DESIGN OPTIMIZATION OF EXTERNAL COOLANT FILTER FOR METAL MACHINING MACHINE

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

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DECLARATION

I hereby declare that the work in this thesis entitled " Design Optimization of External Coolant Filter for Metal Machining Machine" is my own except for summaries and quotations which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ……………………………..

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Date: ……………………………..

DEDICATION

To Ibu and Ayah, I did my very best and I hope I make you proud.

I dedicate my thesis to my beloved parents

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I would like to express my heartfelt appreciation to my supervisor Mr. Febrian bin Idral for giving me this opportunity to conduct and complete my final year project. He never hesitated to give me advice and guidance whenever I was confronted by problems. Furthermore, I am extremely thankful for his patience and advice while leading me in this project.

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ABSTRACT

Machining has been one of the fundamental processes in engineering when it comes to metal processing as well as product forming. Machining process can be briefly described as the process of removing material from a work piece. This study focuses on designing and optimising the selected design of an external coolant filter for metal machining machine. The use of coolant in metal machining process is to obtain a higher quality surface finish. Without proper handling of the coolant in use, the workpiece may even be damaged. The design of the external coolant filter was made in reference to an existing product. In order to prevent this from happening, analysis had been done. By using thermal equilibrium concept, the temperature can be controlled. Aside from that, particle size during machining process was also considered, resulting in the best filtration media selection.

ABSTRAK

Proses pemotongan menggunakan mesin merupakan salah satu proses terpenting di dalam proses yang melibatkan pemprosesan besi dan juga pembentukan produk. Proses ini boleh dinyatakan sebagai proses membuang bahagaian dalam bentuk serpihan berskala kecil dari bahan yang diproses. Kajian ini memfokus pada mereka bentuk dan mengoptimumkan rekaan tersebut bagi kegunaan mesin pemproses besi. Penggunaan penyejuk dalam proses tersebut adalah untuk mendapat kualiti pemprosesan yang lebih tinggi. Tanpa pengendalian penyejuk yang betul, bahan yang diproses juga berkemungkinan untuk rosak dari proses. Rekabentuk penapis tersebut dibuat dengan rujukan dari produk sedia ada. Bagi mencegah kerosakan dari berlaku, analisa telah pun dilakukan. Dengan mengaplikasikan konsep kesamaan termal, suhu sejuk penyejuk dapat dikawal. Selain itu, saiz serpihan yang terhasil dari proses tersebut juga telah diambil kira sekaligus menentukan media penapis yang terbaik bagi proses tersebut.

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LIST OF SYMBOLS

$\dot{Q}_{conv}$	-	Convection Energy
η_{th}	-	Efficiency
℃	-	Degree Celsius
As	-	Surface area through which convection takes place
E	-	Energy
h	-	Convection heat transfer in W/m2. C
K	-	Thermal conductivity of material
Kg	-	Kilogram
L	-	Length
r	-	Radius
T∞	-	Surrounding temperature
Ts	-	Surface temperature

LIST OF ABBREVIATIONS

AiRTX	-	Air Research Technology Company
ANSYS	-	Analysis of System Software
ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Drawing
CATIA	-	Computer Aided Three Dimensional Interactive Application

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CHAPTER 1

INTRODUCTION

1.1 Background

Machining has been one of the fundamental processes in engineering when it comes to metal processing as well as product forming. Machining process can be briefly described as the process of removing material from a work piece which includes the process such as cutting, grinding, honing and drilling by using machine tools in order to obtain the desired shape. In high-speed machining, the most dramatic increase in applications are detected to be in the manufacturing of aluminium components at which the volumetric material removal rates can be extremely high which approaches thousands of cubic centimetres per minute (Davis and Burns,2001). Generally, every process of machining for example cutting process is the result of dynamic interactions between 3 elements which are present during the process which is the machine tool, the cutting tool as well as the work piece (Balachandran, 2001).

Extensive research on machining was made and it was discovered that these processes are affected by static and dynamic effects which causes the machining system to deviate from the desired geometry. Some of the factors contributing to these effects includes slide speed variations of chips formed and stick-slip friction of the chips (Balachandran, 2001). In order to get a smooth surface finish with respect to the tolerance of in-house quality specifications, these problems were reduced by the application of coolant in machining process. Coolants functions as cooling and lubrication system in machining processes, as well as improving the surface quality of the work piece by constantly removing fine chips from the tool and the cutting zone. Coolants also helps in prevention of the chips to be welded on the cutting tool which in time will affect the surface quality (Childs T et. al, 1988).

In general, a coolant flows from the reservoir to the pipelines within the machinery and then through pipes in the working space of a machine which it will execute the cooling processes and then reabsorbed into the reservoir via sinkhole in the workspace. That being said, the chips which were swept away from the work piece and the tool will flow alongside the coolant into the reservoir. Coolants shows signs of contamination when it turns brown. In machineries which uses coolant, most often the cause to the colour change is deep within the reservoir at which sludge starts to form. This dissertation discusses on a design which will elongate the life time of a coolant within a machine by the use of an external filter

1.2 Problem Statement

A metal machining machine was running for 24 hours a day for Panasonic Air Conditioning Malaysia Sdn. Bhd. in order to achieve the target production rate per day. The parts which were processed was in variety of shape and undergoes different processes. Some undergoes drilling while some undergoes milling and lathe process. A few examples of these parts are the cylinder, piston as well as the upper and lower bearing of an air conditioner compressor. Often companies tend to maximize the capabilities of each machine in order to be cost effective. As the machines are running non-stop, the contents of the coolant used becomes contaminated with chips and burrs from previous processes which in time will affect the quality of the finishing of the product as well as the tool life. Most of the machines used are back dated and roughly aged in between 20 to 10 years old. The pre-installed filter on the machines were not able to filter contaminants thoroughly which then results in formation of metal sludge. This leads to high cost consumption on maintenance. The challenge then comes on keeping the coolant at optimum level in order to elongate the tool life while producing high quality product finish. This dissertation discusses on design optimization of the current filter at which the outcome of this research is targeted to be an external stand-alone filter which is able to filter the coolant flow thoroughly and at the same time reduces heat level of coolant flow.

1.3 Objective Study

1. To design an external stand-alone type external coolant filter for a 24 hours working machine
2. To ensure the reduction in temperature of the coolant up to 5%

1.4 Scope Project

1. To design and develop a 3D solid modelling of the overall system of the external coolant filter by using CAD software such as CATIA V5R20.
2. To optimize the design of the external filter and system in order to gain the most optimum performance by reducing heat
3. To reduce coolant heat level and ways to reduce them through the heat exchanger

1.5 Methodology View

In the initial stage, this project which is design optimization of external coolant filter for metal machining machine was studied on the basis of coolant flow in a metal machining machine. This later on move to the effect and importance of coolant usage when machining metals. Then the design specifications of the external coolant filter which includes the size, flow process and material selection is determined with reference to an existing product. These specifications should be followed for safety, precaution and hazard purposes. This project then proceeds to the construction of 5 conceptual designs according to the project's requirement as well as the filter's criteria. The proposed design was then evaluated by using Weighted Selection Method, followed by the matching of parts by using Pugh Selection Method in order to produce 3 best designs. These designs are then converted into 3-Dimensional models by using CATIA V5 R20 software. Considering the flow and the temperature of the coolant in the machine, the temperature drop effectiveness of the filter is analysed by using ANSYS software. The same thing is done for the flow of coolant within the designed filters as whole. Finally with reference to the analysed results, the best design was selected and improvised in order to fulfil the criteria needed with an appropriate factor of safety.

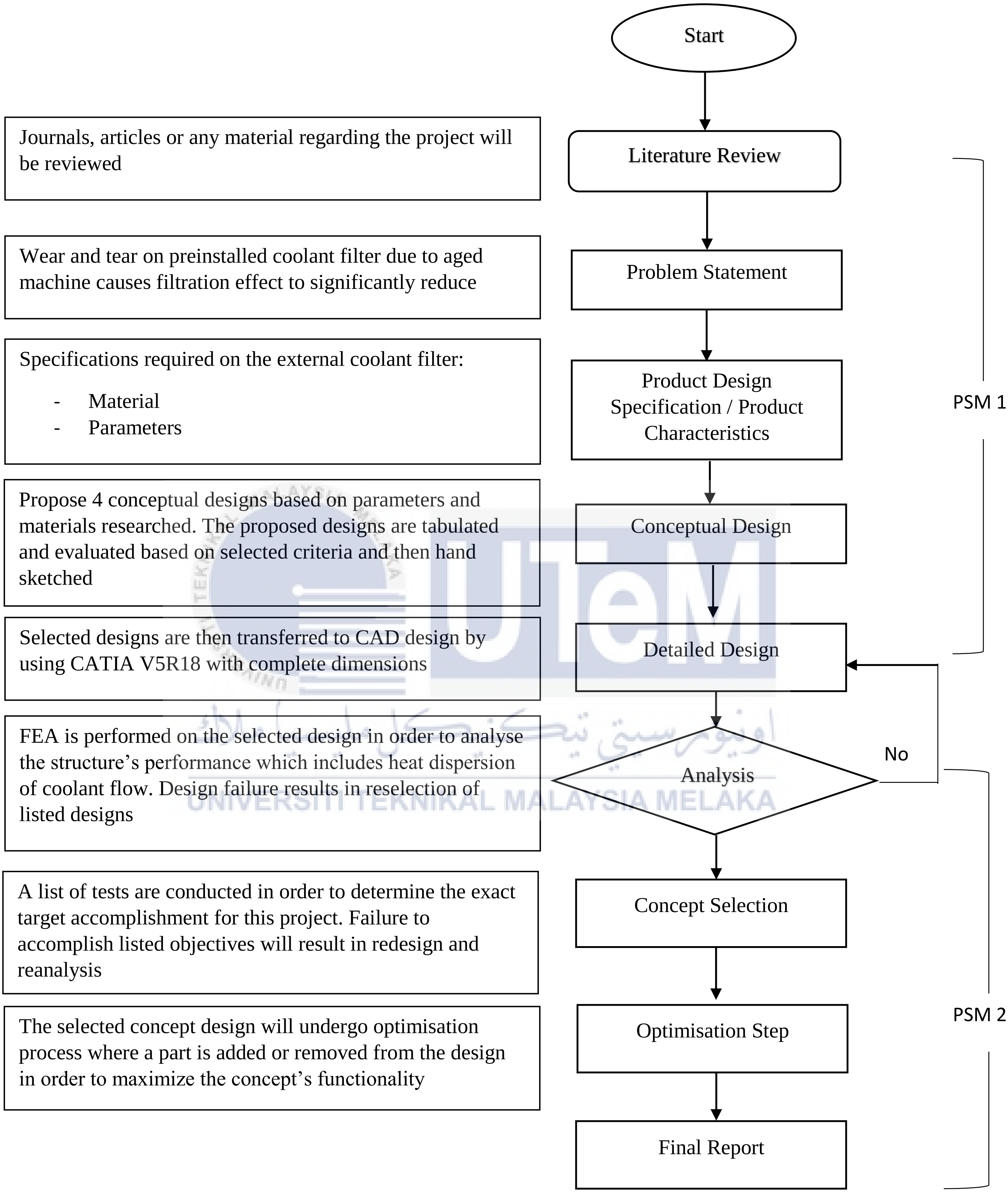


Figure 1.1: Overall project flowchart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Literature Review

This section explains the literature review of metal machining issues which are related to surface finish in general. This later on moves to coolant issues in industrial manufacturing sectors revolving around filtering and flow systems in a coolant filter. The explanation continues to the process of designing and flow analysis of the filter by generation and evaluation of the designed concept. The source of information and data was collected from various sources which includes academic journals, produced product specifications as well as books.

2.2 Metal Machining

Metal machining is one of the processes categorised under machining. It is a process where metal raw piece of materials are removed or cut into a desired geometry by a controlled material removal. These processes are nowadays known as subtractive manufacturing. The "controlled" term used in the definition is a variable which are controlled by many factors during the process which includes type of tool used, spindle speed during cutting as well as feed removal rate. There are however other methods which are used in order to process selected raw metals such as flame cutting and plasma cutting. Generally there are 3 types of metal machining which are widely used until today. These classifications include turning, milling and drilling while other operations can be considered as miscellaneous or as a sub category from the main 3 processes including shaping, boring, planning, broaching and sawing. Going through the 3 processes stated; turning processes are operations where the workpiece are rotated in order to remove materials. Millings however are operations which contradicts turning. In milling the tool rotates against the workpiece while drilling is an operation of producing holes or refining them by using rotation cutter tool. Figures below shows some common machining processes.

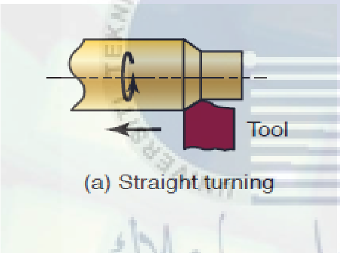


Figure 2.1: Straight turning motion

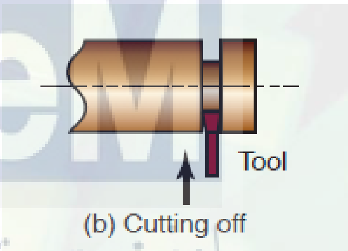


Figure 2.2: Cutting process by turning

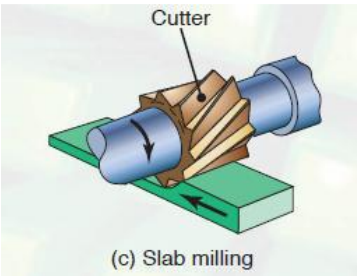


Figure 2.3: Slab milling process

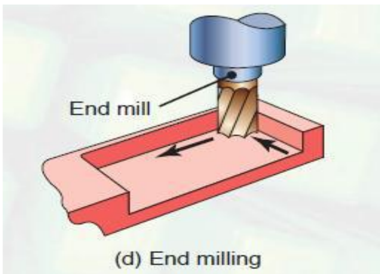


Figure 2.4: Milling motion

(Source: Chockalingam, P., Kuang, K. C., & Vijayaram, T. R. (2013))

Nowadays, instead of being manually steered, materials are often processed in an orderly manner with the help of programmable logic controller (PLC). PLC helps in navigating the movement of the table and tool including the workpiece prior to cutting. The presence of PLC in machining eases the accuracy of dimensioning of the intended part thus increasing sensitivity and geometrical accuracy of the desired workpiece. The leverage of PLC results in smoother surface finish. There are also a few other factors which contributes to good surface finish of the end product such as tool wear rate with respect to spindle speed and feed rate, workpiece table alignment as well as the presence of coolant during cutting process.

2.3 Coolant Use in Machining Processes

Coolants can be considered as an underappreciated element in machining. The main purpose of operating coolants in metal machining machines are to be used as cooling agent. Aside from that, coolants are able to function as a cutting tool additive which increases the longevity of the tool. They provide appropriate surface finish by reducing thermal distortion on workpiece surface and flushing away machined chips. The presence of coolant in a machining process altogether is able to provide the user with increase in productivity by setting back prices on multiple sectors such as quality control as well as tool wear and tear while providing satisfactory surface finish. The flexibility or the ability of the cutting fluid or coolant in use to penetrate and apply its effect on the cutting zone is essential or else the presence of a coolant in a machining process is useless. The employment of cutting fluid during a process enables higher spindle speed and cutting speeds, higher feed rate removal with enhanced surface finish. This is due to the purpose of coolant where it reduces the temperature of the cutting tool thus preventing chips from being welded on the cutting tool instantaneously during cutting process.

2.3.1 Properties and Types of Coolant

Coolants can be classified into 2 categories:

2.3.1.1 Performance properties

Performance properties are those that contributes to the reduction parameters such as forces, improvement on tool life, higher surface and dimensional stability associated on the economy of production.

2.3.1.2 Service properties

Service properties of a coolant associated with their impact on the machine, workpiece and operator and their stability. There are several principles which these coolants abide such as no unwell impact on traditional lubrication, no deterioration of paint or end lubrication of the machine in use, no oxidization or corrosion of the machine or workpiece, no cyanogenic or alternative morbid impact on operator and optimum service life. These classifications of coolant are derivation from types of coolant available in the market.

i) Gaseous type

Mist is that the most ordinarily used foamy fluids within the style of coolant. In mist cooling system, compressed gas is employed to atomize the agent and carry it to the purpose of the cutting within the types of mist. Gases like greenhouse emission, Freon and argonon are used for special applications. This coolant fluids performs lubrication, cooling flushing action. Gaseous application of agent significantly will increase the effectiveness of the agent however is costlier compared to alternative strategies

ii) Soluble Oils

Soluble oil type of coolant contains mineral oil which provides lubrication, emulsifier in order to break into small globules, rust inhibitor to prevent rust from occurring since water is able to cause rust, bactericide to control the growth of microorganism within used coolant particularly anaerobic bacteria which causes foul smell. Since oil is insoluble in water, the presence of emulsifier breaks down the oil into tiny particles. This is due to the fact that specific heat capacity, thermal conductivity of water is better than oil while lubrication is only able to be provided by the presence of oil in the mixture of coolant.

iii) Synthetic Coolant

Contrary to soluble oil type coolants, synthetic coolants do not contain mineral oil. Instead, they contain some synthetic chemicals as substitutes. This type of coolant has an advantage of not being affected by bacterial growth. In addition it also has a long life properties. They are capable of emulsifying in hard water. On the other side synthetic coolants

2.4 Coolant Filter

A coolant filter is aimed to remove contaminants from the coolant as it passes through the filtration media. Coolant filters can be in the form of cartridge, spin-on design or even flat -bed type where coolant is filtered openly. Some filtration media also adds chemicals to the coolant in order to add important protectants which may be lost over time.

2.4.1 Types of filtration mechanism

There are four fundamental mechanism of filtering. These can be listed as below

i) Depth Straining

This mechanism applies to felts and non-woven materials which are relatively thick when compared to pore diameters. Particles go through the pores until they reach a necking point where the diameter becomes smaller than the particle. Hence, the particle is trapped in the pore.

ii) Depth Filtration

Depth filtration involves a mechanism where the particle is still removed even though the particle is larger than the diameter. The mechanism involves a few theories which can be listed as inertial impaction, interception, diffusion and electrostatic attraction.

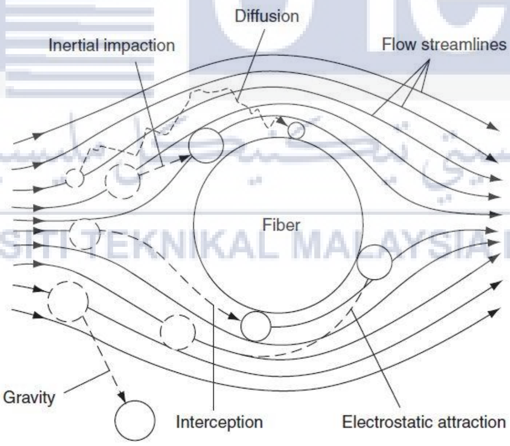


Figure 2.5: Mechanism of particle capture (Source: Chanson, H. (2004))

iii) Surface straining

Particle which is larger than the pores cannot pass through. Similarly, the case is reversed for particles which are smaller than the pores. This type of filtration is generally not associated with nonwoven fabrics but rather with materials or media with uniform pore opening.

iv) Cake filtration

This type of filtration captures particles on or near the surface of the filter medium. The residue of filtered particles left on the filter surface is targeted to participate in the filtration process. In some chemical operations, this process is important so as to collect the residue on the surface at the end of the operation.

2.4.2 Coolant filter positioning

Filter positioning is one of the crucial thing when defining a filter. 2 main positions are horizontally assembled as well as vertically assembled. When comparing both positions with respect to its effectiveness, an extensive research done by Eastman Kodak facility which is located in the northwest US resulted in major difference in filtering efficiency when it comes to vertically pressed filter (Knapp,A. 2017). This applies to their inlet and outlet positioning where the fluid flows from the top to the bottom, hence the name vertically pressed filters.

2.5 Sedimentation

Sediment can be listed as materials and compounds, aggregates be it organic materials or associated chemicals. These properties affects particle behaviour in flowing water. A few parameters which affects the settling velocity such as shape, size and density of particles plays their own role in sediment transport rate and at what point particles deposit (Martin, 1955). Chemical properties of a particle will determine whether particles will aggregate and forming larger particles with different shapes and lesser densities. Commonly the densities of the aggregates are significantly lesser than that of primary particle (Rhoton, 1983).

2.5.1 Basic Principles of Sedimentation

The particle settings of sediments can be divided into four types according to their concentration and tendency to hinder each other.

2.5.1.1 Discrete particle settling

This setting refers to the settling with low concentration in a solution where each particle tend to fall independently.

2.5.1.2 Flocculent settling

Flocculent settling refers to settling particles of dilute solutions merge and form particles with larger mass and higher velocities.

2.5.1.3 Hindered settling

This settling refers to settling in which particle concentration is high that forces between the particles caught up with the settling of surrounding particles. This results in uniform settling of particles. It can be distinguished by a liquid-solid interface at the top of the solid mass.

2.5.1.4 Compression settling

This type of settling denotes in which particles are too concentrated that inter-particle bridging forms a stable structure. This bridging requires compression in order to further settle which resulted from the weight of additional particles settling on top of the settling mass.

2.6 Basic Heat Transfer Mechanisms

Heat transfer mechanisms are ways which defines the transfer of thermal energy between objects where they rely on basic principle that kinetic energy or heat to be at equilibrium or at energy equal states. (Cengel and Boyles (1989)

2.6.1 First law of thermodynamics

Also known as the conservation of energy principle, this principle states that energy can neither be created nor destroyed during a process. However it is able to change forms. Hence, every bit of energy must be considered during any process. The energy balance for any system undergoing any process can be expressed as:

$$\text{(Total energy entering system)} - \text{(Total energy leaving system)} = \text{(Change in total energy)} \tag{2.1}$$

Energy can be transferred to or from a system by heat, work, and mass flow such that the total energy of a simple compressible system is represented by internal, kinetic, and potential energies, therefore this expression can be written as:

$$E_{in} - E_{out} = \Delta E_{system} \tag{2.2}$$

2.6.2 Heat transfer mechanism in solid fin due to fluid motion

The heat transfer considered in this is on a solid fin which is in contact with coolant in motion. As such, the mechanism of heat transfer occurred is by convection. According to Cengel and Boyles (1989) convection can be defined as energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. This can be conveniently expressed by Newton's law of cooling:

$$\dot{Q}_{conv} = hA_s(T_s - T_\infty) \tag{2.3}$$

Where;

h = convection heat transfer in W/m2. C

As = Surface area through which convection takes place

Ts = Surface temperature

T∞ = Surrounding temperature

2.6.3 Heat transfer mechanism in tubular frame

The mechanism of heat transfer in a tube can be considered as conduction. According to John R. Thome, conduction in a metallic body is largely due to the random movement of electrons through the metal. Electrons present in the higher temperature of the solid have a higher kinetic energy compared to the cold part. The transfer of heat occurred due to the transfer of kinetic energy transfer from hot region to the cold region of the metal (John. T, 2004). Conduction can be represented by the Fourier's Equation:

$$\frac{Q}{A} = q = k\left(\frac{T_1 - T_2}{X_1 - X_2}\right) = k\frac{\Delta T}{\Delta X} \tag{2.4}$$

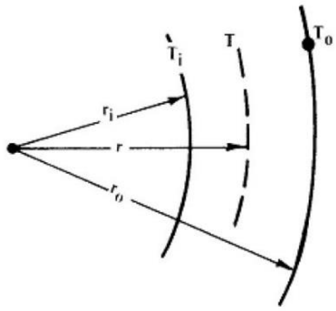
Where k = thermal conductivity of material

The heat transfer for tubular frame with radius r and tube length L can be written as:

$$\frac{Q}{2\pi rL} = -k\frac{dT}{dx} \tag{2.5}$$

For thin walled-tubes, the ratio of the outer to the inner radius is close to unity, therefore the equation can be written as:

$$Q = \frac{2\pi r_o L(T_i - T_o)}{r_o - r_i} \tag{2.6}$$



Where L is the total length of the tube

Figure 2.6: Conduction through a cylindrical wall (Source: R, Thome. J. (2004))

2.6.4 Theoretical Fin Efficiency

In a case where a heat exchanger has a large number of plate fins of more than with constant cross sectional area, the definition of theoretical fin efficiency can be written as (Kang, 2012):

$$\eta_{th} = \frac{\boldsymbol{Q}}{\boldsymbol{Q_{max}}} = \frac{Actual\ Heat\ Transfer}{Maximum\ Possible\ Heat\ Transfer} \quad (2.7)$$

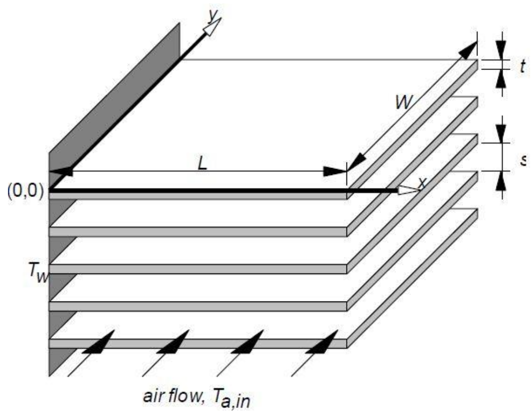


Figure 2.7: Heat exchanger with plate fins (Source: R, Thome. J. (2004))

If the boundary conditions are $\boldsymbol{T_f} = \boldsymbol{T_w}$ when x = 0, $\frac{\partial T_f}{\partial x}$ = 0 when x=L and under the assumption of:

I) Constant fluid temperature

II) Uniform heat transfer coefficient

III) One dimensional heat transfer

The equation of efficiency can be written as

$$\eta_{th} = \frac{tan\ hmL}{mL} \tag{2.8}$$

The parameter $mL = (\frac{hA}{kAc\ L})^{1/2}L$, where L, h, A, k, and Ac are length of fin, pure-heat transfer coefficient, fin surface area and thermal conductivity of fin and cross-sectional area of fin respectively

2.7 Selection Methods

Selection design is a process of evaluation concepts that had been design with respects to the customer needs and other engineering characteristic related to the project that we need to design. Also, this process is related the comparing the relative strengths and weakness of the concepts and selection the best concept design with comparing to other design and reference design. The selection of an overall product will be focuses from the beginning of development process before selecting the best design.

2.7.1 Pugh Selection Method

The pugh selection method was developed by Stuart Pugh who was a professor at the University of Strathclyde in Glasgow. The method is used in order to evaluate alternatives against certain baselines. Pugh selection method helps engineers in design decisions by establishing a procedure to choose the best design from the considered designs (Lugo, 2012). The steps taken when applying pugh selection method is explained below:

1. A list of criteria to be compared between different designs is required. Each criterion should be objectively quantifiable measure.
2. Weight factors for each criterion is to be established. It can be listed as 1 for important, 2 for very important and 3 as crucial to be part of the criteria needed.
3. List the ideas for designs to be analysed. Pugh selection method is best used for 3 or more designs. Each criteria is related to the designs available. Evaluation can be made based on the importance of the criteria as mentioned in step 2
4. Calculate each design score. This can be done by summing all the values for the designs which has been analysed. The design with the higher score is considered as the best design and the decision was made taken into consideration all of the criterions and designs in an objective manner (Lugo, 2012)

2.7.2 Concept Scoring

Concept Scoring is used when increased resolution will better differentiate among competing concepts. In this stage, weight is the relative importance of the selection criteria and focuses on more refined comparisons with respect to each criterion. The concepts scores are determined by the weighted sum of rating. In describing the concept scoring process, it's only focus on the differences relative to concept screening.

STEP 1: Prepare the Selection Matrix

As in screening stage, the next actions are preparing a matrix and identify a references concept. The concepts that have been identified for analysis are entered on the top of the matrix. Then, the concepts have typically been refined to some extent since concept screening and may be express in more detail. After the criteria are entered, the importance weights will be added to the matrix. Several different schemes can be used to weight the criteria, such as assigning an important value from 1 to 5, and allocating 100 percentage points among them.

STEP 2: Rate the Concept

In this stage, it's used a finer scale for the need of additional resolution to distinguish among competing concepts. Figure below shows an example of rating the concept.

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Figure 2.8: Rating for relative performance (Source: (Pugh, 1990))

STEP 3: Rank the Concepts

Once the ratings are entered for each concept, weighted score are calculated by multiplying the raw scores by the criteria weights. The total score for each concept is the sum of the weighted scores.

STEP 4: Combine and Improve the Concepts

As in the screening stage, the changes or combinations that improves concept can be looking. Although the formal concept generation process is typically completed before concept selection begins, some of the most creative refinements and improvements occur during the concept selection process as the requirement realizes the inherent strength and weakness of certain features of the product concepts. Table below shows an example of concept scoring.

Table 2.1: Concept Scoring (Source: (Pugh, 1990)

		Concept							
		A (Reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose metering accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	

2.8 Material Consideration and Selection

In designing process, material consideration is crucial because this step will affect the effectiveness as well as the durability of the design. A suitable material needs to be selected mainly based on the targeted function of the design made.

2.8.1 Copper Types and Properties

Copper is the most commonly used material for sheet and strips. In this context, the copper stated complies with ASTM B370 where it consist of 99.9% copper and is available in six tempers designated by ASTM B370 as 060 (soft), H00 (cold rolled), H01 (cold rolled, high yield), H02 (half hard), H03 (three quarter hard) as well as H04 (hard) (Copper Dev. Assoc, 2016). The actual number of ASTM tube and pipe specifications under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys requires analysis. According to Copper Development Association, the first three principal classes of copper tubular products is commonly referred to as commodity tube which includes the K-Type as the heaviest, L-Type for standard weight, and M-Type defined as the lightest wall thickness as classified by ASTM B88, B306 and B19. The significant properties of the ASTM B370 designated tempers can be summarized as in table below.

Table 2.2: Properties of Cold Rolled Copper (Source: Copper Development Association Inc.,www.copper.org)

Specific Gravity	8.89 – 8.94
Density	0.322lb./cu. In. at 68°F
Thermal Conductivity	226 BTU/Sq Ft/Ft/Hr °F at 68°F
Coefficient of Thermal Expansion	0.0000098/°F from 68°F to 572°F
Modulus of Elasticity (Tension)	17,000,000 psi
Tensile Strength	32,000 psi min
Yield Strength (0.5% Extension)	20,000 psi min.
Elongation in 2" – approx.	30%
Shear Strength	25,000 psi
Hardness –	
Rockwell (F Scale)	54 min.
Rockwell (T Scale)	15 min.

The bar chart below sums up the thermal properties of copper when compared to stainless steel. Later on, stainless steel is then compared with Aluminium in the next chapter.

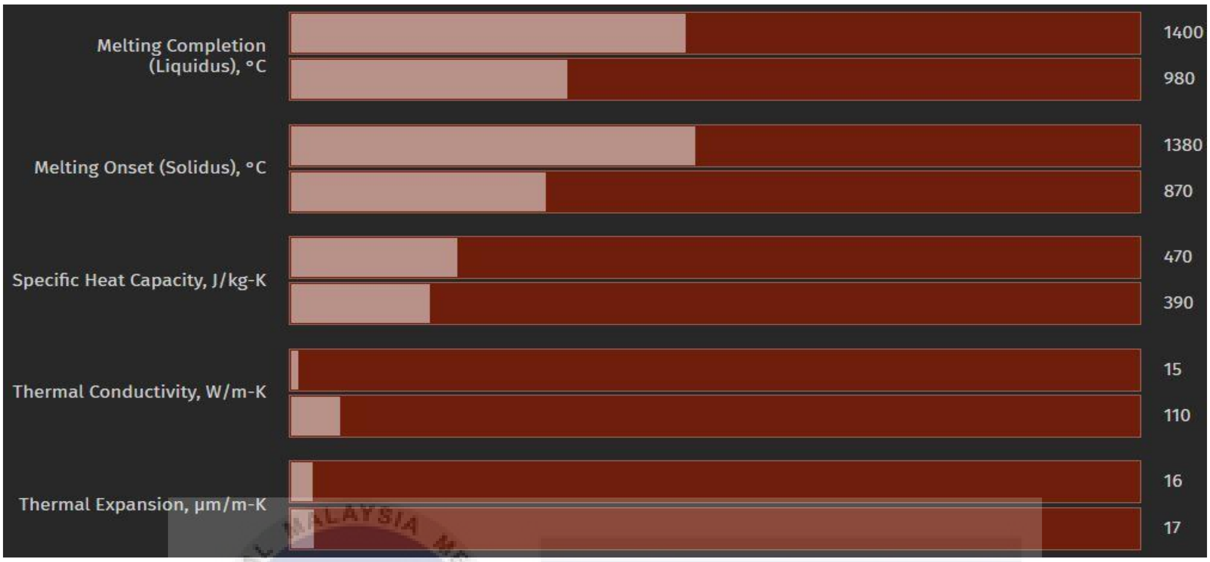


Figure 2.10: Thermal properties of copper versus stainless steel (Source: www.makeitfrom.com)

2.9 Room temperatures in Malaysia

In urban environment, a comfortable indoor condition can be considered as essential in order to set a healthy environment. Thermal comfort for humans can be related with several factors such air temperature, air movement, amount of clothing worn, as well as activity level including the human body itself (Jamaludin, 2015). The most distinctive trait of urban climate is that the temperature of air is higher than that of rural areas. In 2007, the Department of Standards Malaysia has published a guideline for a standard indoor temperature designed for Malaysian climate which recommends a temperature ranging from 25°C to 28°C. This amendment was made from the previous guideline of 23°C to 26°C in 2005 being that 25°C is the normal ambient temperature in Malaysia.

2.10 Vortex Tube

Vortex tube was designed by Georges Ranque, a French Physicist in 1930s. It has no moving mechanical parts. According to Smith and Pongjet (2008), a vortex tube or Ranque-Hilsch vortex tube is a device that enables the separation of hot and cold air as compressed air flows tangentially into the vortex chamber via inlet nozzles. A typical vortex tube is able to separate compressed air into a hot and a cold output. This can be seen in figure 2.11 below. According to ATX Air Company (AiRTX), depending on the input temperature of the compressed air, the cold outlet of the tube can reach as low as -40 degree Celsius while the hot outlet can go as high as 110 degrees Celsius.

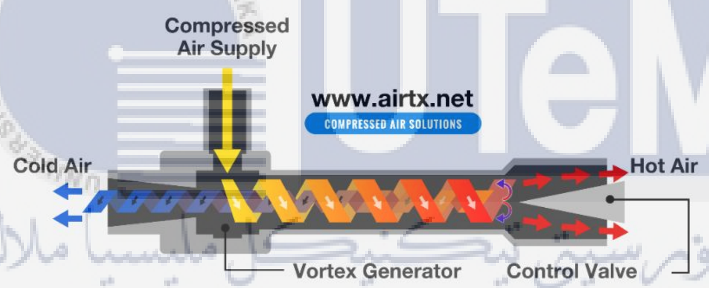


Figure 2.11: Working mechanism of a vortex tube (Source: www.airtx.net)

According to Farno.B (2016), a typical vortex tube with a 50% cold fraction will produce a temperature drop of 28.3 ℃ when inserted at a pressure of 1.4bar. The table below will provide a clearer view of the temperature drops.

Table 2.3: Summary of temperature drop for vortex tube cold outlet and pressure rise for hot outlet based on cold fraction. (Source: Farno.B (2016))

Pressure Supply	**Cold Fraction %**						
BAR	**20**	**30**	**40**	**50**	**60**	**70**	**80**
1.4	34.4	33.3	31.1	28.3	24.4	20.0	15.6
	8.3	13.9	20.0	28.3	35.6	46.1	59.4
2	40.9	39.6	37.1	33.8	29.2	24.0	18.1
	9.8	16.4	24.0	33.3	42.6	54.6	69.5
3	50.4	48.7	45.7	41.6	36.0	29.7	21.9
	12.0	19.9	29.6	40.3	52.3	66.5	83.5
4	56.9	54.7	50.9	46.1	40.0	32.9	25.1
	13.2	21.9	32.4	43.9	57.1	72.5	91.2
5	61.6	59.0	54.8	49.4	43.0	35.4	26.9
	13.7	23.3	34.2	46.5	60.9	77.2	97.1

Based on the table, a standard vortex tube with a 50% cold fraction when supplied with 1.4bar of compressed air will give a reduction of 28.3℃ to the initial temperature value. For this study, the compressed air pressure was measured to be at 1.4bar. Numbers in the shaded area gives the temperature rise of hot air in ℃, while numbers in the white area gives the temperature drop of cold air in ℃.

CHAPTER 3

DESIGN SPECIFICATIONS

3.1 INTRODUCTION

In this section, the design of the external filter is investigated through multiple criterions. These criterion includes number of filters, filter position, filtered coolant output position, cooling system, and presence of multiple types of filter as well the engineering factor of heat transfer coefficient for cooling mechanism present in the project. The gross dimensions of the filter are compiled in this chapter as initial assumptions before proceeding with the detailed design process.

3.2 Product Design Specifications

Main purpose of design process planning is to identify, search as well gather as much information to know whether the product development is a good investment for the manufacturer to decide the marketing purpose. Product design specification (PDS) is an important document in design process since this part contains the information of the external coolant filter.

3.2.1 External Filter Parameter

This section highlights on the specifications of the proposed external coolant filter structure. For this project, 2 types of coolant filter chambers were focused on. These can be listed as the vertical chamber and the horizontal chamber. According to a sample of an existing product by CMP filtering company, the inlet for the coolant is 36 inches (91.44cm) for a wetted filter area of 4 square feet on a vertical chamber. This inlet width is maintained until the wetted area is 30 square feet. For the horizontal chamber, the coolant media inlet is smaller for up to 6 square feet of wetted area, which is 12.75 inches (32.39cm). The general requirement of a typical flow rate from the reservoir is needed to be 30 Gallons per square feet. As for the filtration media, a standard industry blend of rayon or polyester paper roll is used. These paper roll blend has a particle tolerance size up to 10 microns. Lastly, the sample product has a width of 27 inches (68.8 cm) and a length of 67 inches (170.18 cm) in length which is able to process up to 100 Gallons per cycle. These initial dimensions are roughly used as a reference and may differ on the actual presented ideas. Tables below summarizes the reference product as stated.

Table 3.1: Dimensioning for reference products (Source: CMP Filtration)

Model	Wetted Area (sq.ft)	Flow Rate (GPM)	Paper Width (inches)	Tank Width (inches)	Tank Length (inches)	Tank Volume (gallons)
HPS/HPN-15/PBLS-6.5	6.5	10-20	24	27	67	100
HPS/HPN-20/PBLS-10	10	20-30	36	39	67	150
HPS/HPN-30/PBLS-15	15	30-40	36	39	91	200
HPS/HPN-40/PBLS-18	18	40-50	36	39	103	225
HPS/HPN-50/PBLS-20	20	50-60	48	51	91	250
HPS/HPN-70/PBLS-24	24	60-70	48	51	103	275
HPS/HPN-90/PBLS-28	28	80-90	48	51	115	300
HPS/HPN-130/PBLS-38	38	100-130	48	51	144	375
HPS/HPN-150/PBLS-50	50	130-150	48	51	180	475

3.2.2 Vertical and Horizontal Chamber

According to CMP Filtration, their vertical chamber high pressure filter can be classified into 5 products. These products can be listed as PFV-4, PFV-10, PFV-15, PFV-30, and PFV-60. The product reference number varies according to their wetted filter area in square feet which is 4, 10, 15, 30 as well as 60. The media width is the same for the first three models; 36 inches. Larger wetted areas brings larger media width with 65 inches and 72 inches. The filter head dimensions are listed in the table below.

Table 3.2: Vertical chamber high pressure filter specifications (Source: CMS Filtration)

Vertical Chamber High Pressure Filter

Model	Wetted Filter Area (sq. ft)	Media Width (in.)	Filter Head Dimensions LxWxH (in.)
PFV-4	4	36	79x58x72
PFV-10	10	36	114x58x72
PFV-15	15	36	135x58x99
PFV-30	30	65	135x88x99
PFV-60	60	72	200x88x147

As for the horizontal chamber high pressure filter, it varies significantly from the vertical series. It has 8 models with a range of wetted filter area starting from 3 square feet up to 36 square feet. The media width differs starting from the third model with 27 inches, on the fifth model with 36 inches and lastly on the seventh model with a media width of 51 inches. The filter head dimensions are listed in the table below.

Table 3.4: Horizontal Chamber High Pressure Filter dimensions (Source: CMP Filtration)

Horizontal Chamber High Pressure Filter

Model	Wetted Filter Area (sq. ft)	Media Width (in.)	Filter Head Dimensions LxWxH
PF-3	3	12.75	5'6"x3'3"x5'6"
PF-6	6	12.75	5'6"x3'3"x5'6"
PF-9	9	27	7'x4'3"x5'6"
PF-12	12	27	8'6"x4'3"x5'6"
PF-15	15	36	8'x5'6"x5'9"
PF-18	18	36	9'6"x5'6"x5'9"
PF-24	24	51	10'3"x5'6"x5'9"
PF-36	36	51	11'6"x5'6"x5'9"

3.2.3 Filtration Media

For their filters, CMP Filtration uses the same material, a standard industry rayon or polyester blend paper roll media. It is also equipped with gravity paper bed filters. Filtration media can be categorised according to their width. Different width are used with respect to the desired filtered particle size. A 19.5 inched media is capable to filter up to 80 microns. This comes with a weight of 0.50 ounces. For a 27 inched media, the filtered size of particle is up to 40 microns with heavier weight of 0.80 ounces. The filtered particle size decreases by half for 29 inched media and 30 inched. However, their weight in ounces increases to 1.25 ounce for 29 inched media, and 1.50 ounces for 30 inched media. Filtration media provided by CMD Filtration varies in length for each type. This can be summarised by the table below.

FILTRATION MEDIA

Standard industry rayon/polyester blend paper roll media used with most domestic and import gravity paper bed filters. Media can be ordered in custom widths as well as polypropylene and other grades,

Width (inches)	Rating (Micron)	Weight (oz)	250 Yd (OD)	500 Yd (OD)
19.5	80	.50	8"	11"
27	40	.80	9"	13"
29	20	1.25	10"	14"
30	10	1.50	11"	15"
36				
39				
40				
48				
50				

Table 3.5: Filtration media dimensioning with particle size tolerance (Source: CMS Filtration)

3.3 Cooling Fins and Tube Materials

Material selection is one of the crucial steps in a design process. Material selected must be according to the desired properties. For this section, since copper has been described in the previous chapter; three metals were compared simultaneously and ranked according to the desired features and properties. This is done by using the CES Selector software. The three metals are aluminium, galvanized coated steel, and austenitic stainless steel – AISI 205. These materials are compared in terms of maximum service temperature, thermal conductivity as well as melting point. The result for comparisons are shown in the graphs below.

3.3.1 Maximum service temperature

According to the software, aluminium is ranked as the lowest, followed by galvanized coated steel. An austenitic stainless steel gives the highest fracture toughness and maximum service temperature. Considering that coolant temperature exiting the machine is slightly higher than room temperature, therefore either one of the three materials compared can be used for the idea.

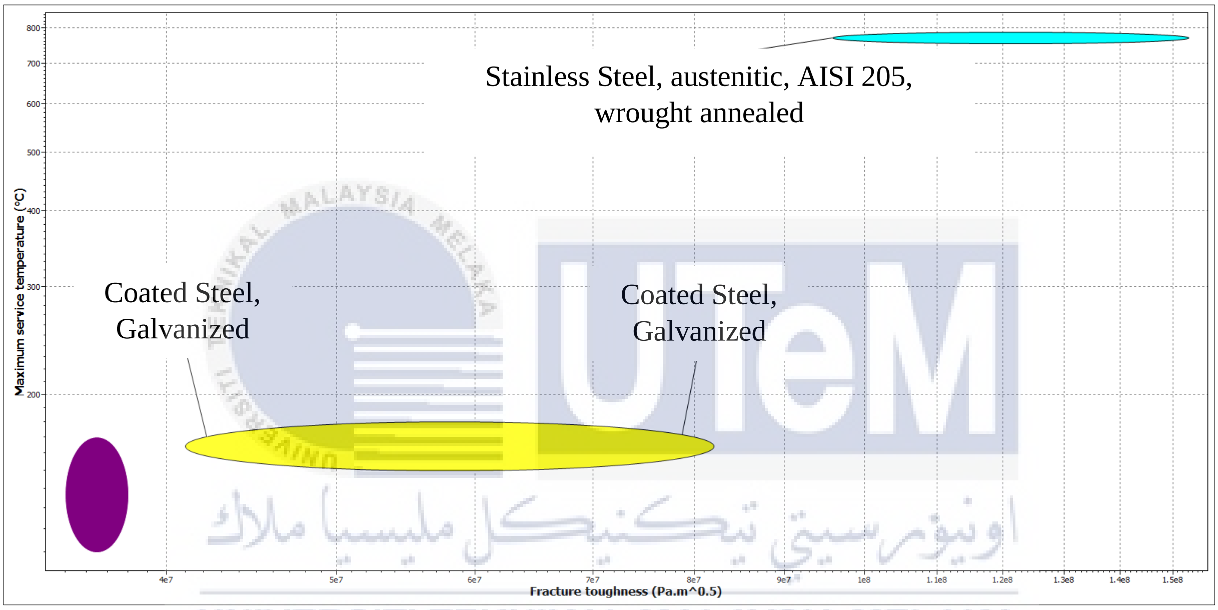


Figure 3.1: Fracture toughness (Pa.m^0.5), Maximum Service temperature

3.3.2 Thermal conductivity of material

Based on the graph below, galvanized steel has the lowest thermal conductivity, followed by austenitic stainless steel. Aluminium gives the highest thermal conductivity of 205 W/mK. For this section, the material with the highest thermal conductivity is to be chosen in order to maximize the cooling effect of the filter. However, it aluminium also yields to be the most expensive material between the three.

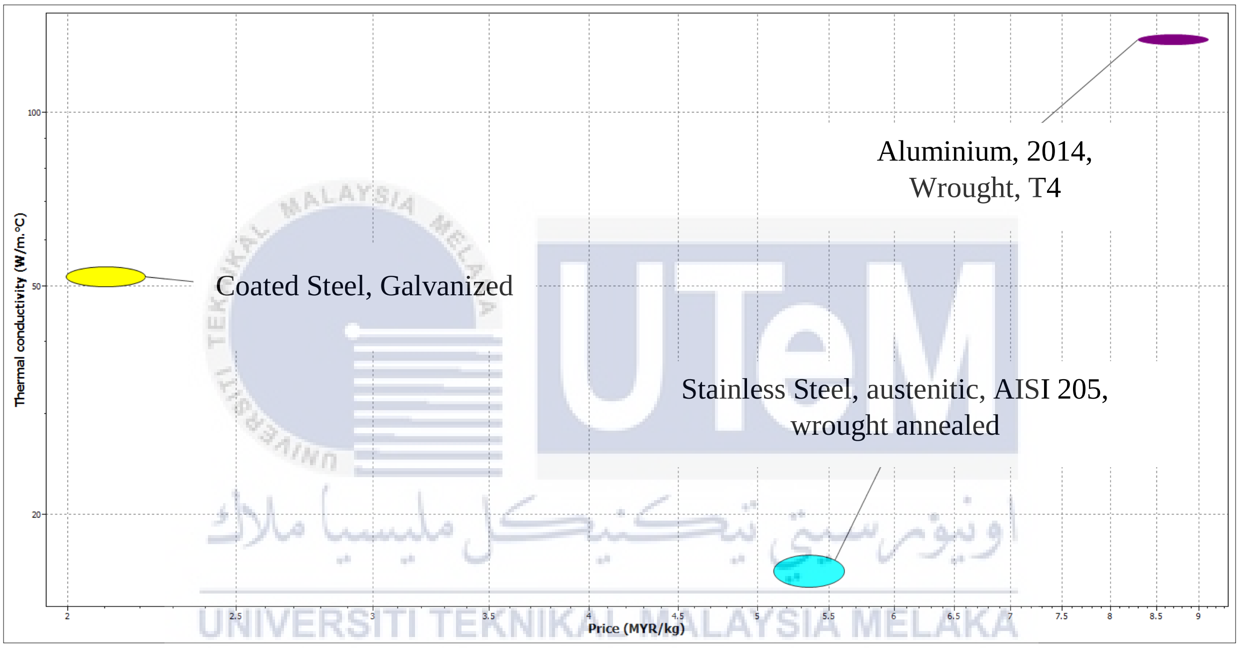


Figure 3.2: Thermal conductivity vs Price per kg

3.3.3 Melting point

The result shown below on the graph shows that galvanized steel has the highest melting point. This is followed closely by austenitic stainless steel and lastly the material with the lowest melting point, aluminium. Since the temperature of the coolant entering the filter deviates slightly from room temperature, any of the three materials can be chosen.

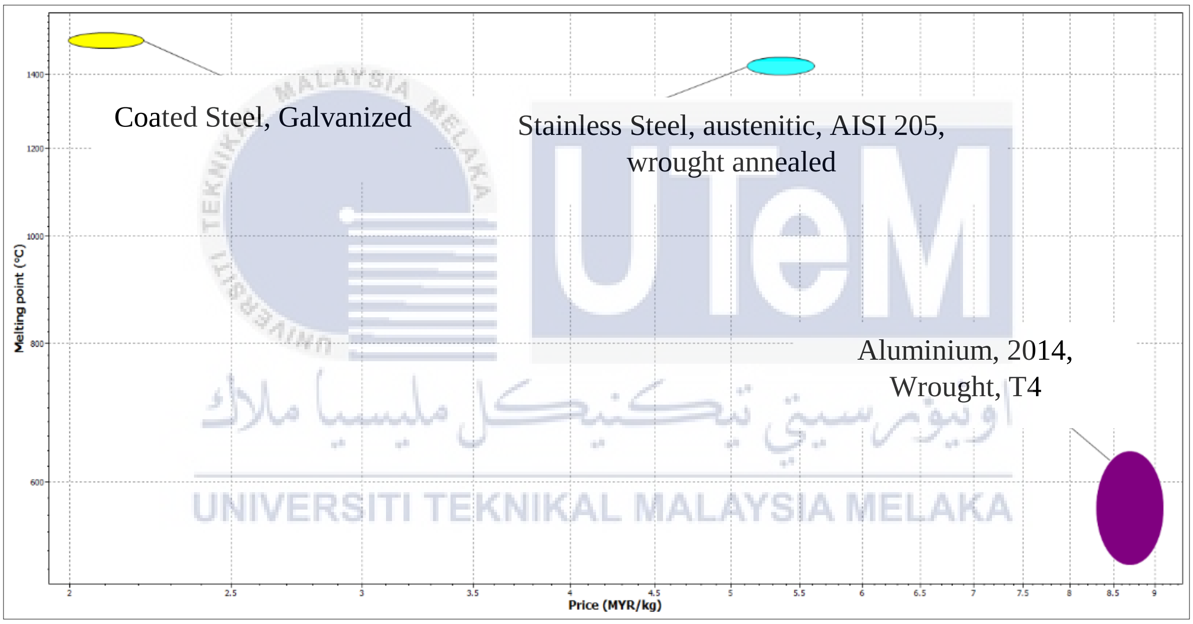


Figure 3.3: Melting point of material in Celsius vs. price per kg in MYR

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter will cover the methodology of the project flow that would be used along this project. Methodology is a process for implementation and developing the project. This is a crucial step in order to get satisfactory results. The objectives and the successfulness of the project depends on how this project plan is executed. The methodology flow chart process will be the master plan on this project and all the process will be discuss in this chapter. At the end of the plan, this project should follow the criterion and specifications discussed on previous chapters. Other than that, methodology also acts as guideline of the project in order to achieve the objectives of this project. Basically, the drawing process is important for landing ideas onto the field. Afterwards, the desired drawing is obtained and furthered with detail design using CAD software.

4.2 Literature Research

Literature research is the core of this project. This part determines the goals and objectives of this project. In this part, all of the information and data must be facts, correct and accurate in order to study and analysis the information before we can start the project. In literature research, all information and data are from various sources such as books, journals, articles, magazine, internet and more. Other than that for this section, the study of previous researches and project which is similar to this project will be conducted in order to get more information and act as references that helps in finishing this project. In chapter 2, all the information that we obtained will be compiled and noted

4.3 Concept Design

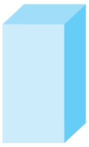
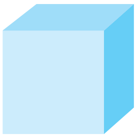
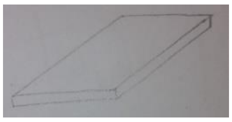
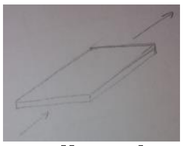
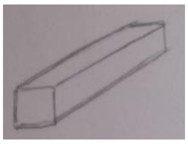
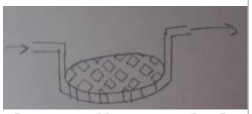
Concept design is one of the main process in designing a new product that comes from generating idea in designing product/ part/ system that based on several specifications mentioned before. For the external coolant filter project, the concept design will be created based on ideas and functions of the design. According to Pugh (1991) and Pahlete al. (2007), conceptual design of product development process is a preliminary stage of design activities because various decision making problems are addressed at this stage such as materials selection, design concept selection and manufacturing process election. Therefore, considering the right decision at this stage is very important and critical. Also, this concept design is generated from the brainstorming, research from journal, internet, book as well as articles.

In this section, several concept designs will be generated which conclude different type of mechanism, shape and part, system functioning and also technical aspects. Other than that, in order to generate the best concept of external filter, we must think creatively and innovatively in developing ideas based on information obtained. In addition, the concept designs will need a few researches on existing product or system as specification reference in order to generate the good quality of concept design. Whole concept designs are obtained by combining elements in morphological chart.

4.3.1 Morphological chart

Morphological chart is a method applied to generate as many as possible conceptual design. They can be expressed as a method to widen the search of possibilities in optimizing design. The procedure starts with listing all desired aspect or functions of the product. List of functions were placed in the first column in the table. Each function is followed by means or sub solutions in the next columns. These sub solutions can be infinite, thus the number should be kept reasonably short for possible combinations. Combinations are made by combining elements in each row at a time. Table below indicates the morphological chart used for this project.

Table 4.1: Morphological chart for external coolant filter

Main Body Shape					
Number Of Filters	**3**	**2**			
Cooling System	 Metal Fins	 Hollow Thin Plates	 Metal Fin Strips	 Cylindrical Thin Hollow Metal	 Thin Hollow Holed Plate
Filter Position	Vertical	Horizontal			
Outlet Flow Position	**Topside**	**Bottom**			

Next, the concept design will be created as a rough sketch of drawing or three-dimensional model from clay or paper. For this project, the concept design will be expressed by sketching. Also, the concept design will be reviewed and modified several times in order to improve the concept designs to become more effective and suitable for this project. The concept design process begins with a set of customer needs and target specification and results in asset product concepts from which product will be final selection (Karl T. Ulrich et al. 2003).

4.3.2 Conceptual Design of External Coolant Filter

The concept of external coolant filter is inspired from a problem emerged at Panasonic Air Conditioning Sdn. Bhd. as mentioned before. The idea is to lower the coolant temperature in order to obtain a more satisfying surface finish. Therefore the filter must be able to lower coolant temperature along with filtering functions.

Concept 1 shown in figure below is made of hollowed cubicle as the base shape. This design is accompanied with three removable filters to ensure thorough filtration. Furthermore, there are cooling flap fins extending from the insides of the structure. These flaps also acts as flow guide ways to ensure coolant flows from down to top. The design is equipped with three filters with different filter media size, which is smaller than the previous filter thus ensuring a thorough filtration.

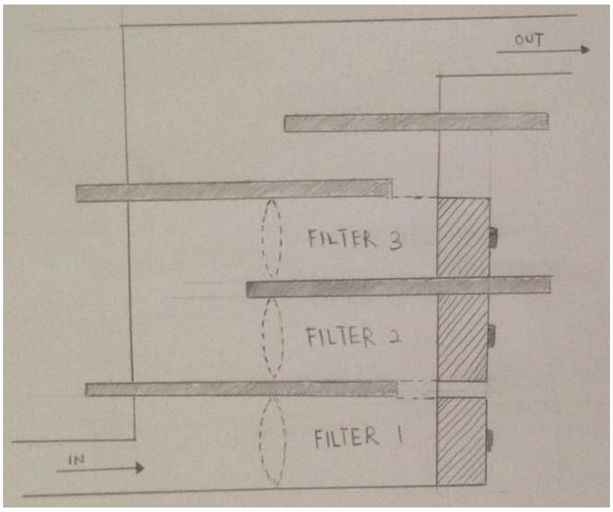


Figure 4.1: Concept 1

Concept 2 shown below was developed from the same base shape as concept 1. However, on the contrary this design is equipped with 2 filters with different types of filter. The first filter is aimed to filter large sized contaminants while the second filter is targeted to be able to filter smaller contaminants which passes through the first filter. The difference is that this concept has hollowed metal sheet bar attached in the middle. This sheet bar is aimed to function like a cooling strip fin, only it cools the surrounding faster by flowing compressed air through.

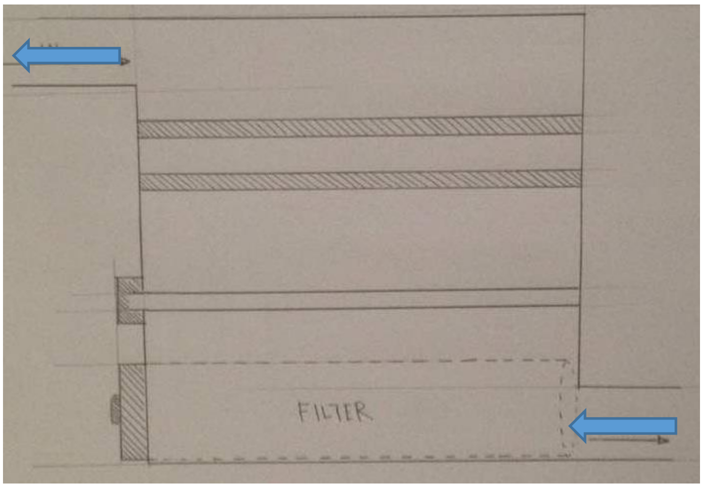


Figure 4.2: Concept 2

Moving on to the third concept, this design has the interior body shaped like “D”. It is then covered in a cylindrical shaped outer case. This design combines both cooling strip fins mechanism with air flow. Compressed air will flow in between the interior and exterior body, passing through the metal fins and exits from the top. This concept design flows coolant from the top to the bottom. For this design, it is equipped with 2 types of filters with different filter media sizes. This is to ensure thorough filtration. The first filter is aimed to filter larger contaminants while the second filter located at the bottom is aimed to filter smaller contaminants.

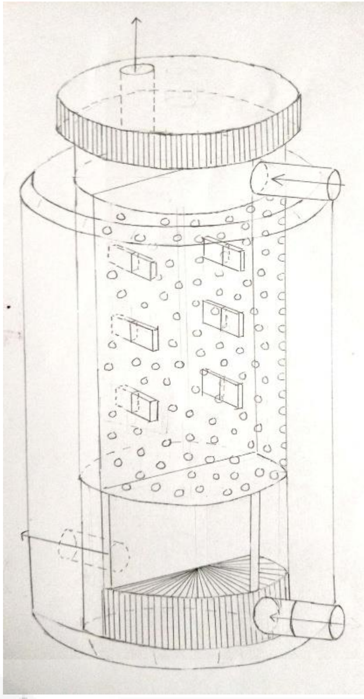


Figure 4.3: Concept 3

Next, by using the same concept, concept 4 is designed with a cylindrical inner and outer body. By applying the cooling mechanism concept in concept 2, the hollow metal sheets is converted in to tubular frames and wrapped around first filter. This design is targeted to lower coolant temperature faster with decent filtering capacity per minute. This concept filters coolant starting from the top flowing to the bottom where filtered coolant exits.

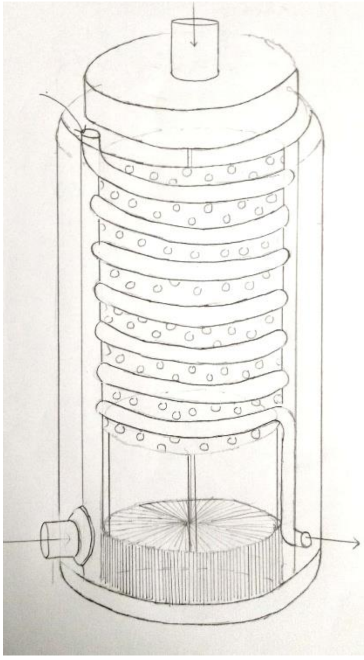


Figure 4.4: Concept 4

The last concept uses cylindrical shape as its base body. The filtering system is similar to concept 3. On the other hand, the cooling mechanism attached to this concept is made up of metal sheets with holes. This allows coolant to flow through and making it as a heat exchanger.

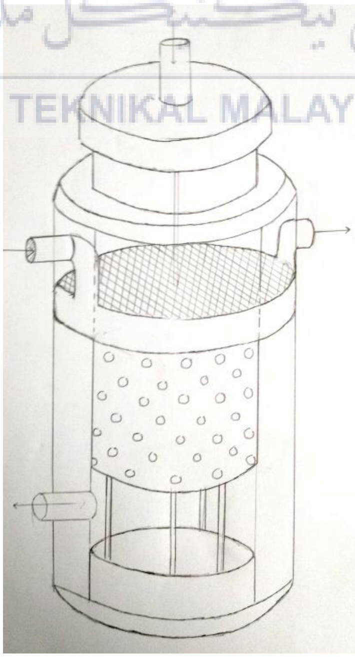


Figure 4.5: Concept 5

4.3.3 Pugh Selection method

Table 4.2: Pugh Selection Method for all Concept

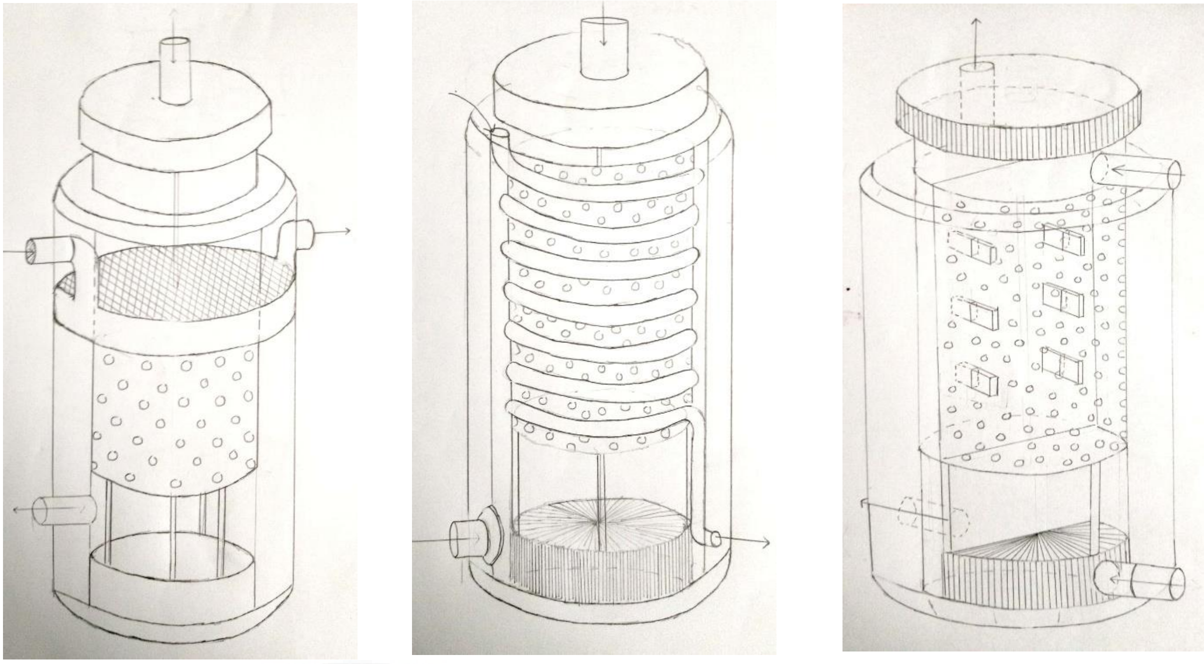
Criteria	Datum	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
No. of Filters	D	+	+	+	+	+
Filter Position	A	-	-	+	+	+
Output Position	T	+	-	-	+	+
Cooling System	U	+	+	+	+	+
Multi Filter Type	M	-	+	+	+	+
Ease of Maintenance		-	-	-	+	+
Net Score		+3	+3	+4	+6	+6
Rank		**5**	**4**	**3**	**2**	**1**
Continue?		No	No	Yes	Yes	Yes

Table above shows Pugh selection method. By using current existing product produced by CMP filtering company, there are 5 criteria listed as reference. With respect to these criteria, the concepts obtained are distinguished by points. The first criteria is number of filters present in the current product. For concept designs with more filter numbers, a positive sign is awarded. However for concept designs with similar or less filter numbers a minus sign is awarded. Second criteria is filter position where the current product offers a horizontally placed filter. A '+' sign is given for designs with contradicting filter position while '-'sign is awarded for no change of filter orientation. A vertically placed filter will save more space and is more efficient as stated in the literature review section. The next criteria is output position. The current product releases filtered coolant lower than the inlet position. Considering sedimentation to occur, normally lower outlet position compared to the inlet position will cause sediments to flow alongside with the coolant. However, if this occurs during filtering-flow process then the design is considered a failure. As such, a point is awarded if the design follows the current product’s flow positioning. Next criteria to be considered is the multi filter presence in the designs. Current product has only 1 type of filter installed.

By inserting 2 or more filter types, cleaning of filter need not to be done regularly. Lastly, ease of maintenance is to be considered as a criteria since complicated filter designs tend to lead to longer maintenance time.

4.4 Three best concept

Based on the Pugh Selection Method shown earlier, three concept designs which were evaluated out of 5 concepts showed the highest ranking. In short, the top three concepts advances into the next step. The three concepts are then prepared for detailed drawing process by using CATIA V5 R20 software. The highest ranked concept is the fifth design which triumphed the selection method with 6 points. Similarly, the second design chosen was the fourth concept. The last concept which was chosen is the third concept with a total of 4 extra points compared to existing products. These concepts are shown below.



Concept 5(1) **Concept 4(2)** **Concept 3(3)**

Figure 4.6: Three best concept

4.5 Detailed Drawing

Each conceptual drawings were transferred into detailed drawings by using CATIA v5 R20 software. Some drawing were modified based on aspects such as material reduction and functionality. These specifications may change after simulation process takes place to analyse heat flow. Then, the final dimensions are obtained by optimizing the design in order to obtain optimum design specifications.

The Figure 4.7 shows the detail drawing of concept 5 in isometric view. Meanwhile, the Figure 4.8 shown is concept 5 with internal parts outlined as hidden lines.

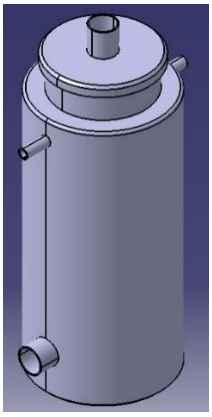


Figure 4.7: Detail drawing of concept 5 in isometric view

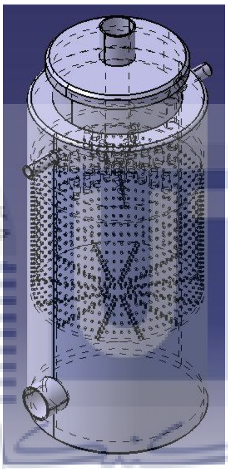


Figure 4.8: Detail drawing of concept 5 with outline

Figure 4.9 shows the detail drawing of concept 4 in isometric view. Meanwhile, the figure4.10 shown is concept 4 with internal parts outlined as hidden lines.

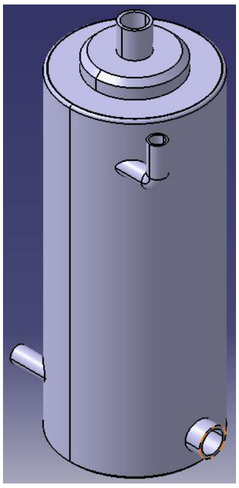


Figure 4.9: Detail drawing of concept 4 in isometric view

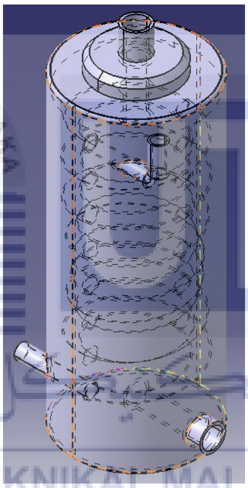


Figure 4.10: Detail drawing of concept 4 with outlines

Figure 4.11 shows the detail drawing of concept 3 in isometric view while figure 4.12 shown is concept 3 with internal parts outlined as hidden lines.

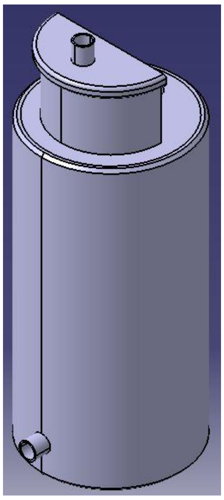


Figure 4.11: Detail drawing of concept 3 in isometric view

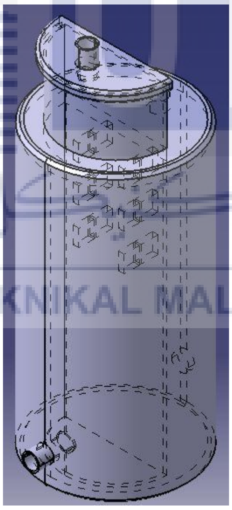


Figure 4.12: Detail drawing of concept 3 with outlines

These selected conceptual designs were prepared to proceed with heat flow analysis in order to obtain the results of performance for each design.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

This section provides the method used in order to obtain the results through engineering analysis by means of software analysis. For this section, the software in use is ANSYS 16.0. In a design process of any product, the selected best designs will be filtered through means of analysis in order to determine the most appropriate and effective concept.

5.2 Analysis of Conceptual Design

For this project, all three best concepts were analysed by using ANSYS 16.0 with the same parameters. These parameters include air inlet temperature and coolant inlet temperature. Later on, the concepts were then tested with a range of temperature starting from 25 ℃ to 30 ℃. The purpose of the analysis is to determine the most efficient concept with respect to the objective of this study. The design which gives the most temperature reduction percentage is to be selected for the design optimisation process and later on undergo the same analysis of temperature drop percentage.

According to Dieter and Schmidt, in engineering design activity, any product or system needs to be evaluated in terms of performance before proceeding with manufacturing processes. This allows analytic efficiency and deficiency or failure of the proposed design. An approach to efficiently analyse a product or system requires descriptions of each proposed design that are detailed enough to be calculated or accurately analysed and calculated. This description for analysis is called a model. The model can include a representation of the criteria such as the shape and constraints on the design detail to be modelled and mathematical equations that defines its behaviour.

In order to perform heat flow analysis on each design, the inlet and outlet for both air and coolant is to be declared. The Figure 5.1 shows the flow for air and coolant for all 3 concept designs. Note that the light blue arrow indicates air inlet (AI), blue arrow indicates hot air outlet (HA), red arrow indicates hot coolant inlet (HC) and orange arrow indicates cooled coolant outlet flow (CC).

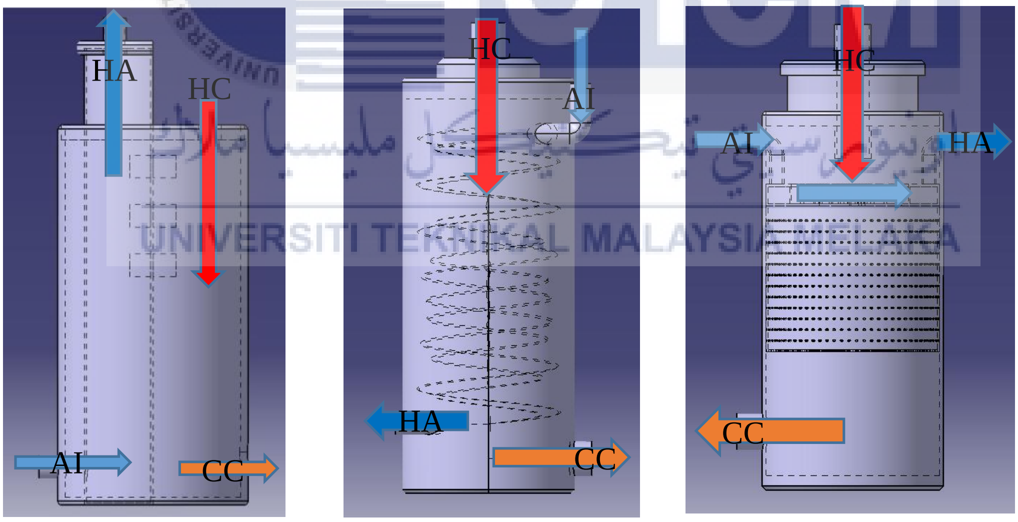


Figure 5.1: Air and coolant flow direction for concept 3,4 and 5 respectively

5.2.1 ANSYS Result on Heat Flow Analysis

ANSYS inc, is a computer-aided engineering developer company that originated in Pennsylvania, United States. The main product from this company is simulation-driven software ANSYS. ANSYS Mechanical software is a comprehensive FEA analysis (finite element) tool for structural analysis, including linear, nonlinear and dynamic studies. The engineering simulation product provides a complete set of elements behaviour, material models and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermo-electric analysis. Figure 5.4 shows an example of ANSYS analysis.

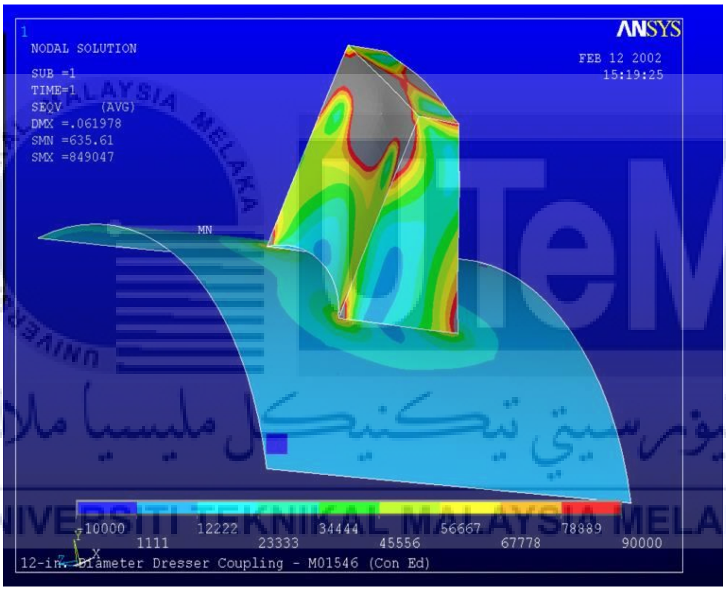


Figure 5.2: Sample of an ANSYS analysis (Source: ANSYS)

At the beginning of the analysis, all 3 concepts were analysed by using 27℃ as the temperature for the coolant inlet as stated earlier in this chapter. Later on, the concepts were analysed again with a temperature range of 25℃ to 30℃. This is to determine the efficiency of the concepts with variable temperature range thus determining the most efficient concept design.

5.2.1.1 Concept 3 Analysis

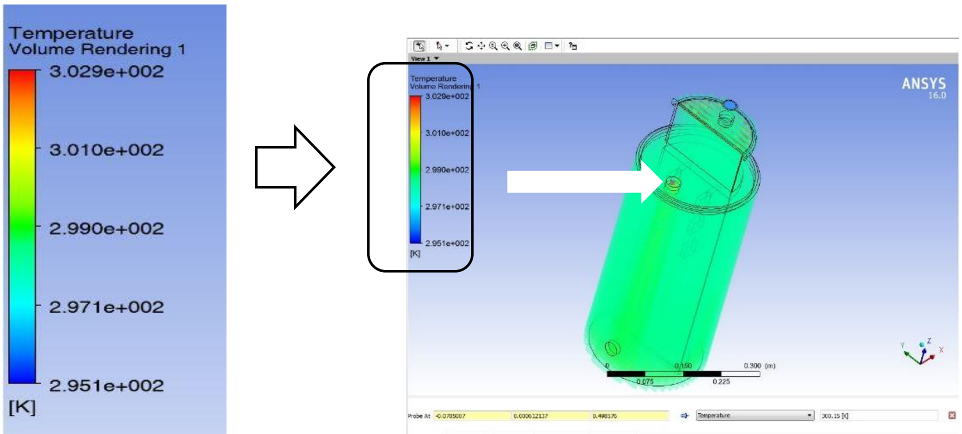


Figure 5.3: Coolant inlet temperature set at 27 °C

Figure 5.3 above shows that the coolant inlet temperature was set at 27℃ and the coolant outlet temperature after analysis of 25℃. The temperature shown in the figure is in Kelvin.

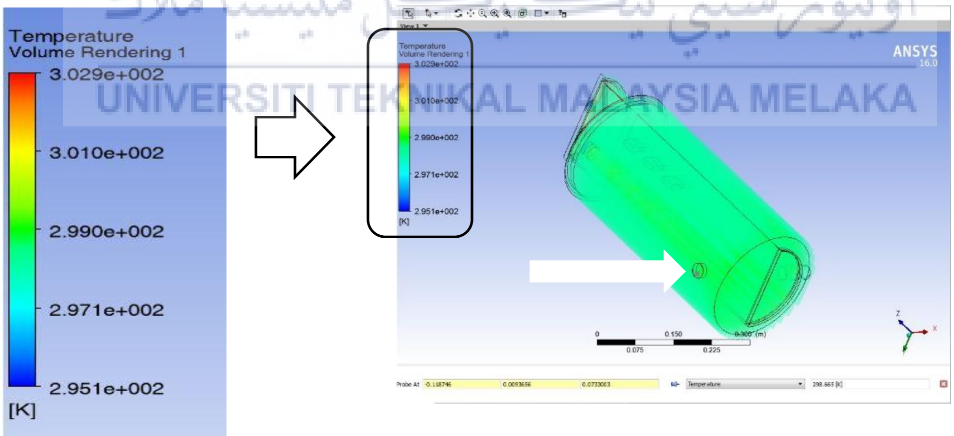


Figure 5.4: Corresponding coolant outlet temperature of 25 °C

Figure 5.4 above shows that the coolant inlet temperature was set at 27°C and the coolant outlet temperature after analysis of 25°C. The temperature shown in the figure is in Kelvin.

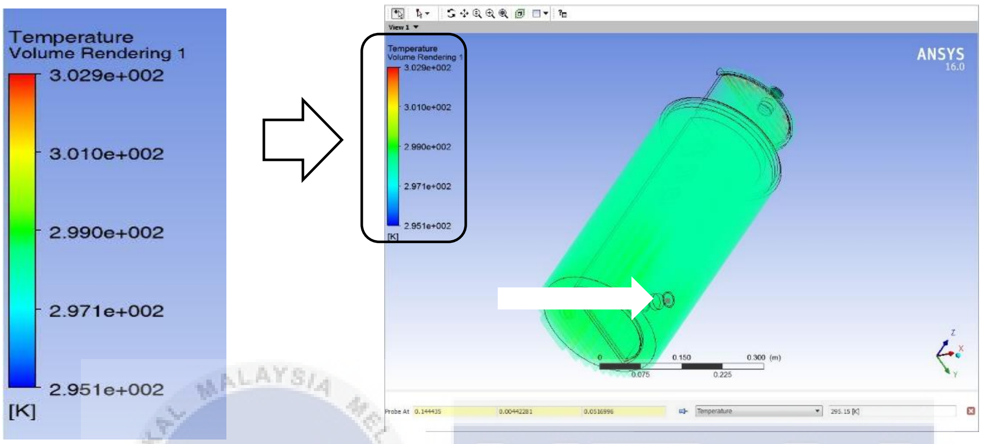


Figure 5.5: Air inlet temperature set at 22 °C

Figure 5.5 above shows the inlet air temperature of 22°C and its corresponding air outlet temperature of 25°C after analysis. The temperature shown in the figure is in Kelvin.

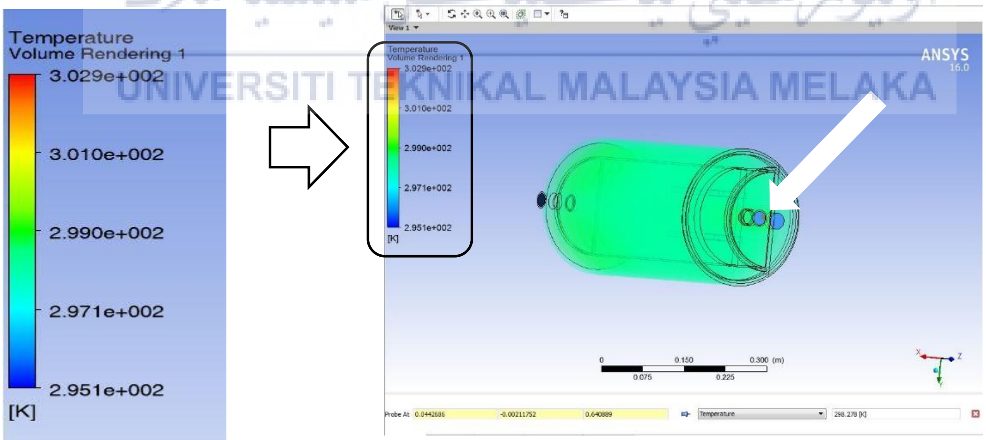


Figure 5.6: Corresponding air outlet temperature of 25 °C

Figure 5.6 shows the inlet air temperature of 22°C and its corresponding air outlet temperature of 25°C after analysis. The temperature shown in the figure is in Kelvin.

5.2.1.2 Concept 4 Analysis

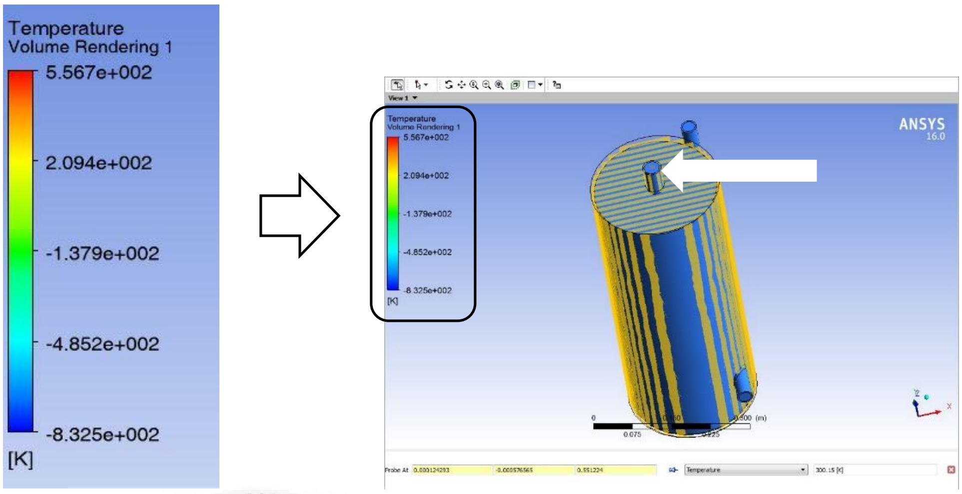


Figure 5.7: Coolant inlet temperature set at 27 °C

Figure 5.7 above shows that the coolant inlet temperature was set at 27°C and the coolant outlet temperature after analysis of 25.05°C. The temperature shown in the figure is in Kelvin.

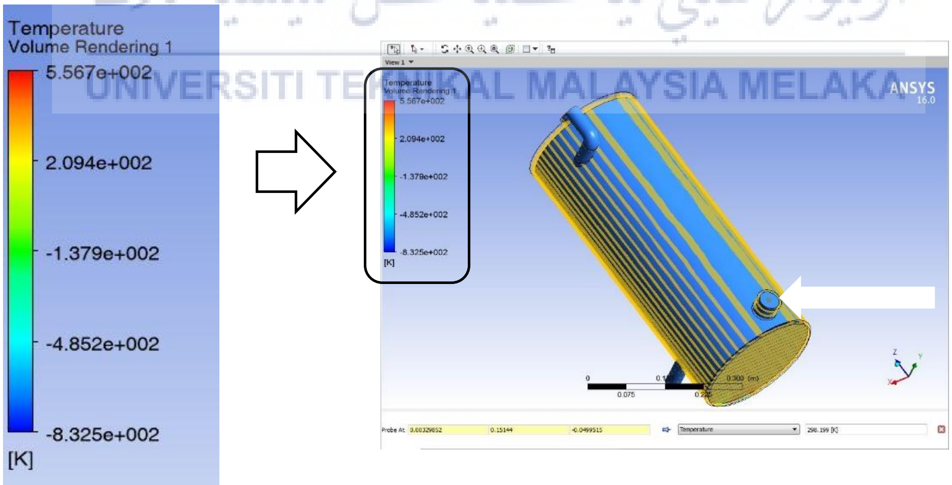


Figure 5.8: Corresponding coolant outlet temperature of 25.05 °C

Figure 5.8 above shows that the coolant inlet temperature was set at 27℃ and the coolant outlet temperature after analysis of 25.05℃. The temperature shown in the figure is in Kelvin.

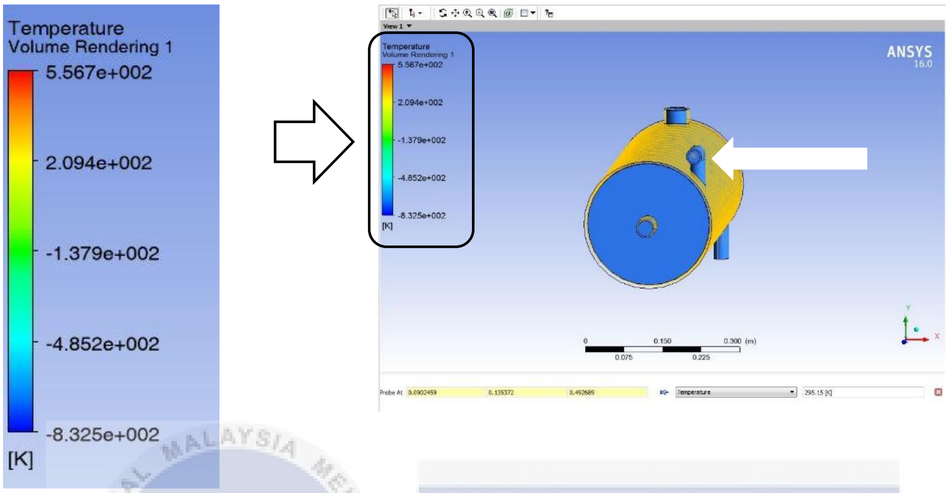


Figure 5.9: Air inlet temperature set at 22 ℃

Figure 5.9 shows the inlet air temperature of 22℃ and its corresponding air outlet temperature of 25℃ after analysis. The temperature shown in the figure is in Kelvin.

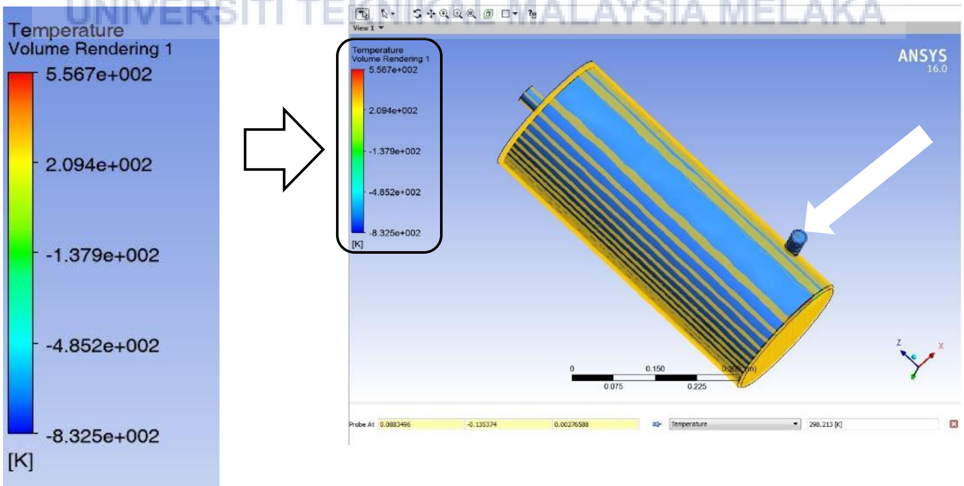


Figure 5.10: Corresponding air outlet temperature of 25 ℃

Figure 5.10 shows the inlet air temperature of 22°C and its corresponding air outlet temperature of 25°C after analysis. The temperature shown in the figure is in Kelvin.

5.2.1.3 Concept 5 Analysis

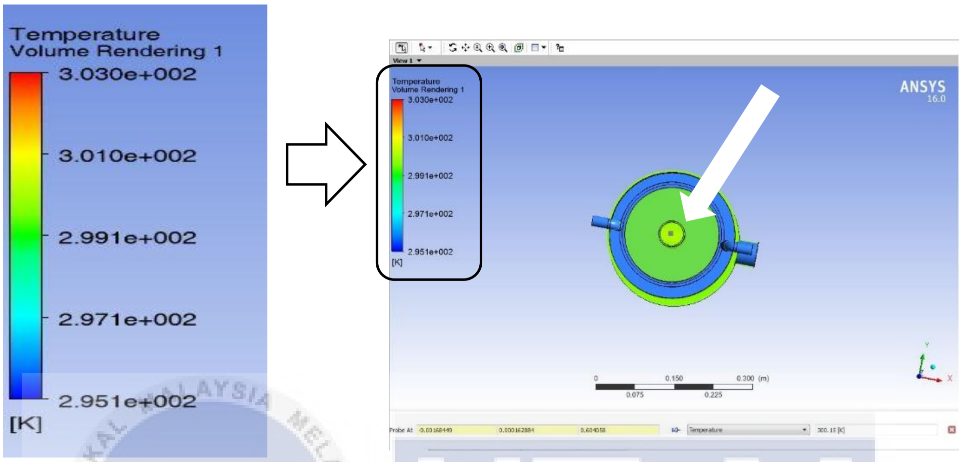


Figure 5.11: Coolant inlet temperature set at 27 °C

Figure 5.11 above shows that the coolant inlet temperature was set at 27°C and the coolant outlet temperature after analysis of 26.5°C. The temperature shown in the figure is in Kelvin.

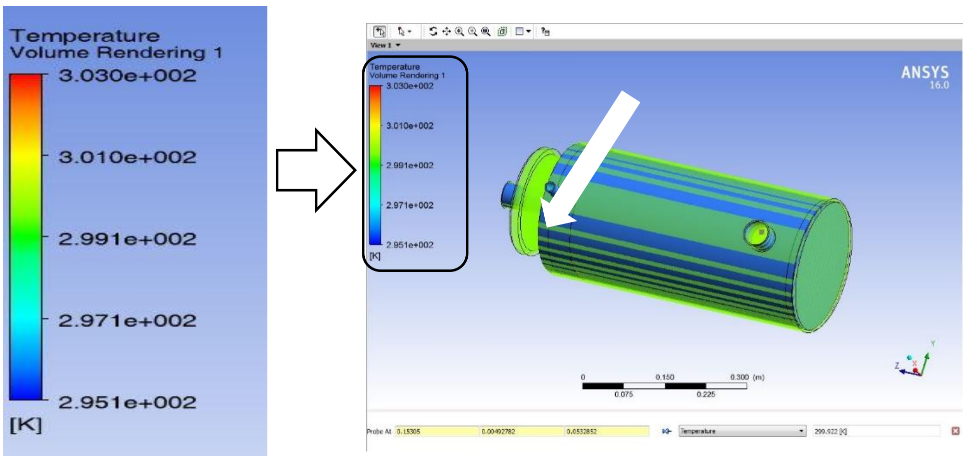


Figure 5.12: Corresponding coolant outlet temperature of 26.5 °C

Figure 5.12 above shows that the coolant inlet temperature was set at 27°C and the coolant outlet temperature after analysis of 26.5°C. The temperature shown in the figure is in Kelvin.

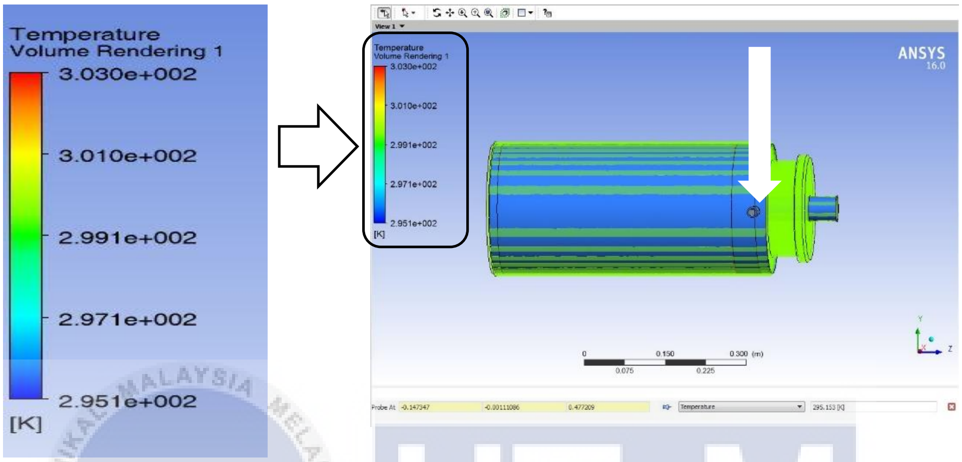


Figure 5.13: Air inlet temperature set at 22 °C

Figure 5.13 shows the inlet air temperature of 22°C and its corresponding air outlet temperature of 24.7°C after analysis. The temperature shown in the figure is in Kelvin.

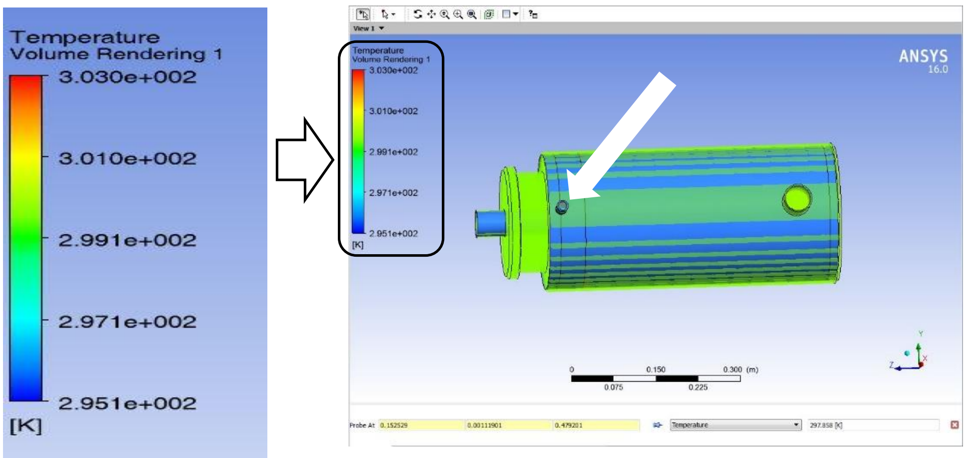


Figure 5.14: Corresponding air outlet temperature of 24.7 °C

Figure 5.14 shows the inlet air temperature of 22℃ and its corresponding air outlet temperature of 24. ℃ after analysis. The temperature shown in the figure is in Kelvin.

5.2.2 Result Analysis

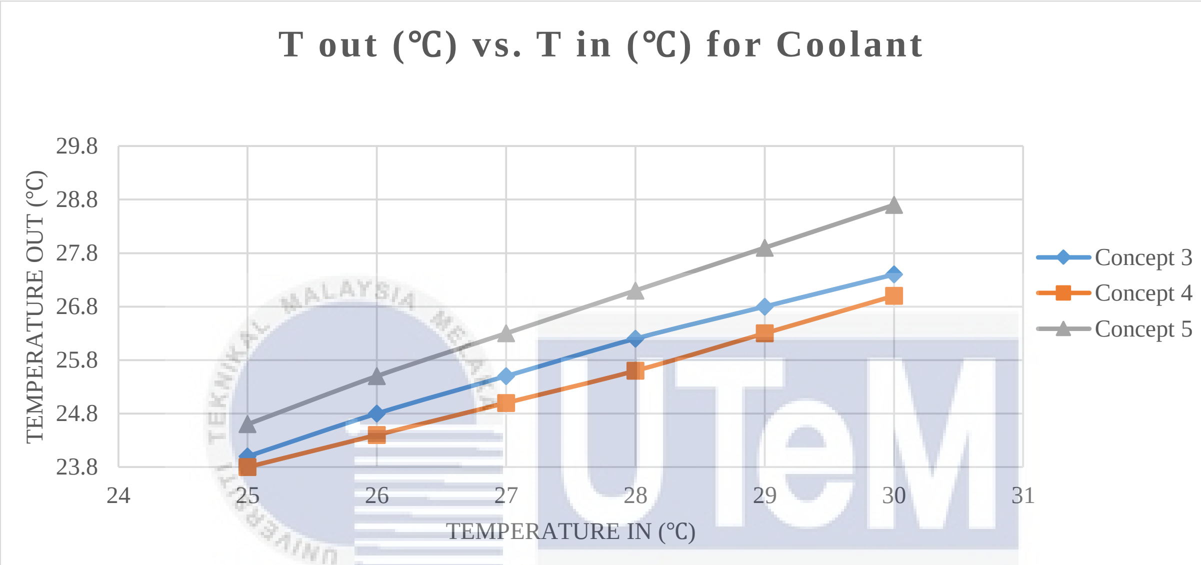


Figure 5.15: Temperature in for selected conceptual design against temperature out for coolant

The graph of temperature in for selected conceptual design against temperature out for coolant was plotted as shown in Figure 5.15. The analysis was performed by applying an initial inlet temperature of 25°C and increased to 30°C. As indicated by the plotting, the trend shows that the temperature outlet increases linearly for each concept due to the rise on inlet coolant temperature. Result shows that concept 4 has the lowest overall coolant outlet temperature with 27°C outlet temperature for an inlet temperature of 30 °C followed by concept 3 with 27.4℃ for an inlet of 30°C while concept 5 has the hottest outlet temperature of 28.7°C for an inlet temperature of 30°C. The result differ for each concept due to different designs used to build the concept structure itself.

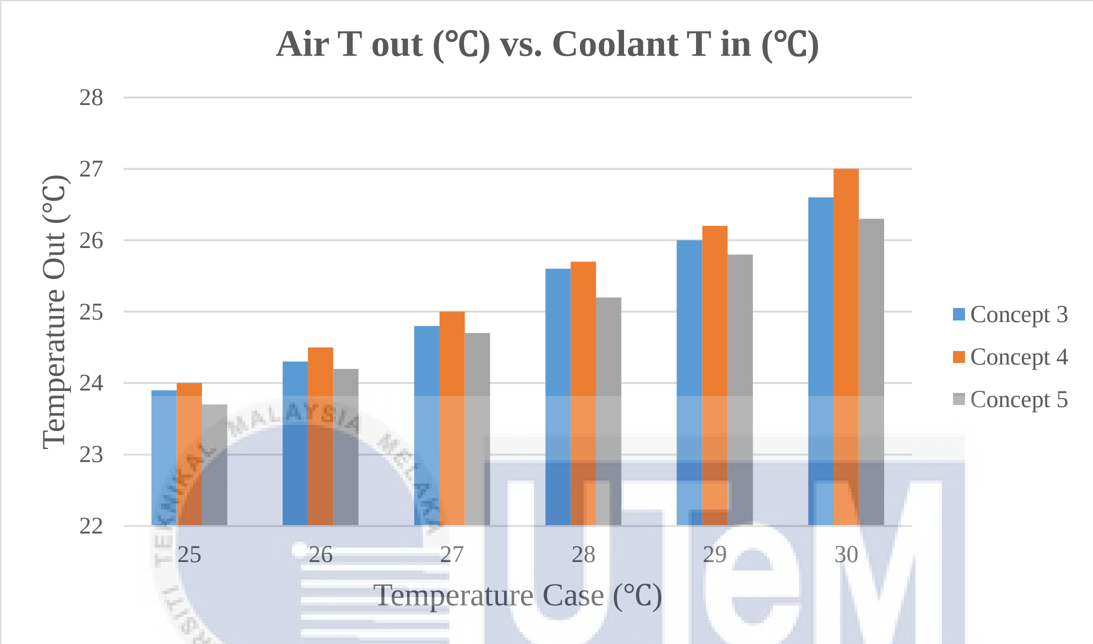


Figure 5.16: Temperature out against temperature in for air

Another parameter kept in check during the analysis was the inlet and outlet of air temperature for each concept. The temperature was recorded from inlet temperature for coolant of 25°C to 30°C. However, the air inlet temperature was kept constant by 22°C for each test case. The trend shows that the air outlet temperature increases in a linear pattern due to increase in case temperature. As indicated, concept 4 gives out the highest temperature for the case of 30°C of coolant inlet temperature with 27°C followed by concept 3 with 26.6°C while concept 5 gives out the least temperature of 26.3°C. The pattern of temperature rise for each temperature case is constant, which leads to the hypothesis convection is the most effective in concept 4.

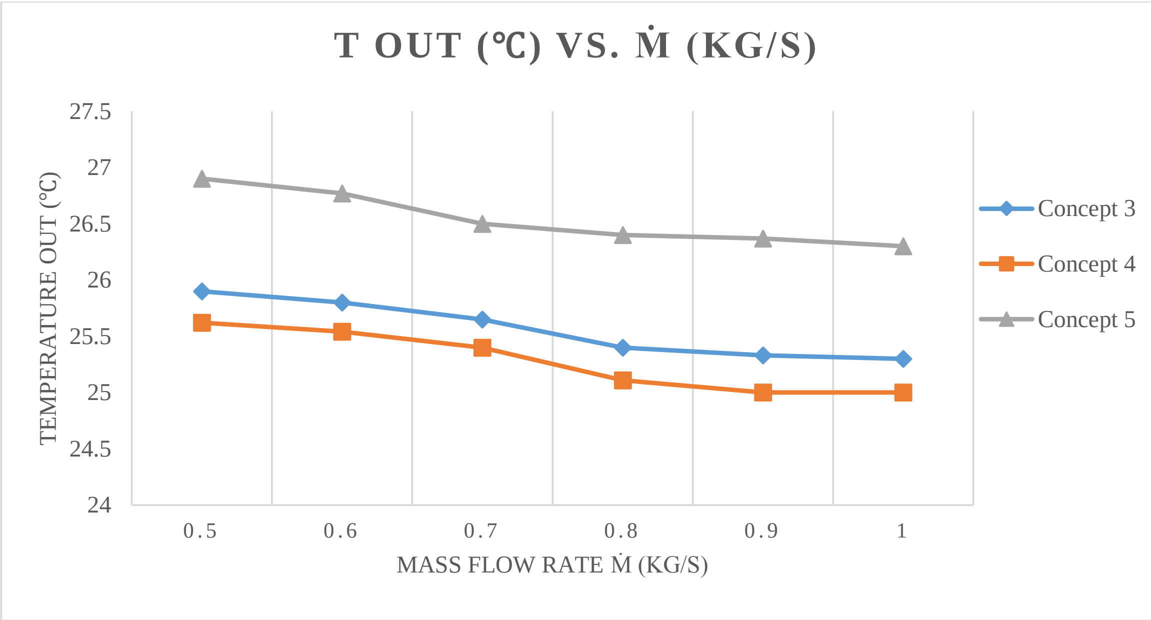


Figure 5.17: Temperature out against the mass flow rate

The concepts were then tested again with different coolant flow rate, ranging from 0.5 kg/s up to 1kg/s. For this study, the manipulated variable is coolant flow rate, the initial coolant inlet temperature of 27℃ was kept as a constant. Whereas the responding variable is the coolant outlet temperature. The purpose of this study is to monitor the effectiveness of the concepts under different flow rates. As shown in Figure 5.17, concept 4 shows the lowest overall outlet temperature, followed by concept 3 and concept 5. According to Gunnerson et. al, 2009, an increase in heat coefficient is observed if the area is kept constant while doubling the flow rate, resulting in 92% increase in the heat transfer coefficient.

5.3 Choosing Conceptual Design

Based on the results obtained, all parameters tested are pointing towards concept 4 as the best design. Hence, concept 4 is selected as the best design. Table below summarises concept 3, 4 and 5 in all parameters tested.

Table 5.1: Table on Summary of Coolant Temperature Reduction

Concept	Coolant T_{in} of 25 ℃	Coolant T_{in} of 26 ℃	Coolant T_{in} of 27 ℃	Coolant T_{in} of 28 ℃	Coolant T_{in} of 29 ℃	Coolant T_{in} of 30 ℃	Avg reduction **%**
Coolant T out, Concept 3	24	24.8	25.5	26.2	26.8	27.4	
Reduction % $\left(\frac{T_{in} - T_{out}}{T_{in}}\right) x\ 100$	4	4.61	5.55	6.42	7.58	8.67	**6.14**
Coolant T out, Concept 4	23.8	24.4	25	25.6	26.3	27	
Reduction % $\left(\frac{T_{in} - T_{out}}{T_{in}}\right) x\ 100$	4.8	6.15	7.41	8.57	9.31	10	**7.71**
Coolant T out, Concept 5	24.6	25.5	26.3	27.1	27.9	28.7	
Reduction % $\left(\frac{T_{in} - T_{out}}{T_{in}}\right) x\ 100$	1.6	1.92	2.59	3.21	3.79	4.33	**2.9**

Table 5.1 shows that concept 4 has the lowest reduction rate of 4.80 % with 25 ℃ coolant inlet, and can reduce the temperature of coolant outlet up to 10.0 % reduction with an inlet temperature of 30 ℃. Based on Table 5.1, concept 4 has an average reduction of 7.71% which is the highest reduction rate when compared to the other 2 concepts. Hence, concept 4 is selected for optimisation step.

5.4 Filter Media Size Selection

M. Ilić et. al (2013), conducted an analysis on particles emission during the process of grinding of steel. In their research they managed to distinguish the size of the cut particles and tabulated the results. **Figure 5.18** below shows the result of the analysis.

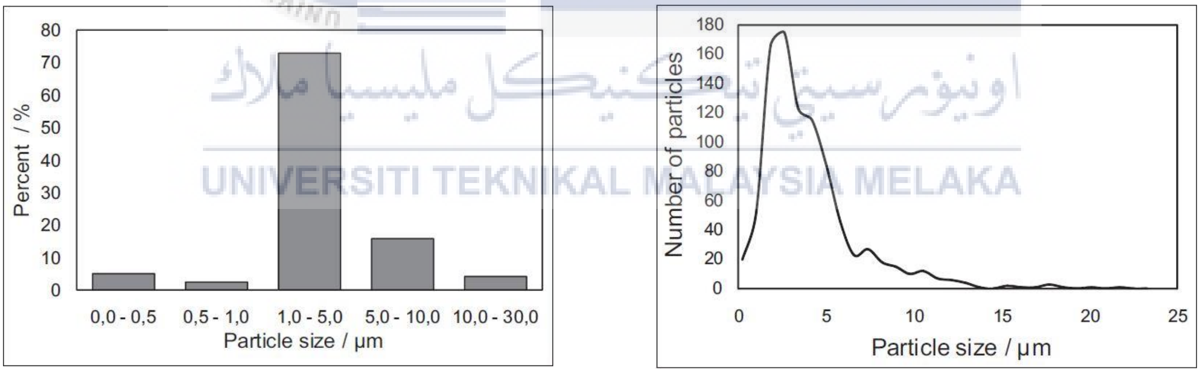


Figure 5.18: Distribution of particle sizes (left) and the frequency of occurrence of certain particle sizes (right). (Source: M. Ilić et. al (2013)

Based on **figure 5.18** above, the highest percentage of particle size was determined as 1 to 5 microns while the occurrence frequency is at its highest on the same size. Hence, as mentioned in the literature review section, the optimum size for media filtration is to set to be 10 microns. Multiple filtration process by this media size will allow the filter to distinguish contaminants from coolant thoroughly. In addition, the trapped particles will form cake filtration mechanism where it is targeted that contaminants filter contaminants selectively.

5.5 Design Optimization

Concept 4 was selected to undergo design optimization in order to enhance its performance. The purpose of this process is to obtain the nearest temperature drop percentage parallel to the objectives. The process begins by adding a Ranque-Hilsch Vortex Tube at the inlet of the compressed air. As mentioned in the literature review, a vortex tube is is a device that enables the separation of hot and cold air as compressed air flows tangentially into the vortex chamber via inlet nozzles.

Based on the table as mentioned in the literature review, for this study the initial compressed air was found to be at 22 ℃. By using a 50% cold fraction vortex tube at 1.4 bar, hence the final cold air temperature which will enter the filter is

$$22℃ - 28.3 ℃ = \mathbf{-6.3 ℃}$$

Meanwhile, the output air from the vortex tube based on the table provided in the literature review will be

$$22℃ + 28.3 ℃ = \mathbf{50.3℃}$$

The new air inlet temperature will be tested for ANSYS analysis to determine the new coolant output temperature. The results of the analysis is shown below.

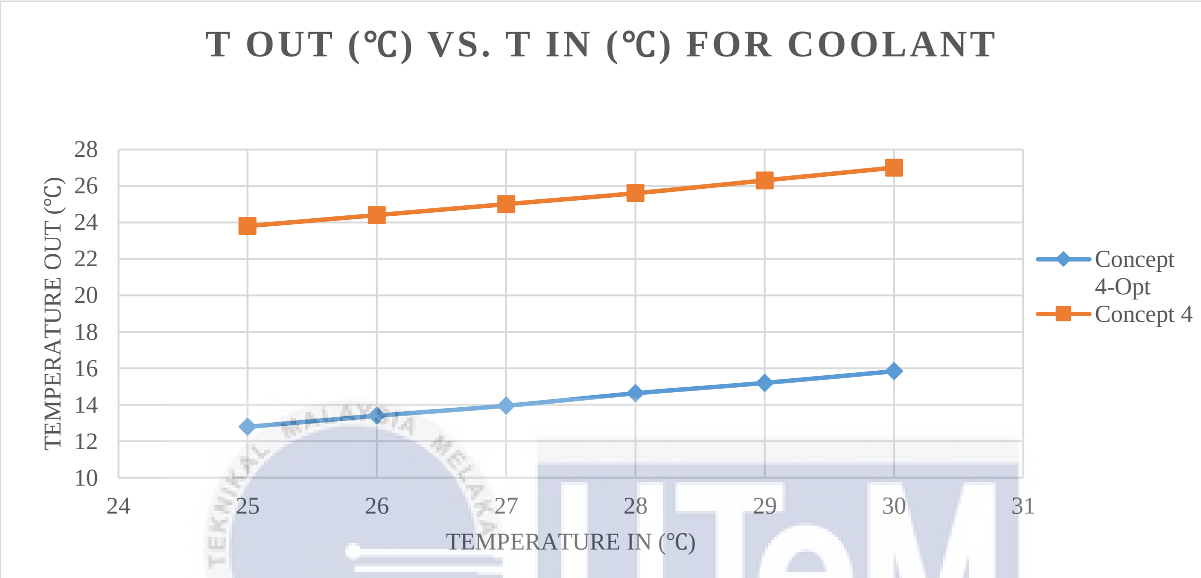


Figure 5.19: Comparison of coolant temperature between optimised results with previous result for concept 4

When tested with the new air inlet temperature, for 25℃ of coolant inlet the temperature was reduced to 12.79 ℃. This shows 48.84% of reduction from the initial value of 25℃. When compared to the previous result which exhibited a 4.8% reduction, the new temperature showed a tenfold increase in efficiency of temperature reduction. When tested with 30℃ of inlet temperature, the coolant temperature dropped by 47.2% to a figure of 15.84℃.

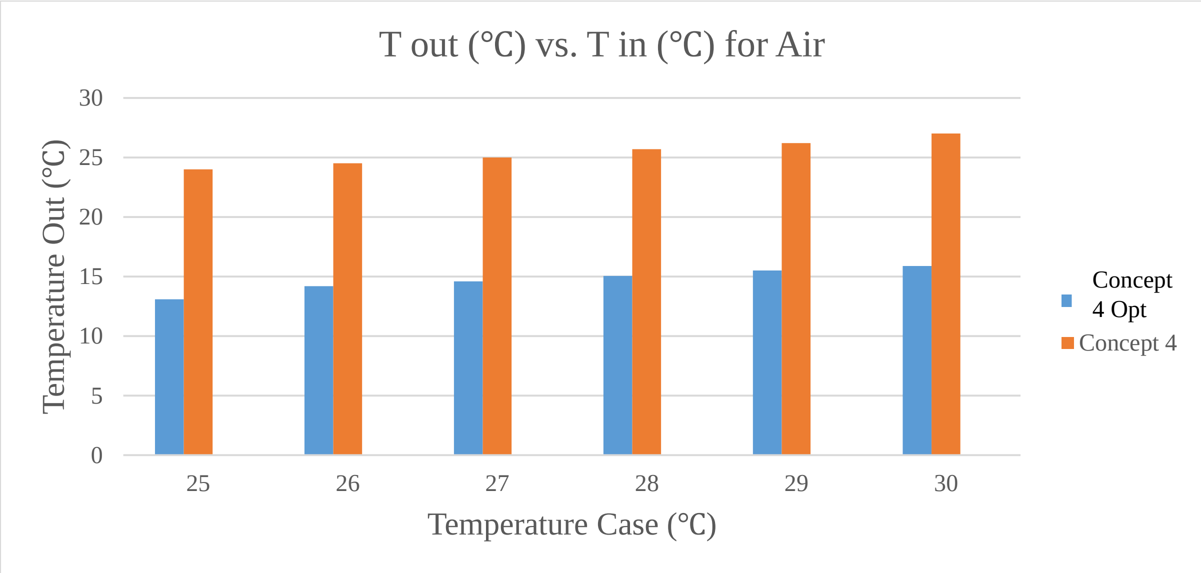


Figure 5.20: Comparison of air temperature between optimised results with previous result for concept 4

The air outlet temperature was also compared with the precious results obtained from concept 4. Based on the graph, the outlet air temperature drops as well for each case. For inlet temperature of 25℃, the output air temperature was analysed to be 13.1℃, compared to the previous result of 24℃. The output air will be released into the surroundings for both vertex tube hot air outlet as well as the filter air outlet.

5.5.1 Summary of Temperature Drop

Table 5.2: Comparison of before and after results obtained

Temp. Case (℃)	Initial Results	% of Reduction $\left(\frac{T_{in} - T_{out}}{T_{in}}\right) x\, 100$	Optimised Results	% of Reduction $\left(\frac{T_{in} - T_{out}}{T_{in}}\right) x\, 100$
25	23.8	4.8	12.79	48.84
26	24.4	6.15	13.4	48.46
27	25	7.41	13.95	48.33
28	25.6	8.57	14.63	47.75
29	26.3	9.31	15.2	47.59
30	27	10	15.84	47.2
	Avg Reduction	7.71 %	**Avg Reduction**	48.03 %

When comparing results from concept 4 before and after optimisation process, it can be observed that the temperature drop percentage rose significantly after the implementation of vortex tube. The trend shown in the initial results indicates that the temperature percentage drop increases with every temperature case. However, for optimised percentage of temperature drop, it can be seen that the temperature tends to maintain a certain margin of reduction. Based on the table above, it can be summarised that by implementing vortex tube, the average temperature drop increases by 40.32% which is from 7.71% to 48.03%. Hence the objective of the study is achieved.

CHAPTER 6

CONCLUSION

6.1 CONCLUSION

The concept design of the external coolant filter for metal machining machine and its analysis was done by knowing all engineering aspects and usable elements present on a standard industrial working line. The process started with the generation of 5 conceptual designs. These 5 designs were then filtered to 3 most high ranked by using Pugh Selection Method. After transferring the 3 conceptual designs into detailed drawings by using CATIA V5R20, all 3 concepts were analysed using ANSYS software for their performance based on the objective of the study. As a result, concept 4 gave out the highest percentage of average temperature drop of 7.71%. This concept later on undergoes optimisation process, where an additional component namely the vortex tube was added. Upon addition of the tube, the temperature drop rose significantly by 40.32%, from 7.71 % to 48.03%. Meanwhile, as for the media filtration size selection, a study conducted by M. Ilić et. al (2013) shows that for steel grinding process, the particle emission size was discovered to be 1 to 5 microns in abundant. Hence, the best filtration media was selected. For this design, it is expected for cake filtration process to occur.

6.2 RECOMMENDATION

Filtration process is very crucial when it comes to metal machining processes. This is due to the fact that one of the factors affecting the finishing quality of a surface depends on the level of contamination of the coolant. A well maintained coolant will also prolong the lifespan of tools and in time reduces maintenance time or breakdown time for machining machines. Aside from temperature of the coolant, there are other aspects which requires further studies such as the effect of different types of coolant in use and the cutting angle of the tool. Ultimately, a theoretical value obtained from an analysis may differ from the actual value obtained by testing.

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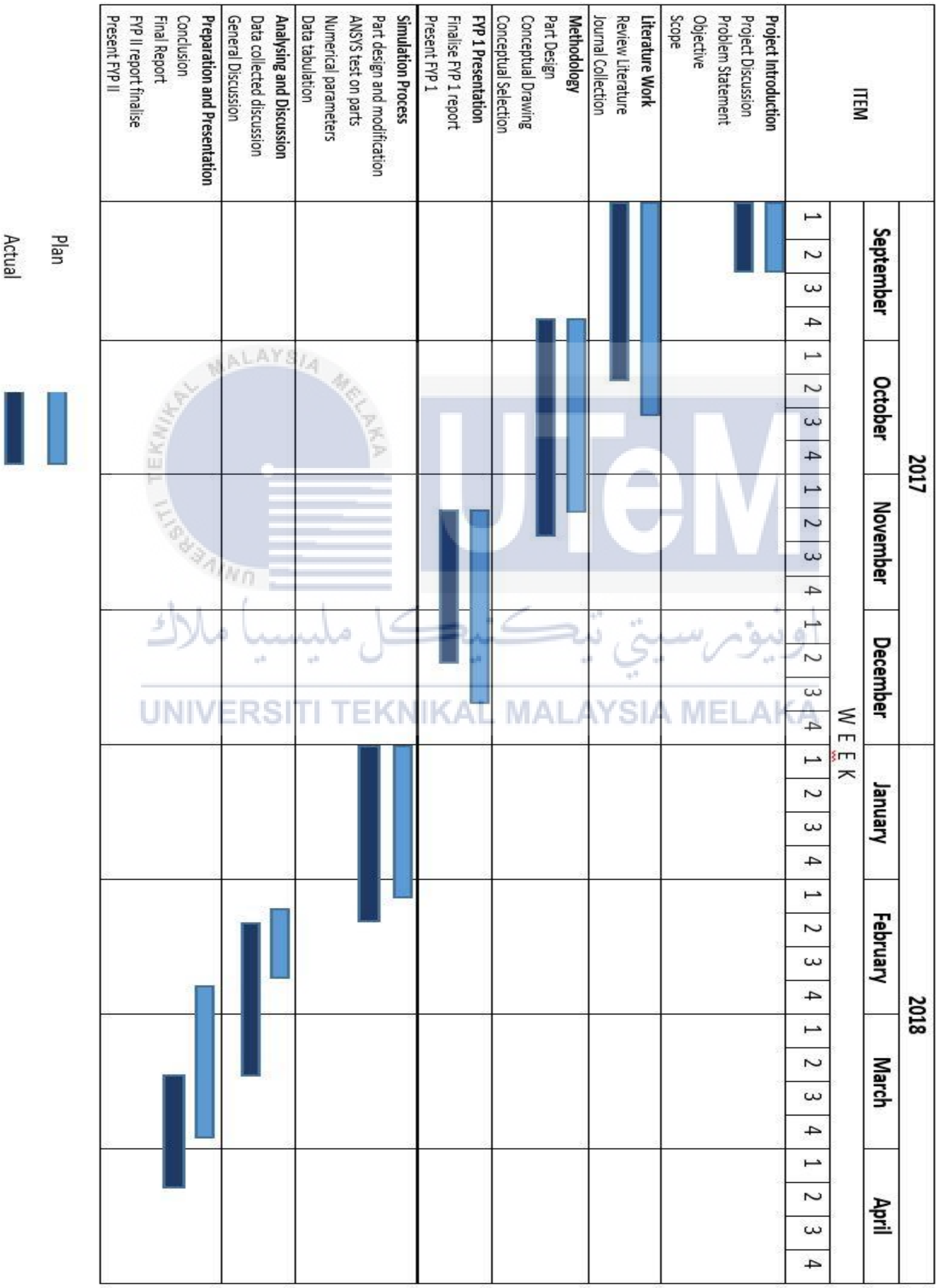
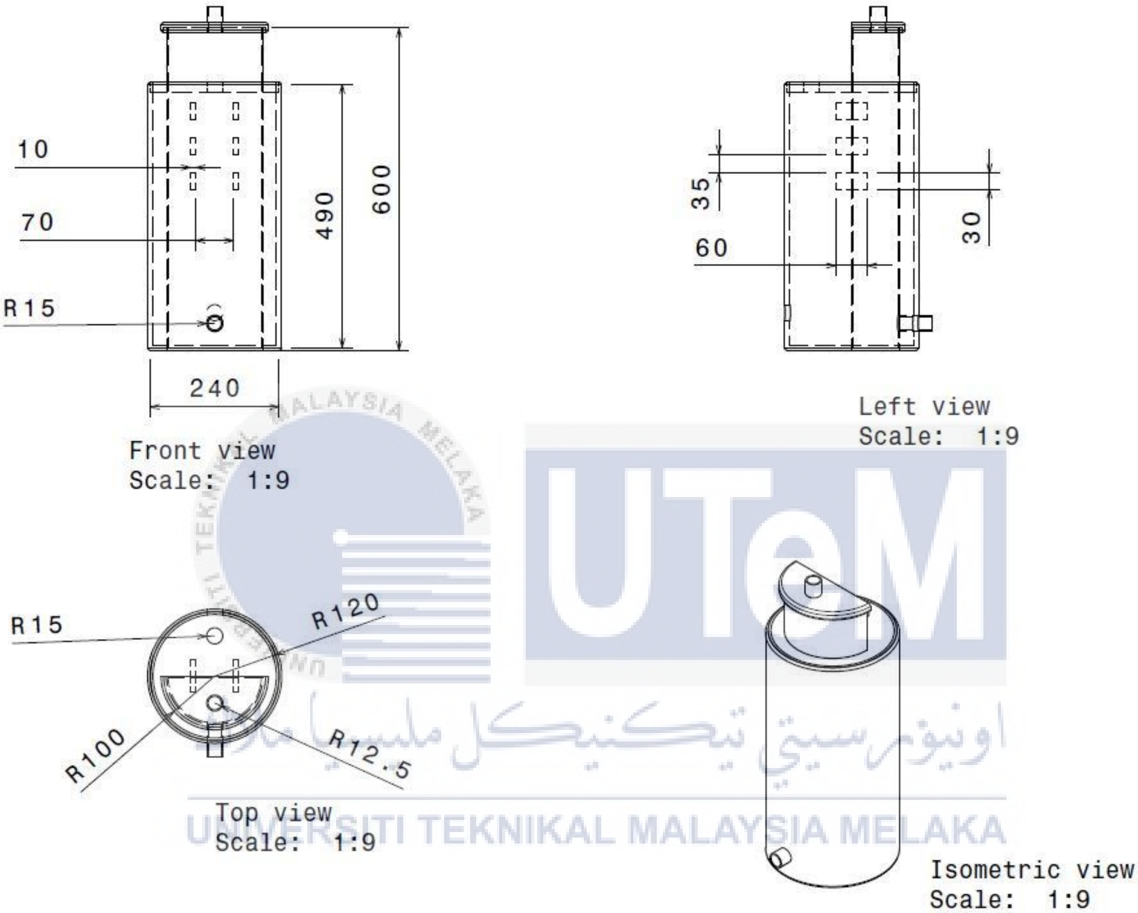
APPENDIX A



ITEM
2017
2018
September
October
November
December
January
February
March
April
WEEK
1
2
3
4
Project Introduction
Project Discussion
Problem Statement
Objective
Scope
Literature Work
Review Literature
Journal Collection
Methodology
Part Design
Conceptual Drawing
Conceptual Selection
FYP 1 Presentation
Finalise FYP 1 report
Present FYP 1
Simulation Process
Part design and modification
ANSYS test on parts
Numerical parameters
Data tabulation
Analysing and Discussion
Data collected discussion
General Discussion
Preparation and Presentation
Conclusion
Final Report
FYP II report finalise
Present FYP II
Plan
Actual

APPENDIX B1



10
70
R15
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35
60
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Left view
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R15
R120
R100
R12.5
Top view
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Isometric view
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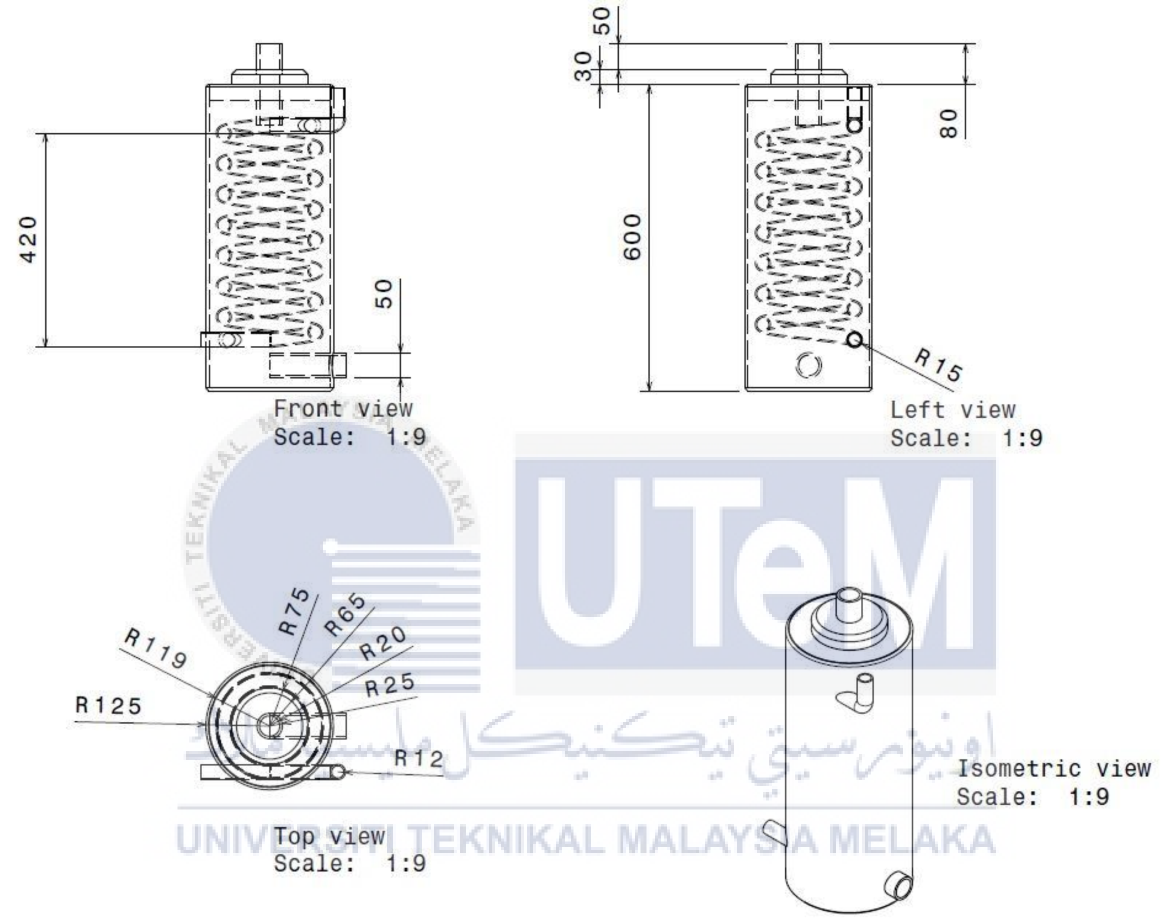
APPENDIX B2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R15
Left view
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R75
R65
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R20
R25
R125
R12
Top view
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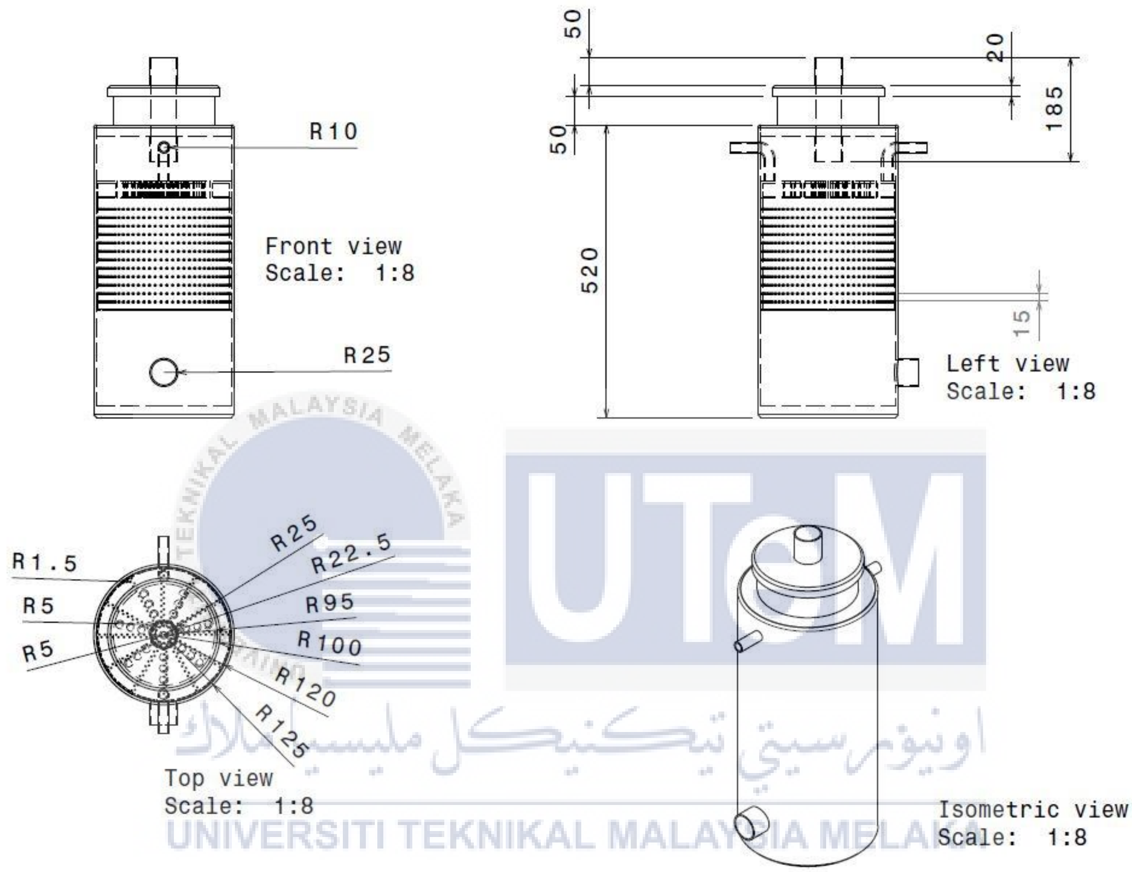
Isometric view
Scale: 1:9

APPENDIX B3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20
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520
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Left view
Scale: 1:8
R1.5
R5
R5
R25
R22.5
R95
R100
R120
R125
Top view
Scale: 1:8
Isometric view
Scale: 1:8