ITS Marine Solar Boat Team as a Design and Body Staff and Boat Pilot. The Author also joined in several On the Job Training, such as: PT Industri Kapal Indonesia in Makassar and PT Garuda Maintenance Facility in Jakarta.

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