Faculty of Mechanical Engineering

THE EFFECT OF DIRT ON AN ENGINE COOLING SYSTEM

NUR KAMAL HISYAM BIN MOHAMAD NAZRI

Bachelor of Mechanical Engineering

2019

THE EFFECT OF DIRT ON AN ENGINE COOLING SYSTEM

NUR KAMAL HISYAM BIN MOHAMAD NAZRI

Project report submitted in fulfilment of the requirement for the Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

"I hereby declare that the work in this whole report is my own except for the summaries and quotations which have been duly acknowledged"

Signature: ……………………………

Author: Nur Kamal Hisyam Bin Mohamad Nazri

Date: ……………………………

APPROVAL

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.

Signature : ....

Name of Supervisor: MOHD HAFIDZAL BIN MOHD HANAFI

Date : ....

DEDICATION

To my beloved father Mohamad Nazri Bin Mohd Noor,

My beloved mother Ayu Yusnita Binti Razali,

My beloved sisters,

Nur Aimi Balqis, Nur Aini Batrisya,

&

My supportive friends,

Tengku Azeruddin, Arif Sufian

ABSTRACT

This report analytically focus on study the automotive engine cooling system and the effect of dirt on engine cooling system. The function of automotive cooling system is to cooling the engine after running for a long time. The engine will generate huge amount of heat and must be cool to avoid an engine damage. As the vehicle goes through the muddy and dusty road, the dirt will accumulate on the surface of the radiator and it will affect the performance of the engine. From the experiment result, it shows that increase of the area covered by dirt on the surface of the radiator will proportion increase of the temperature inlet and outlet of the radiator. It also show that mud as covering material, will have the higher temperature of inlet and outlet of the radiator compared the silt. Using brush as a cleaning method, the temperature will decreased to the preliminary condition which is good to the engine.

ABSTRAK

Laporan ini secara analitik menumpukan pada kajian sistem penyejukan enjin automotif dan kesan kotoran pada sistem penyejukan enjin. Fungsi sistem penyejukan automotif adalah untuk menyejukkan enjin selepas berfungsi untuk masa yang lama. Ia akan menghasilkan sejumlah besar haba dan mesti menjadi sejuk untuk mengelakkan kerosakan enjin. Radiator yang selalu dipasang di hadapan enjin digunakan untuk memindahkan haba dari cecair (dipanaskan akibat pembakaran enjin) ke udara yang mengalir melalui sirip radiator. Walau bagaimanapun jika kenderaan itu melalui jalan berlumpur dan berdebu, kotoran akan berkumpul di permukaan radiator dan ia akan menjejaskan prestasi enjin. Daripada eksperimen yang telah dilakukan menggunakan pelantar ujian, ia menunjukkan bahawa peningkatan kawasan yang diliputi oleh kotoran pada permukaan radiator akan meningkatkan kenaikan suhu masuk dan keluar radiator. Ia juga menunjukkan bahawa lumpur sebagai bahan penutup, akan mempunyai suhu yang lebih tinggi dari salur masuk dan keluar radiator berbanding lumpur. Menggunakan berus sebagai kaedah pembersihan, suhu akan menurun kepada keadaan permulaan yang baik kepada enjin.

ACKNOWLEDGEMENTS

The appreciation I dedicated to my supportive supervisor, Sir Mohd Hafidzal bin Mohd Hanafi and Madam Fadhilah binti Shikh Anuar for the unstoppable advices while conducting the research these two semesters of research. Also, for the patience in guiding me to write a proper report. I would like to convey a very special appreciation to all the laboratory management and technician especially Encik Asjufri Bin Muhajir from Air conditioning Lab for the guidance with the fabrication and calibration process throughout the project.

Also, not to forget a very important support from my beloved family on their encouragement, motivation and trust in everything that I do and always be there in through my thick and thin. With their support and love it seems possible to go through tough education all these years. Not to forget my friends and fellow housemate that willing to give example and help look for potential source of reference suitable for my research title and teach a proper way to use Microsoft Office Word.

Finally thank you to everyone who been with me throughout this amazing journey. The sacrifice and commitment they give towards completing my Bachelor of Mechanical Engineering programme. Without them this thesis seems impossible to be done.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS AND SYMBOLS

HVAC	Heating Ventilation Air Conditioning
EMF	Electromotive force
RPM	Revolution per minutes
Kpa	Kilo Pascal
Km	Kilo Meter
min	Minimum
max	Maximum
Cm	Centimetre
mm	Millimetre
ft	Foot
lb	Pound
kW	Kilo Watt
C_c	Coolant heat capacity
T_{ci}	Temperature coolant inlet
T_{co}	Temperature coolant outlet
T_{ao}	Temperature air outlet
T_{ai}	Temperature air inlet
A_a	Area air
A_c	Area coolant
ρ_c	Density coolant
ρ_a	Density air
$C_{p,a}$	Specific heat of air
$C_{p,c}$	Specific heat of coolant
ε	Thermal efficiency
Q	Heat transfer rate
°C	Celsius
m^3	Cubic metre
s	Second

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

An automotive engine generates a huge amount of heat once it is running. It should be cooled continually to avoid engine damage. The maximum temperature attained throughout combustion is approximately equal to the melting point of platinum, and therefore the temperature even of the exhaust gas is higher than that of the melting point of aluminium [1]. Generally, this is typically done by using water mixed with a liquid solution which called antifreeze that passes through special cooling passages.

The antifreeze passes through the engine extract heat around the combustion chamber and dissipates the heat inside the radiator. The radiator is used to transfer heat from the fluid (heated due to engine combustion) to the air flowing through the fins of the radiator. The air flowing is driven by a mixture of the forward motion of the automobile and from a fan enclosed during a shroud connected to the radiator [1]. The radiator acts as a reservoir that stores water for the engine cooling system. Therefore, the basic needs of the radiator are to supply a sufficiently large cooling space for transmission of heat from the fluid (antifreeze) to the air. The fluid passes through the chambers inside the engine block to absorb the heat and spread it far away from other main components [2].

As shown in Figure 1.1, the radiator is regularly placed in front of the engine to increase the stream of air in the cooling of the motor [3]. However, if the vehicles through on the untarred road, a ton of dust and mud would obstruct a large proportion of the radiator fins area. Subsequently, the engine could be overheated, which may influence the performance [3]. These dust accumulations reduce heat removal. Unfortunately, there are only a few published literature on the measurement of dirt on the radiator and its impact on the engine performance. Present studies take on the critical looks at the effects of dirt on the radiator performance.

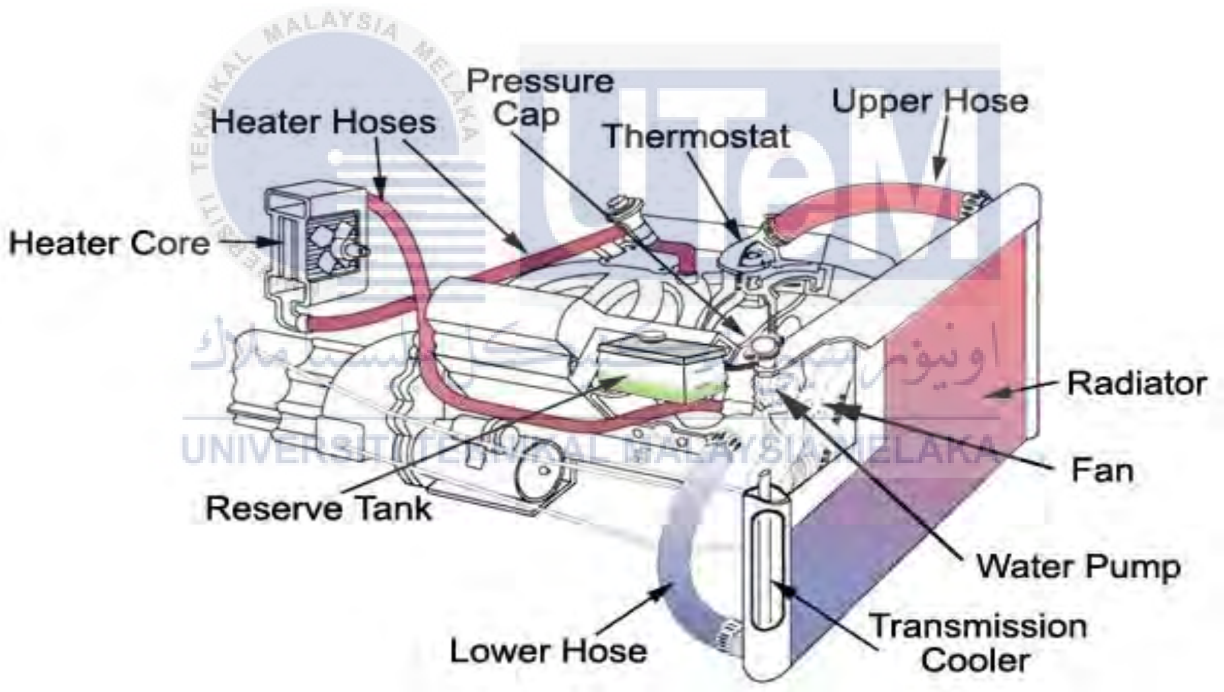


Figure 1.1: Main component on the automotive cooling system [18].

1.2 PROBLEM STATEMENT

Engine overheating is one of the main concern in any vehicle where the temperature of the cooling system should not increase to the maximum level. However, as the vehicle goes through dusty and muddy roads, the dirt may deposit on the radiator and these accumulate of dirt will block the air flows, and subsequently, reduce the efficiency of the cooling system. As the temperature in the cooling system increased, it will cause the engine to be overheating and this will break and seize the overhead cam.

1.3 OBJECTIVE

The objective of this projects are as follows:

i) Investigate the effects of dirt (mud and silt) on the radiator performance.

1.4 SCOPE OF PROJECTS

This study will conduct an experiment on a radiator (Perodua Kancil 850 model), focusing on its performance before and after dirt accumulation. Two type of dirt (mud and silt) will be used and only a part of the radiator will be covered with dirt. The study manipulates percentage or the amount the dirt's on the radiator in addition to different the flow rate and coolant temperature. There will be only one type of coolant in this study which is a mixture of 50 % of water and 50 % of ethylene glycol.

1.5 GENERAL METHODOLOGY

The clarifications and detail for the methodology that will be executed in order to accomplish the objective in this project will be discussed in chapter 3. Generally, the flow of this project is as follows:

(a) Literature review

Collecting data from the previous journal, website, books, article, videos and any related material about the project.

(b) Experiment setup

All the test component will be prepared along the measurement devices such as thermocouple and data logger to conduct the experiment.

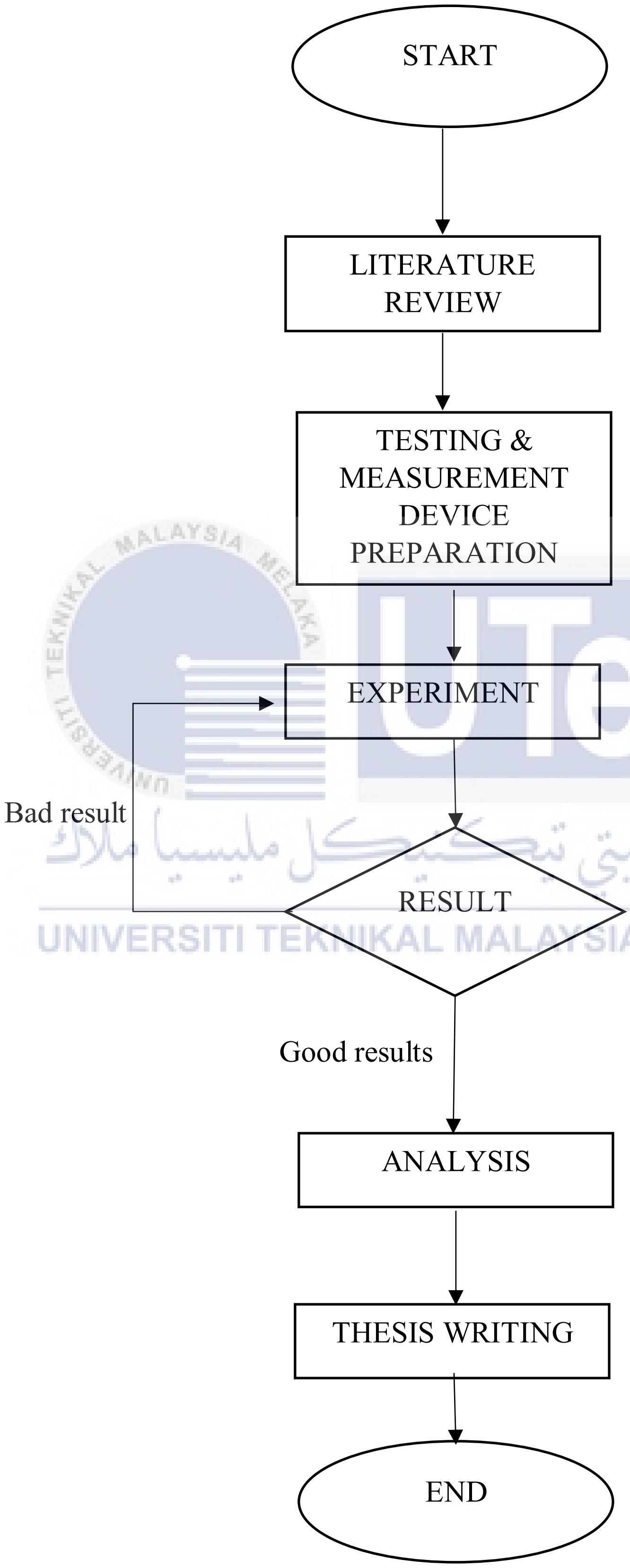
(c) Experiment & analysis

The experiment will be the focused on the temperature of the automotive coolant by collecting data in two different conditions (a) pre-test and (b) post-test. The pre-test is referred to a clean condition before any dusts are placed on the radiator (heat exchanger) surface. While, the post-test is the condition with the addition of dust. The temperature at the inlet and outlet of the radiator will be measured by using several thermocouple. The temperature data will be analysed to investigate the effect of dirt on radiator performance.

(d) Thesis writing

At the end of the project, a thesis will be written that include all the data and analysis of the experiment.

The methodology of this study is simplify in the flow chart as shown in Figure 2.



CHAPTER 2

LITERATURE REVIEW

This chapter will discuss on the past literatures that discussed on automotive cooling system and its performance. This include any factors that influence the efficiency and overall engine performance.

2.1 INTERNAL COMBUSTION ENGINE SYSTEM

The purpose of an internal combustion engine is to create mechanical power from the chemical energy of the fuel. The internal combustion engines, as distinct from external combustion engines, this vitality is discharged by copying or oxidizing the fuel inside the motor. The fuel-air blend before combustion and the burned product after ignition are the real working fluids. The work transfers that provide the desired power output occur directly between these working fluids and the mechanical parts of the engine[4].

An atmospheric engine that was introduced by Otto [4], has utilized the pressure rise due to the ignition of the fuel-air. It charges early in the outward stroke to accelerate a free piston and rack assembly, so that its momentum would generate a vacuum in the cylinder. Atmospheric pressure pushed the internal cylinder, with the rack connected through a roller clutch to the output shaft.

In the past, a German architect Diesel [4] has sketched out in a patent on another type of internal ignition motor. His idea of starting combustion by injecting a liquid fuel into air heated exclusively by compression permitted a multiplying of efficiency over another internal ignition engine. A lot more expansion extension ratios, without explosion or knock, are now possible[4].

An engine produces a high amount of heat while running. This can raise the engine temperature to an abnormal state and can break the engine component. For the security of engine parts, it needs to keep running at a much lower temperature, which is known as engine working temperature [5]. Most susceptible to overheating are the base of the cylinder head, the upper belt of the cylinder liner, the piston crown, the upper compression ring, and the exhaust valve cap.

The stresses from moving the thermal field in these elements, due to the periodic nature of the work of the internal combustion engine, may offer rise to fatigue crack propagation with specific mechanisms, which is more hazardous than crack propagation mechanisms in static thermal fields [6]. It influences the combustion temperature in the engine, by directly affecting its performance and emissions [7]. The engine cooling system keeps the engine running at its working temperature by evacuating excess heat [8]. As shown in figure 2.1, it show that all the part of the internal combustion engine such as piston, engine block, connecting rod and crankcase.

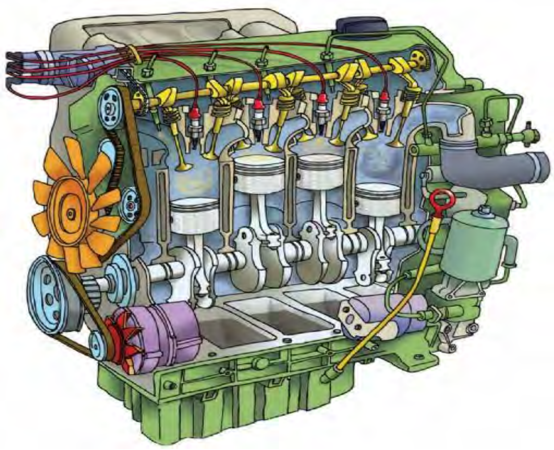


Figure 2.1: Part of Internal Combustion Engine [19].

2.2 ENGINE COOLING SYSTEM

The use of engine cooling system is to keep up the ideal coolant temperature for optimum engine operation. According to Tasuni [9], the water pump will enhance the cooling effect. Water pump is one of the important components in the cooling system as it maintains the circulation of coolant throughout the system. Many researches have been conducted to study the water pump characteristic of an engine cooling system [9]. The experiments usually used a real engine cooling system as a test rig.

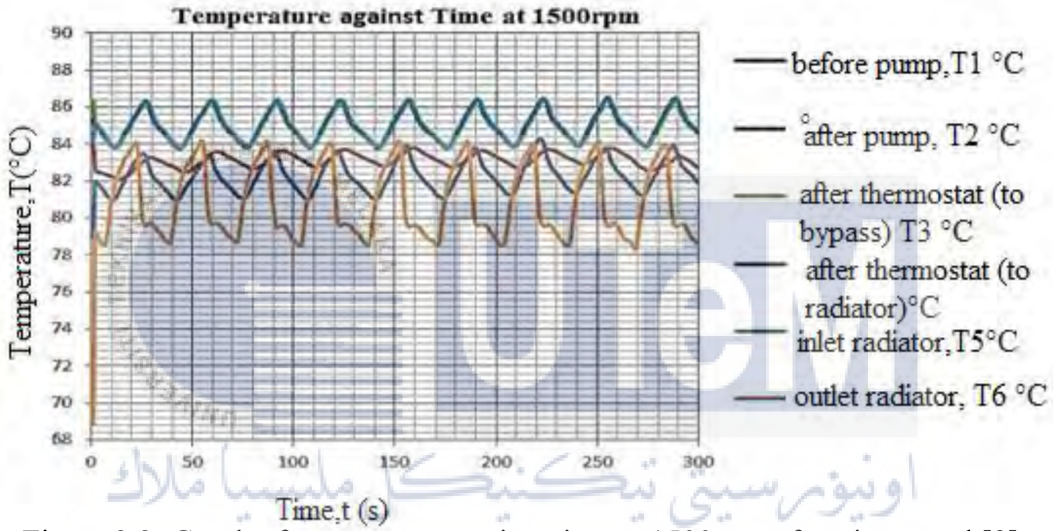


Figure 2.2: Graph of temperature against time at 1500rpm of engine speed [9].

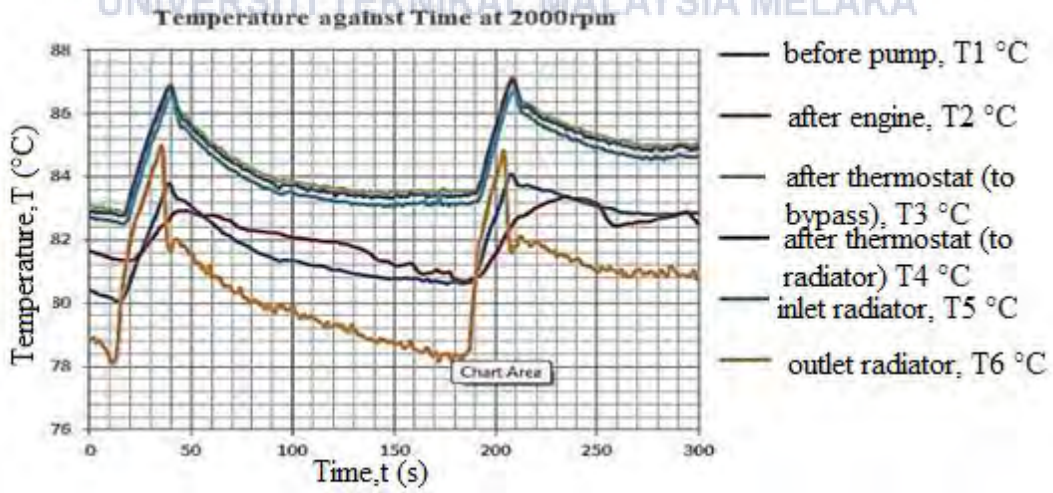


Figure 2.3: Graph of temperature against time at 2000rpm of engine speed [9].

Figure 2.2 and 2.3 show the result of temperature when the electric fans at radiator is switch off and on. When the temperature of water at the thermostat reached at a certain temperature, the thermostat switch will be automatically turn on and the fan starts to rotate and draw in the air from outside of the system. Figure 2.3 and 2.4 also show as the rpm of engine speed increases it takes a longer time to complete the cycle. This show that the engine cooling system required more time to gain heat from the combustion chamber [9].

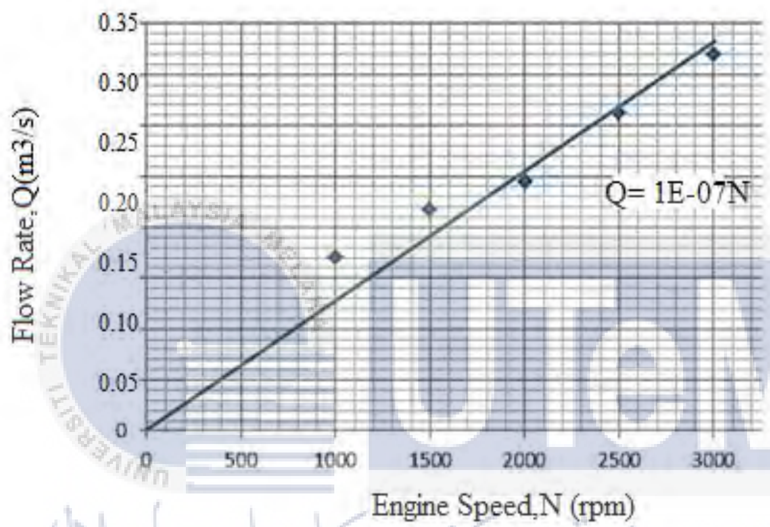


Figure 2.4 : Graph of flow rate against engine speed [9].

Figure 2.4 shows the flow rate of the coolant increment is linear to the engine speed. It proves that the relationship between the engine speed and flow rate is complying affinity law [9]. According to affinity law, the flow rate of coolant is proportional to the shaft speed of the pump. Figure 2.5 shows the temperature are influenced by the power of pump. The maximum power is increasing with the temperature. Due to the temperature rises, both the pressure and power consumption will also be increased.

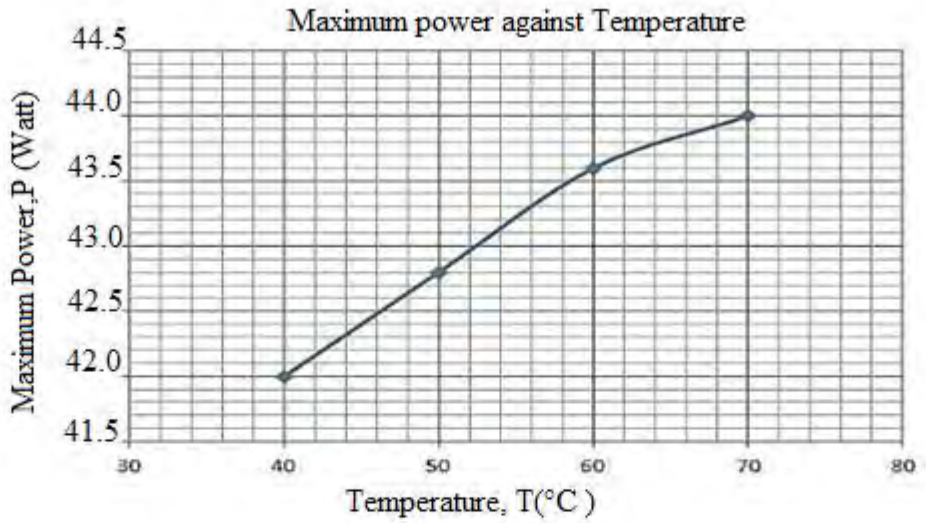


Figure 2.5 : Maximum power against temperature [9].

Other than the water pump, coolant plays a significant role in the automotive cooling system. The coolant is a mixture of water and freezing agent, which is used to cool down the engine. The liquid coolant will circulate through the engine block and heads. While running, the coolant absorbs heat as passing through the cylinder block before returning to radiator [10]. There are many studies that investigate the coolant properties as it influences the radiator performance. According to Yadav [10], water is the best coolant with some limitation as explained in the following section.

The superior performance of the water can be seen in Figure 2.6. The water is always above the mixture in both condition due to specific heat of the water is much greater than the mixture. Figure 2.6 also show if the flow rate is increased, the cooling flow rate is increasing, regardless of coolant type. The water is above the graph when mixture has been used as the coolant. This is because the specific heat capacity of the water is very much greater than the mixture. So, if it is required to increase the cooling capacity with the mixture then its mass flow rate is to be increased [10].

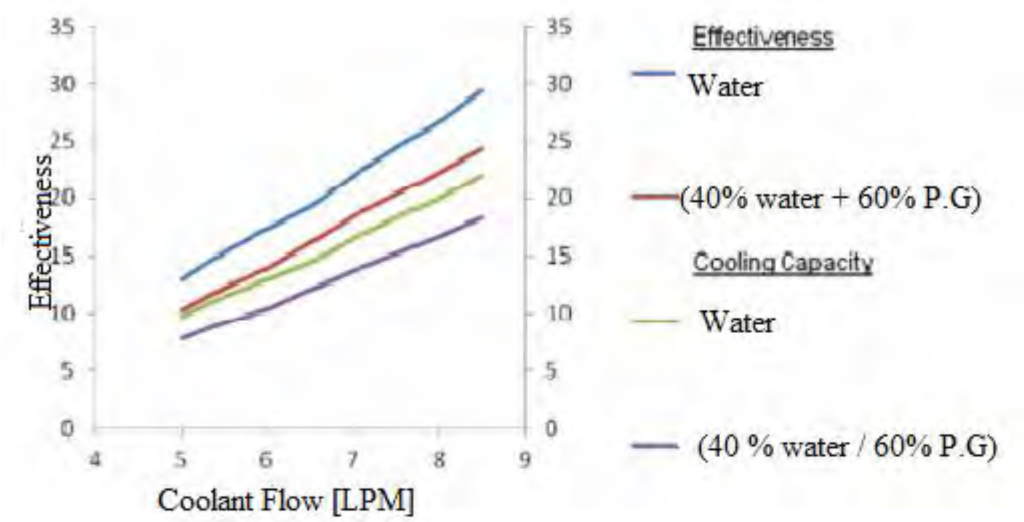


Figure 2.6: Effectiveness and cooling capacity versus coolant flow of radiator [10].

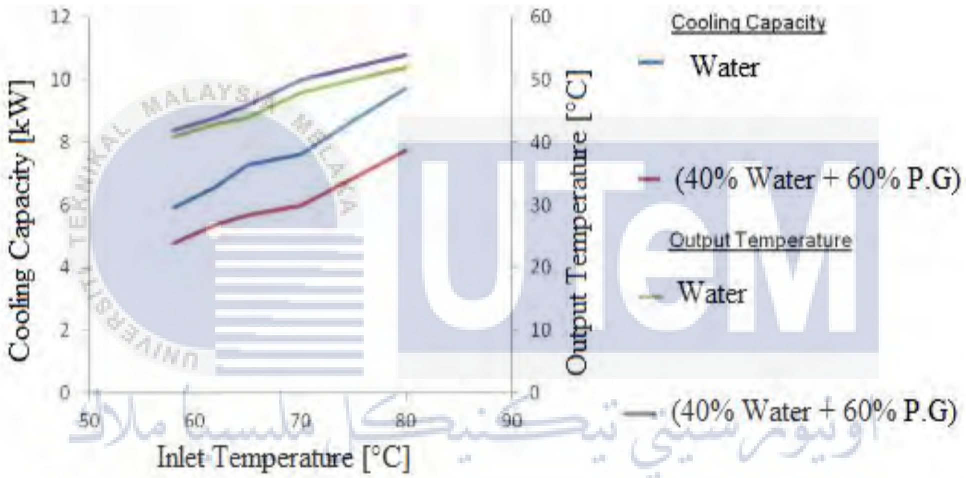


Figure 2.7: Cooling capacity and output temperature against inlet temperature with fans [10].

Figure 2.7 shows that when the inlet temperature is increases, the output temperature and cooling capacity will be increase as well. This happens because the heat transfer between ambient and radiator surface takes place by two heat transfer modes; conduction and convection. In these modes, the heat transfer is directly proportional to the temperature difference i.e. a higher the temperature difference between two medium will cause a heat transfer rate [10]. Figure 2.6 and 2.7 clearly show that the water is the best coolant but it is corrosive and have a dissolved salts that lower the coolant flow passage.

2.3 EFFECT OF DIRTS

Other than coolant and water pump, dirt also affect the performance of the radiator. According to Singh, [10] the higher blockage of dirt on radiator, the higher the coolant temperature in the system. Their study investigated the effect of dirt (mud and silt) that cover the heat transfer area of the radiator and its effect on the engine cooling system. They used a real automotive cooling system. Two thermocouple was fitted at the inlet and outlet of the radiator to read the coolant temperature. The fan and engine speed were held constant during the experiment.

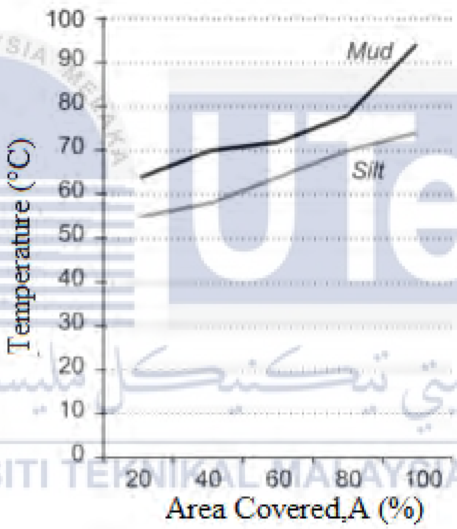


Figure 2.8 : Inlet water temperature against area of radiator covered [1].

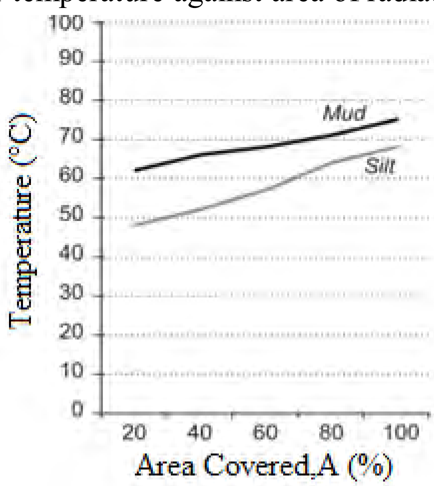


Figure 2.9 : Outlet water temperature against area of radiator covered [1].

Figure 2.8 and 2.9 show that when the mud used as covering material the temperature is higher than the silt. The temperature are different because the material allow different amount of air to pass through its layer. The temperature also increases when the area covered increased. This can be noted from the decrement of heat because the quantity of air that pass through the radiator is decreased.

According to Oduro [3], the engine stopped working in a short time when the area of the radiator was completely covered with dirts. This happens because the heat of the coolant was prevented to move away from the engines walls. Due to the poor heat exchange process, the engine will damage if it is continue running in that condition.

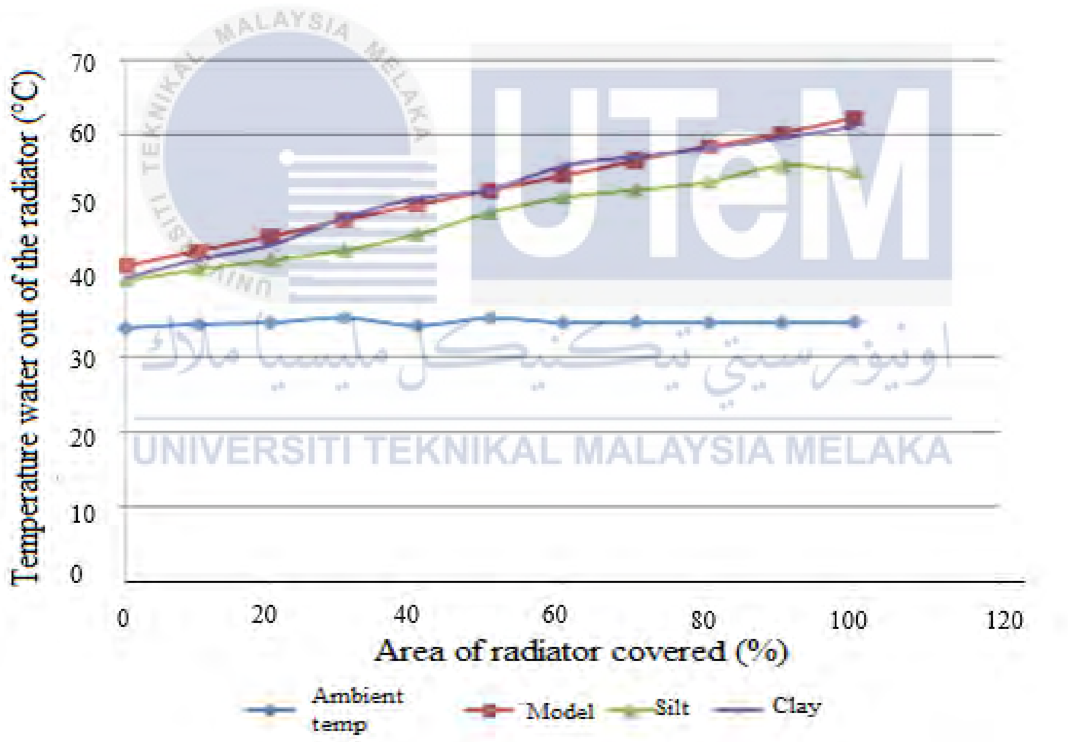


Figure 2.10: Temperature of water out of the radiator against area of radiator covered [3].

Figure 2.10 shows the temperature of the surrounding air was observed to be relatively consistent. This therefore did not significantly affect the rate of heat transfer because the air mass was almost constant just as the thermal properties of the air. In those two cases, at 80% inclusion of the heat transfer territory of the radiator the engine vibrated too much and the lingering was not steady. It very well may be presumed that dirt on the surface of a radiator diminished the performance of the radiator which could influence the engine over the long haul [3].

2.4 COMPONENTS AND WORKING PRINCIPLE OF AUTOMOTIVE COOLING SYSTEM

There are two kinds of the cooling system usually found in the vehicles which are liquid cooled and air cooled. Air cooled system are found on a couple of more established autos, similar to the first Volkswagen Beetle, the Chevrolet Corvair and a couple of others. Numerous modern vehicle are still using air cooled type, yet generally, automobile and trucks utilize a liquid cooling system.

The cooling system in fuel and diesel engines serves a critical job in keeping up the desired coolant temperature for enhanced performance. If the engines work excessively hot, anomalous in-cylinder ignition may happen to degraded fuel economy and tailpipe emissions. Roughly 25% of the total petroleum energy changed over amid the start engine burning procedure is lost to the cooling system [11]. Thus, the cooling system must accommodate a significant amount of heat while working under surrounding working conditions.

To achieve this task, the thermostat valve, radiator, radiator fan, and water pump circulate cooling liquid through the block of the engine and reject heat to the surrounding. Engine cooling system keeps the motor running at its working temperature by evacuating excess heat. A schematic diagram of automotive cooling system is shown in figure 2.11

coolant is blending of water and antifreeze which courses through the engine cooling system to absorb the abundance heat and dissipate it through the radiator [8].

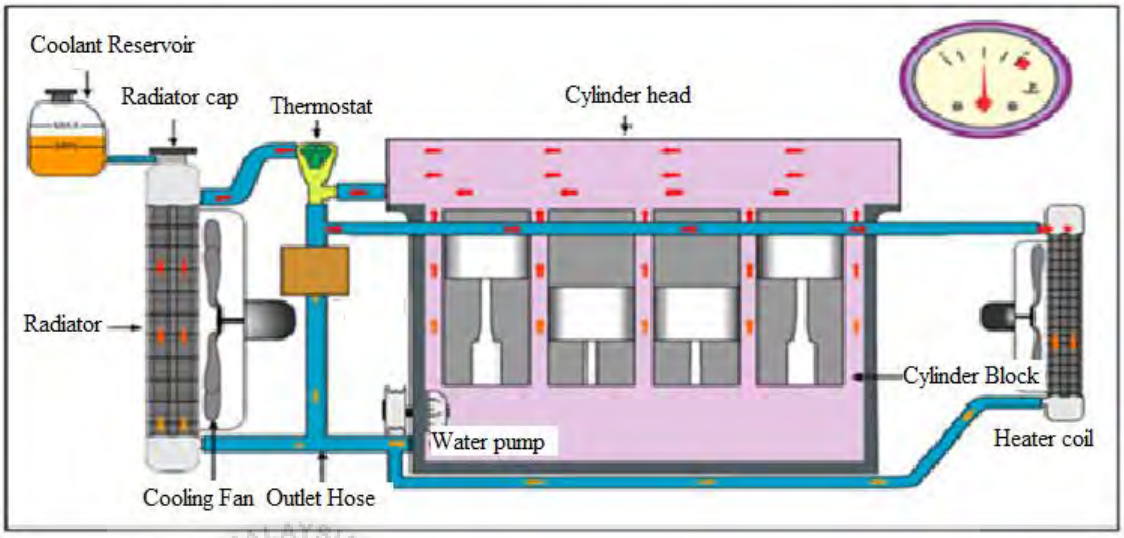


Figure 2.11: Coolant flow of the automotive cooling system [8].

Generally, its function is to remove the excessive heat of combustion from the engine. It also maintain operating of the engine temperature where it works most efficiently. Finally, automotive cooling system will bring the engine up to the right working temperature as fast as possible.

The engines produce power by converting the chemical energy of the fuel into heat by combustion. Total heat produced by the combustion is used to push the piston downward and thereby producing the necessary power. Some of the heat is carried away by the exhaust gases through the exhaust valve. Meanwhile, the remaining heat is absorbed by the engine, which increases its temperature. The heat of the engine is absorbed by the coolant in order to bring the engine temperature within its normal operating range (depending on the vehicle type).

Automotive coolant system consists of a radiator, fan, water pump, coolant reservoir, thermostat, heater core and necessary plumbing for both the radiator and heater core. When the engine is started, the water pump starts to pump the coolant around the engine cylinder from lower the lower radiator tank into the coolant passages. Coolant flow is into lower tank to the engine block, then to the engine head and finally towards the outlet for the radiator. Then coolant begins to absorb the heat produced by the combustion process and flows towards the radiator inlet.

However, the thermostat restricts the coolant to flow towards the radiator until the temperature of the coolant is not raised above the engine operating temperature. At the instance, if the heater inside the cabin is turned on, the coolant is made to flow through the heater core by the bypass core. A thermostat on other ends acts as a regulating valve to control the coolant flow into the radiator and maintain the engine temperature optimum range.

When the coolant through pass the thermostat is at a higher temperature the wax begins to melt. The melting causes thermal expansion of the wax, which in turn pushes the rod and thereby allowing coolant to flow outside. A fan is actuated by a thermostatic switch once the coolant flows outside the thermostat. Coolant past the thermostat valve enters into the radiator upper tank through the upper radiator hose.

Due to the high temperature of the coolant, there are chances of building up of high pressure that might block the coolant from entering into the upper tank. To avoid this, the upper tank is provided with a pressure regulating valve, which opens when the pressure in the system increases beyond the recommended value. The opening of the valve allows the high pressurized coolant to flow into the coolant overflow tank. While flowing downwards, the coolant loses its heat to the air flowing past the space between the flat tubes.

The fan increases the draught of air and thereby increases heat transfer rate. When the coolant reaches the lower tank of the radiator, the temperature of the coolant reduces considerably. This cold coolant is circulated back around the cylinder and the cycle is repeated.

2.4.1 RADIATOR

Radiator is a type a heat exchanger with the objective to take out heat from the engine. Figure 2.12 show the radiator and its component. Here heat is transmitting through coolant liquid medium to air. It comprises of core, top and base tank. Core is structured with two arrangements of way, one set of a tube as well as the fin. Fluid coolant is streams inside the blades when air gets stream its external surfaces. The heat exhibits in the engine are transferred by the coolant and carrying via radiator then exchange to the atmosphere [8].

This mixture (coolant) is pump by the water pump through the engine where it is heated by the combustive response of fuel and oxygen in the air. The fluid proceeds to the radiator, where it circles through tubes wedged between a honeycombs of metal braces give an extensive surface zone of cooling. As a vehicle pushes ahead the air it encounters blows through the network of slats, picking up some of the heat. The liquid in the tubes is cooled by the passing air and it recycles through the engine to expel more heat. Moreover, the movement of parts inside the motor creates more heat. The cooling system and the radiator, specifically, expelled this heat.

Figure 2.12: Radiator [20]

2.4.2 WATER PUMP

Water pump circles the coolant by pushing it through engine sections and radiator. It is generally mounted on the cylinder block and controlled by the engine through the belt [8]. A water pump is crucial to engine operation since it guarantees the coolant continues traveling through the engine block, hoses, and radiator, and keeps up an ideal working temperature. It is driven by a serpentine belt from the crankshaft pulley. Figure 2.13 show the water pump and components such as impeller, bearing and seal.

The water pump utilizes impeller blades and centrifugal force to move the cooled water into the car engine. When the water has flow around the motor it is taken by hoses to the radiator, normally at the front of the vehicle, where the water is cooled by the movement of air over the radiator fins. It at that point leaves the radiator and streams once more into the water pump, where the process begins once again.

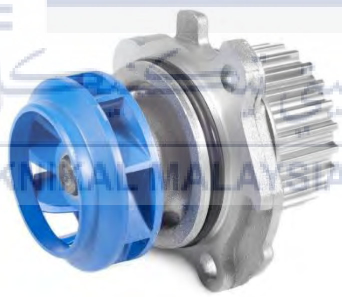


Figure 2.13: Water Pump [21].

2.4.3 THERMOSTAT

The other component in the automotive cooling system is thermostat. This device place between engine and radiator. It function is to obstruct the stream of coolant to the radiator until the point that the engine has warmed up. Thermostat control the engine coolant temperature by steering fluid stream either through the bypass or potentially radiator circles.

The fluid stream is coordinated through the bypass passage during warm-up and the radiator during the cooling period [12].

Thermostat enables the stream of coolant to radiator just when working temperature is achieved attained after starting the engine. This causes the engine to achieve working temperature quickly. It likewise abstains from overcooling of motor and came about fuel wastage [8]. It consist of a chamber filled with wax and a rod which is pressed against it.

The wax expands and proportionally actuates the valve once the coolant comes to a certain temperature. In any case, wax-based thermostat have passive control action dependent on the coolant temperature [12]. It begins to melt when the coolant that flow through the thermostat is at the higher temperature.

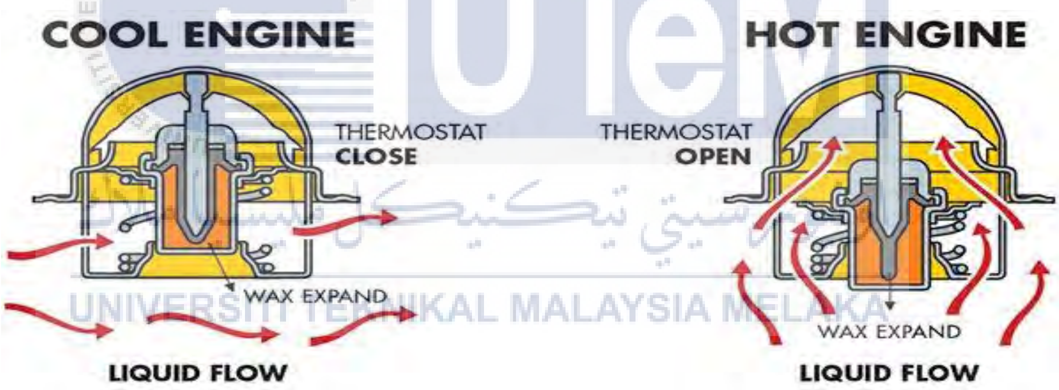


Figure 2.14: Liquid flow during cool and hot engine in thermostat [22].

2.4.4 RADIATOR COOLING FAN

Cooling fan sucks in fresh cool air through the radiator, thus cooling the hot water. The position of cooling fans is between the radiator and engine. Cooling fans are especially useful when the vehicle is stationary or moving at paces too ease back to force air through the grille. The coming of electric cooling fans, which turn on and off as required, demonstrated an improvement over engine-driven fans that slow down exactly when cooling fan needed most.

To manage higher volume stream rates of air pivotal stream fans is utilized to cool the radiators. These fans devour a lot of intensity and in this way, the performance of the axial flow fan is an imperative parameter of the efficiency of the motor cooling system [13]. There are three types of cooling fans based on how it is driven and controlled. First is mechanical fans. It is driven by the engine crankshaft by a belt. The speed is depend on the engine speed. Second is viscous fan. It also driven by a belt but the speed is controlled by a viscous clutch based on the temperature of the radiator. Third is electric fan. It is driven by electric motor. The motor is controlled by a controller based on various parameters like engine temperature, engine speed and A/c operation.

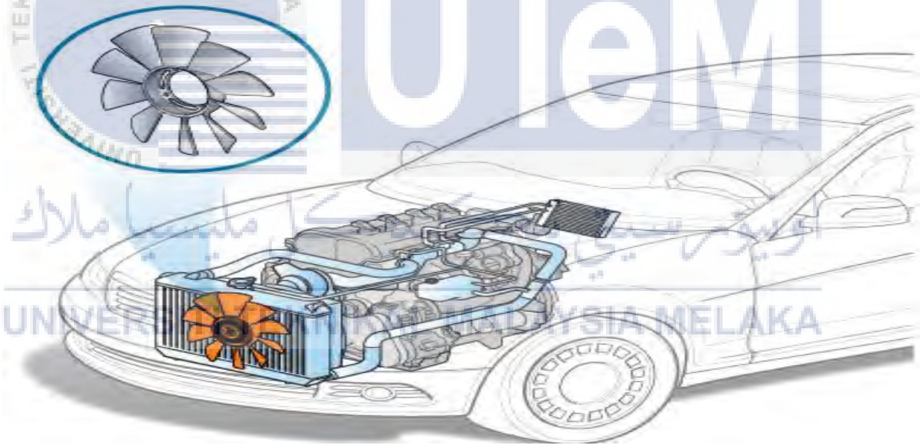


Figure 2.15: Position of fan in automotive cooling system [23].

2.4.5 RADIATOR CAP

While radiator caps looks basic and don't cost much, they are critical for a properly operating cooling system. A malfunctioning radiator cap can bring about overheating, loss of coolant or serious engine damage. It is critical to check it periodically and replaced if necessary [14] . It function is to keeps up a constant high pressure in the cooling system, which increases the boiling temperature of engine coolant. The rise of the temperature helps in simple dispersal of heat to the environment because of higher difference in radiator temperature and ambient temperature [5].

The pressure cap is set at 90 kpa with the objective that the cooling system works under a pressure of 190 kpa. At the point when the pressure surpasses 1.9 Bar, the pressure valve opens and lets out the excessive pressure alongside some coolant. At the point when the engine cools down, the vacuum valve opens and let in the air with the objective that the radiator does not collapse inward due to vacuum.

It will work as pressure relief valves. Radiator cap will avoid the excessive pressure. Unchecked high pressure could damage the radiator, heater core, hoses or water pump seal. The pressure caps likewise keeps radiator hoses and tanks from falling. On the off chance that air was not able to enter it could cause an excessive vacuum [14].

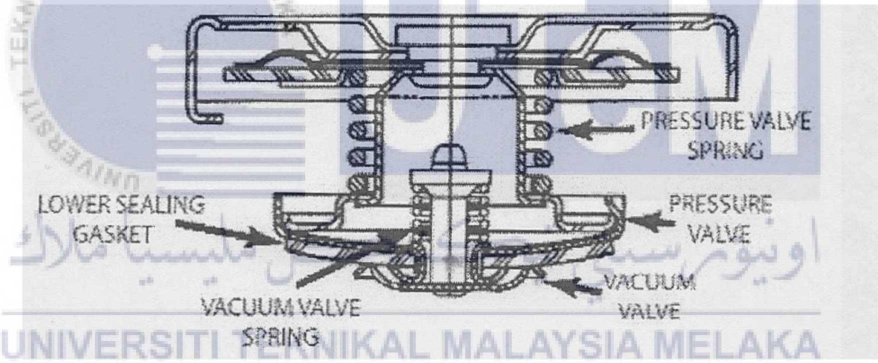


Figure 2.16: Component of radiator cap [24]

2.4.6 COOLANT

Coolant is one of the main component in the automotive cooling system. It is a mixture of water and antifreeze which moves through the engine cooling system to retain the excess heat and dissipate it through the radiator. Engine coolant is a mixture of antifreeze and water. It is commonly mixed in 30:70 to 50:50 ratio depending on weather conditions in which the vehicle is used. About 50% of the antifreeze is used in conditions where the temperature falls below -15 °C. Meanwhile, about 30 % of antifreeze is used in conditions where the temperature does not fall below -15 °C.

Antifreeze is a blend of glycol and additives. It has anti-rust properties to avoid rusting of engine passages. It has a low frosty temperature to abstain from freezing in outrageous cool conditions [5]. In countries with extreme weather conditions, radiator fluid is utilized as an added substance to lower the freezing point or elevate the boiling point of a liquid. Since water has great properties as a coolant, the blend of water as a base liquid with glycol family, particularly ethylene glycol (EG) at various percentages depends on the weather conditions [15].

In the car radiators, the coolant media is pumped through the flats tubes while the air is drawn over the fins by forced convection, where heat trades between the hot circulating liquid and air [16]. When the coolant is in a bad condition, it's an ideal opportunity to have the system flushed. The most common service interval interim for flushing the framework is each 2 to 3 years or 3.8 x 10^4 km to 5.7x 10^4 km.

2.5 RADIATOR MAINTENANCE AND CLEANING

An appropriately radiator working of radiator is fundamental to keep the engine from overheating. Coolant that heated by the engine is directed through the radiator where it cooled by heat exchanger. Radiator and cooling system is very important and needs to be clean in order for it to run smoothly and perfectly. There are natural conditions be that as it may, which reduce the efficiency of internally and externally, thus reducing the performance.

At the point when dust gathering is not severe, brushing down of the approach air side of the core faces is recommended. A delicate sort of brush is prescribed so as not to harm or distort the copper fins. If necessary, this could be followed by blowing compressed air at no more than 700 kPa through the air side of the radiator panels in the opposite direction to the normal air flow till loose material is blown free [17].

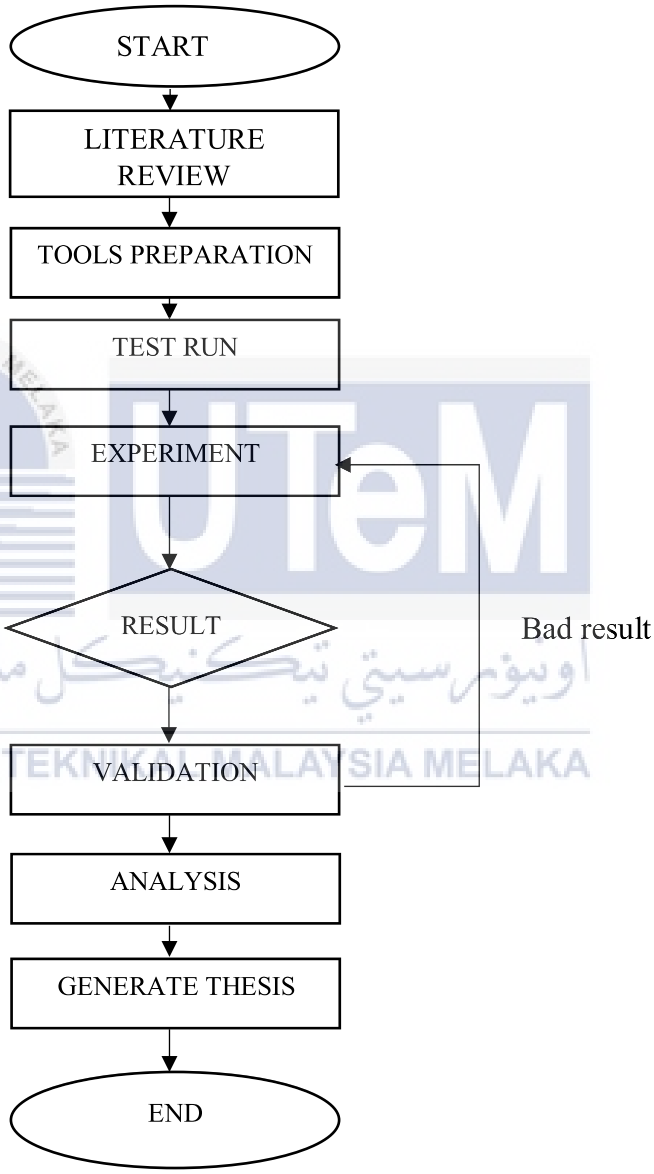
If the fin and tube exterior surfaces are allowed to become caked with dirt, through neglect, difficult regions might be cleaned by washing and hosing down with cleanser and heated water, diluted in water are suitable for this purpose. A low weight (175 kPa) steam jet is likewise succeed in evacuation of external stubborn dirt [17].

It is fundamental that coolant air passage be kept sensibly free from obstacle. Unnecessarily fouled radiator core could cause a critical drop in cooling air amount, with a resultant increment in water and lube oil temperatures. Regular inspection will determine the regularity of external cleaning necessary [17]. Most of radiator failures are the result of lack maintenance of inhibitors, causing erosion and corrosion of the solder joints. Therefore, regular coolant checks are essential to minimise both the cost of repair and down time.

CHAPTER 3

METHODOLOGY

3.1 PROJECT PLAN



3.2 EXPERIMENTAL SET-UP

3.2.1 TEST RIG AND SCHEMATIC DIAGRAM

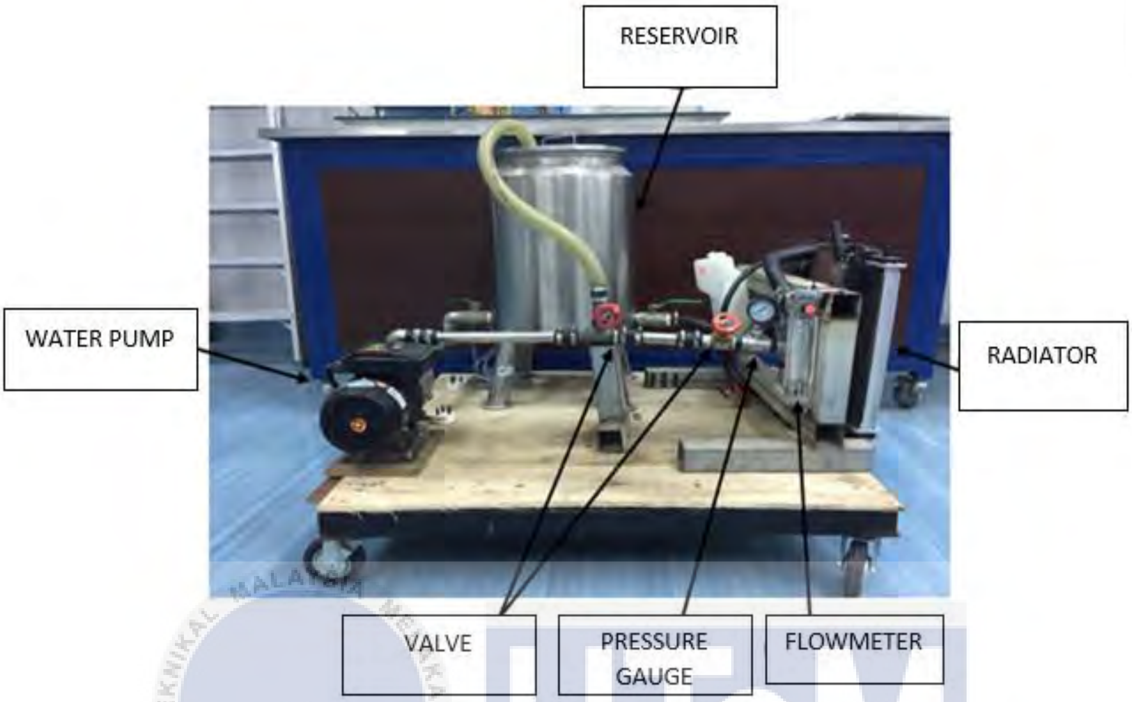


Figure 3.1 : Test rig

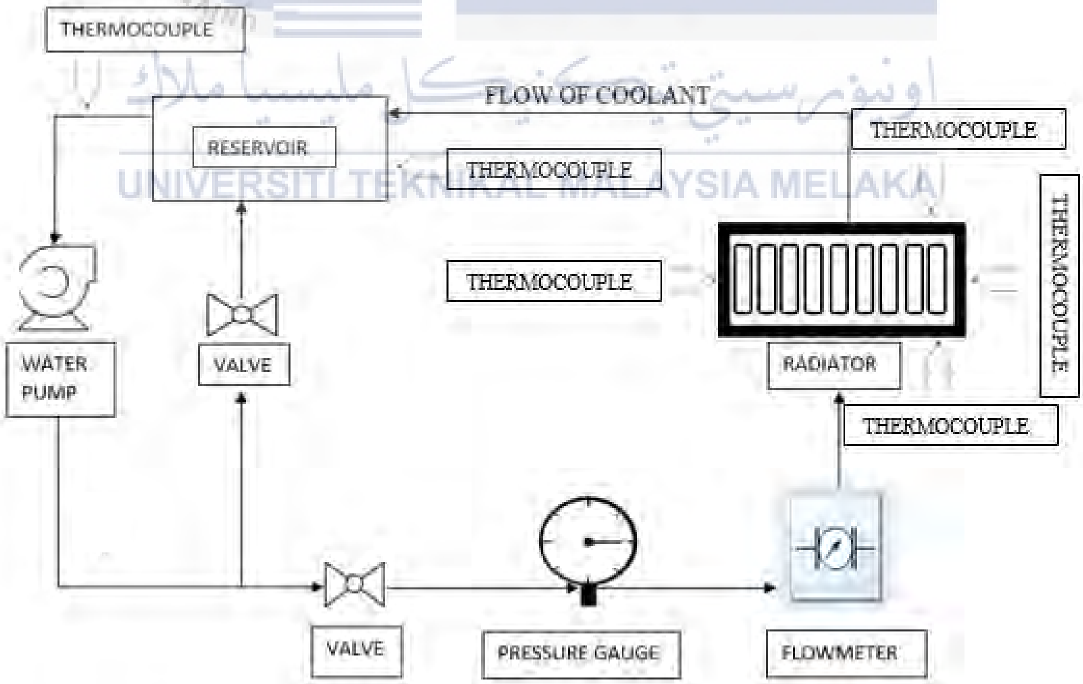


Figure 3.2 : Schematic diagram of experiment

3.2.2 COMPONENT

A. RADIATOR

In this experiment, Perodua Kancil 850cc radiator was used as shown in Figure 3.3. Table 3.1 show the radiator specification.

Figure 3.3: Radiator

Table 3.1 : Radiator specification

Brand	TLX
Height	40 cm
Width	35 cm
Thickness	26 mm

B. RESERVOIR WITH HEATING ELEMENT

As shown in Figure 3.4, the reservoir with heating element in this test rig will act as engine just like an actual automobile cooling system. The heating element is a source of heat.

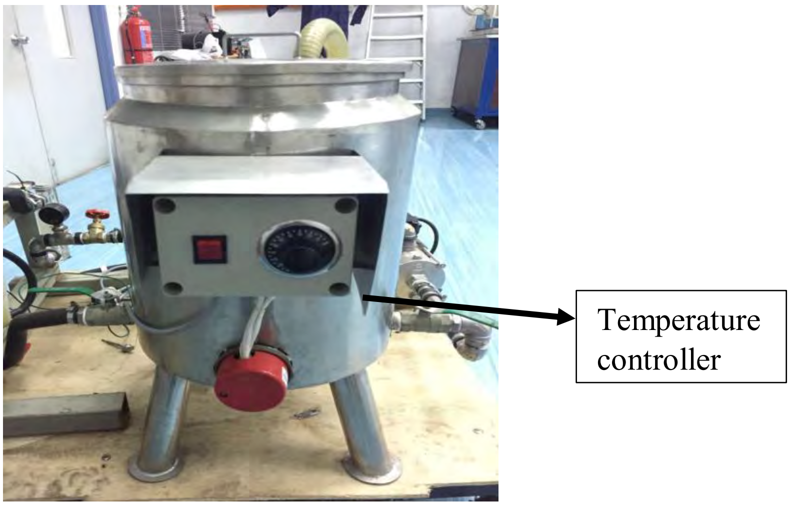


Figure 3.4: Reservoir with heating element

C. WATER PUMP

Figure 3.5 show the water pump uses centrifugal force to send liquid to the outside while it rotate, making liquid be drawn from the center constantly. Table 3.2 show the water pump specification

Figure 3.5: Water Pump

Table 3.2 : CNP water pump specification

Specification	CHL12-30
Power	2.2 kw
Speed	2900 rpm
Head	29.5
Temperature	-15 ºC to +110 ºC
Flow rate	12 (m3/h)
Pressure	1000kpa

D. THERMOCOUPLE AND DATA LOGGER

The most recognized electrical equipment for temperature measurement used the thermocouple. Type-k thermocouple will be connected to the Pico data logger as shown in Figure 3.6 for data collection.

Figure 3.6: Data Logger

E. FLOW METER

The device that used to measure the amount of fluid that passed through during the experiment. Figure 3.7 show the flow meter that have in the test rig.

Figure 3.7: Flow Meter

F. VALVE

To regulate or control the flow of the coolant by opening and closing the passageway. Figure 3.8 show the valve used in the experiment.

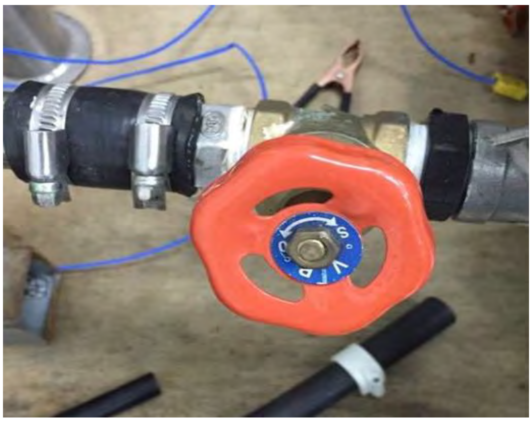


Figure 3.8: Valve

G. PRESSURE GAUGE

To measure and display the pressure of the coolant. As shown in Figure 3.9, this pressure gauge was used in the experiment.

Figure 3.9: Pressure Gauge

3.3 EXPERIMENT

A series of experiment will be conducted is to determine whether the dirt will affected the performance of automotive cooling system.

3.3.1 PROCEDURES

The experiment are conducted at HVAC laboratories Kompleks Kejuruteraan Mekanikal Fasa UTeM. The test rig was fitted with two thermocouple to collect the inlet and outlet temperature of coolant all through the radiator. For the first step, the radiator was cleaned to remove all the particle caught in the fins. Experiment are conducted under four condition which is (1) clean radiator, (2) radiator with dirt (mud and silt) and (3) post experiment.

For preliminary experiment a clean radiator will be used. The data also used as a benchmark to temperature data with dirty radiator. At the point when the coolant temperature reached the maximum value (80 °C) the fan will turned on. The reservoir are filled with mixture, the heater and the pump is switch on. The data will be recorded when a steady state is achieve which is a constant inlet temperature of 80 °C ± 5 °C.

In another experiment (in a separate experiment), mud and silt will be used as the covering material on the radiator, with the covering area is about 25 %, 50 % and 75 % of the total area. Then the same procedure as the preliminary experiment will be repeated. After completing the experiment, all the dirt will be cleaned using a brush. Then, a post-cleaning experiment will be conducted to study the significance of the proposed cleaning method.

3.4 DIRT PROPERTIES

Table 3.3: Mud properties [18].

Properties	Achived value
Density,ppg	10.3
Plastic viscosity,cp	23.0
Yield point ,lb/100ft^2	11.0
Gel strength (10 second)	7.0
Gel Strength (10 minutes)	14.0
Filtrate liss, ml	3.0

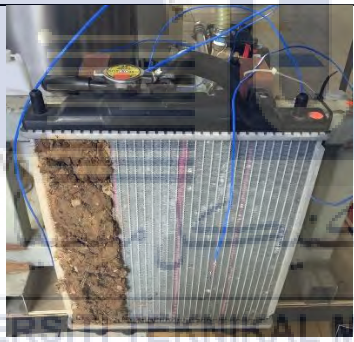
Table 3.4: Silt density

Soil Type	P(lb/ft^3)	[kg/m^3]
Sand	(89)	[1430]
Loamy Sand	(89)	[1430]
Sandy Loam	(91)	[1460]
Loam	(89)	[1430]
Silty Loam	(86)	[1380]
Silt	86()	[1380]
Sandy Clayey Loam	(94)	[1500]
Clayey loam	(87)	[1390]
Silty Clayey Loam	(81)	[1300]

Table 3.3 and 3.4 show the properties of the mud and silt. Basically, the mud is a blend of water and a mix of soil, silt, and clay. Deposits harden over geological time to form sedimentary rock such as shale or mudstone. At the point when geographical stores of mud are shaped in estuaries, the resultant layers are named bay muds. Silt will, in general, have a round shape, giving a high silt soil a soapy or slippery feeling when rubbed between the fingers when wet and is harder to form into a string than clay [19].

3.5 EXPERIMENT WITH DIRT

Table 3.5: Experiment setup with dirt

CONDITION	TYPE OF DIRT	
	SILT	MUD
25% of dirt on the radiator surface		
50% of dirt on the radiator surface		

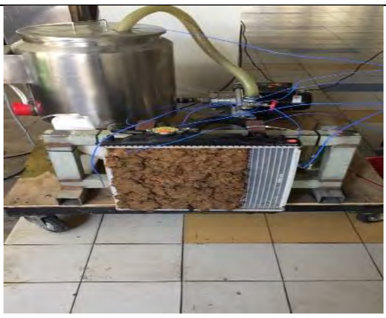
75% of dirt on the radiator surface		

Table 3.5 show the experiment setup that using dirt (mud and silt) as covering material. The dirt have been covered the surface on the radiator of the 25 %, 50 % and 75 % area. The section have been mark using a marker.

3.6 SAFETY PRECAUTION

1. Wear appropriated clothing during the experiment.
2. Must wear a completely cover foot such as shoes.
3. Beware the electric plug during the experiment.
4. Make sure the plug is switch off before connecting.
5. Do not touch the reservoir doing the experiment.
6. Do not smell the coolant.
7. Do not touch any component during the experiment.
8. Make sure the battery is far from the test rig during experiment to avoid a short circuit.
9. The heavy duty extension wire is used to match the 2000W heater.

CHAPTER 4

RESULT AND DISCUSSION

This chapter is about the analysing result obtained from the experimental data. The results obtained from the experiment are the clean (post cleaning experiment which all the dirt was removed using a brush) and with dirt (mud and silt) condition. The results are tabulated into a table and graph to be analysed. The experiment was using three different coolant flowrate which are (4 LPM, 8 LPM and 12 LPM).

4.1 4LPM FLOWRATE DATA AND RESULT

This section show and analyse the result when the experiment using 25 % of mud as covering material and 4 LPM flowrate. The experiment was conducted three time to validate the result.

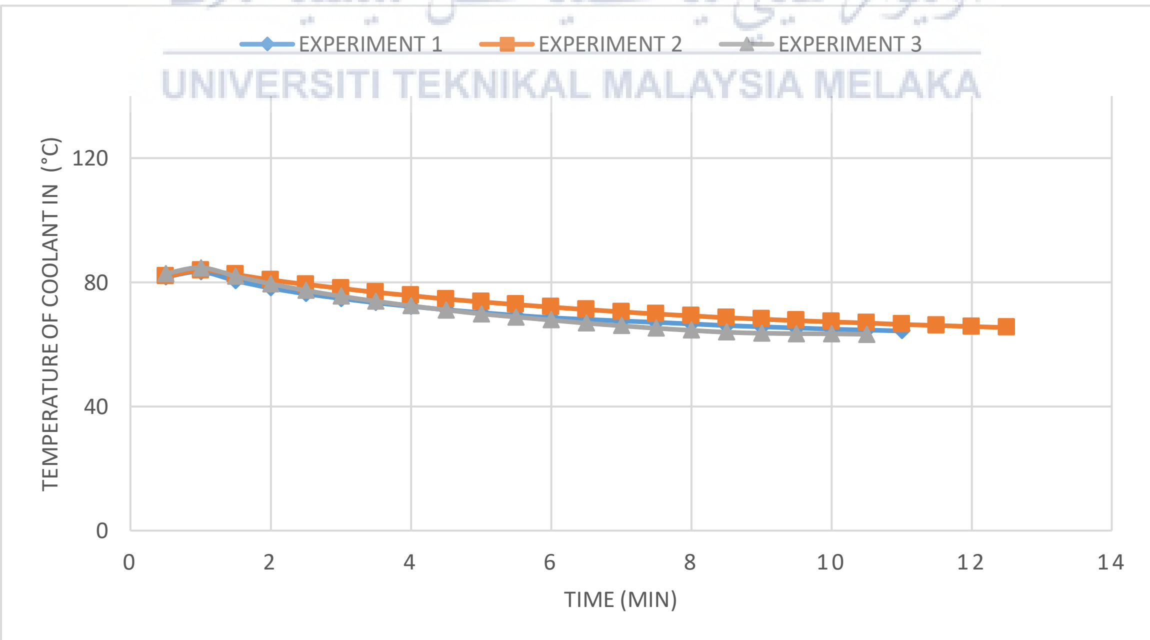


Figure 4.1: Graph of Temperature coolant into the radiator using mud as covering material

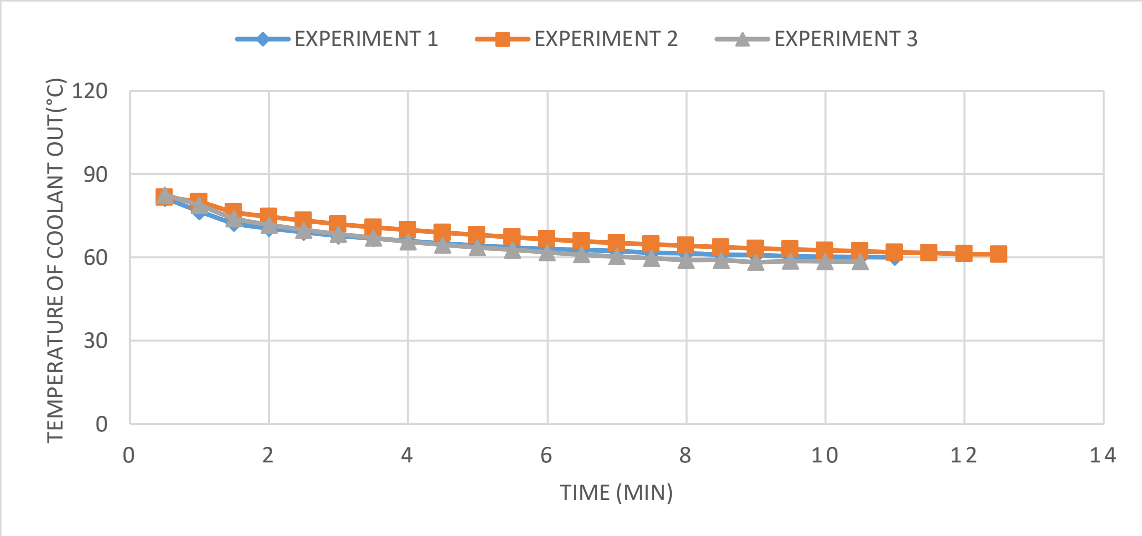


Figure 4.2: Graph of Temperature coolant out from radiator using mud as covering material

As shown in Figure 4.1, for the first experiment the temperature of coolant into the radiator recorded at the first minute is 81.72 °C and it slowly decreased when the fans was switched on. This is due to the different of temperature between the coolants and surrounding because of the rate of heat transfer will affect the temperature different. This factor will increase the rate of heat transfer and also increase the heat release to surrounding. After nine minutes, the temperature remain constant which is 64 °C.

For second experiment, the temperature of coolant into radiator recorded is 81.85 °C and it slowly decreased. When it reached to ten minutes the temperature remain constant which is 66.42 °C. For the third experiment it show that the temperature at the first minute is 82.8 °C and it slowly decrease when the fan is switch on. The temperature remain constant 63.6 °C when it reached to nine minutes.

Figure 4.2 shown the temperature of coolant out from the radiator. For the first experiment, at the first minutes, it shown the temperature is 76.46 °C and slowly decreased when the fans was switched on. The temperature remain constant at nine minutes which is

60.86 °C. For second experiment, temperature remain constant at ten minutes which is 61.83 °C and the third experiment the temperature remain constant at 59.29 °C when it reached to the minutes.

As shown in Figures 4.1 and 4.2, it was observed that the trend of the graph plotted remained almost exactly the same. So, the results are verified because of the constant trend.

4.2 MUD AS COVERING MATERIAL

Mud was applied as covering material for the radiator in the experiment. There are three parameter used in the experiment which are flowrate, percentage of dirt and clean condition.

4.2.1 RESULT OBTAIN WITH DIFFERENT FLOWRATE

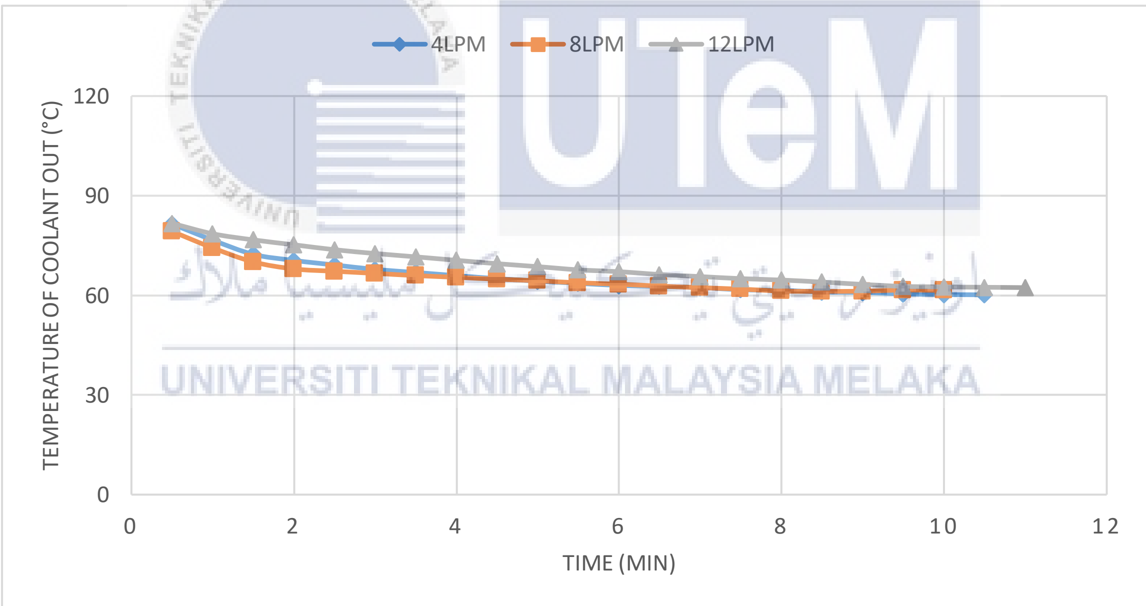


Figure 4.3: Graph of temperature coolant out from radiator using 25% of mud with different flowrate

By referring Figure 4.3 above this experiment was using 25 % of mud. The maximum temperature obtained for the coolant out from radiator was achieved when the 12 LPM of flowrate was used. The temperature remain constant when it reached eight minutes which is 62.67 °C. When 8 LPM of flowrate was used the temperature remain constant at 61.34 °C and the lowest temperature gained when the 4 LPM of flowrate is used. The temperature remain constant at 60.25 °C when it reached eight minutes.

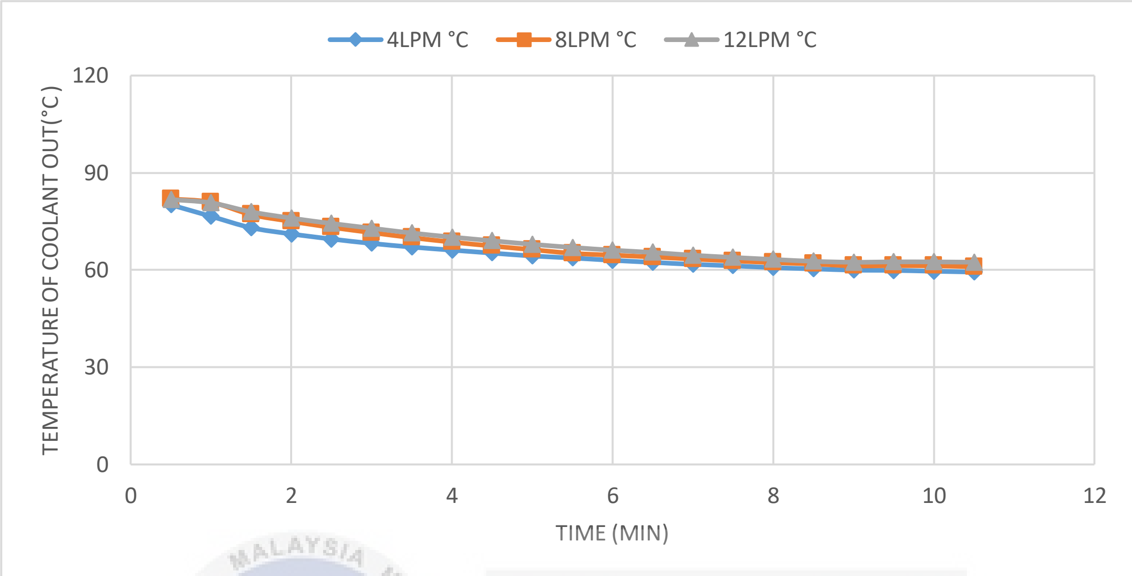


Figure 4.4: Graph of temperature coolant out from radiator using 50 % of mud with different flowrate (LPM)

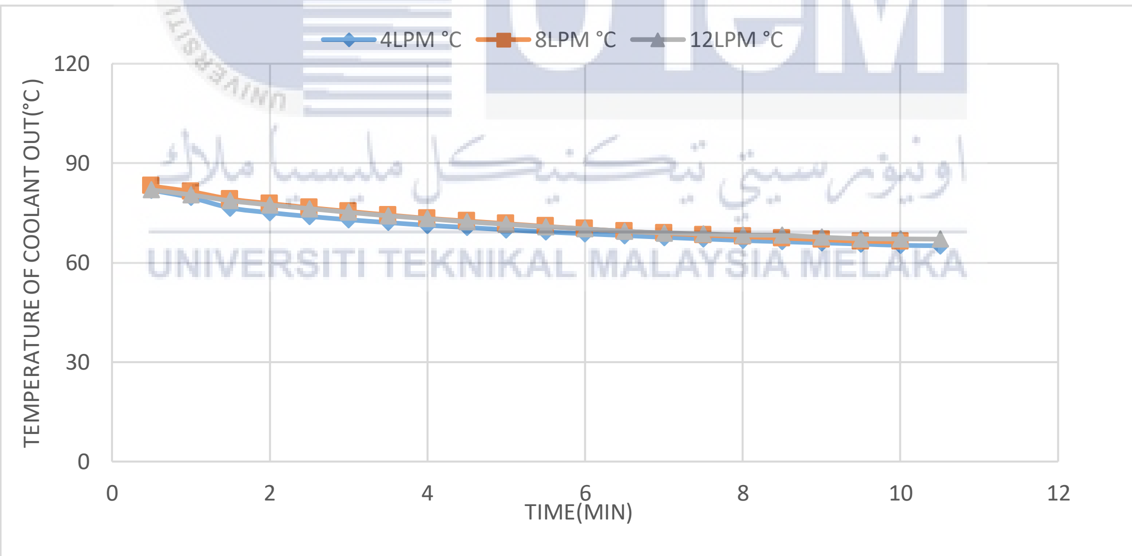


Figure 4.5: Graph of temperature coolant out from radiator using 75 % of mud with different flowrate (LPM)

By referring to Figure 4.4, this experiment was using 50 % of mud. The maximum temperature obtained for the coolant out from radiator was achieved when the 12 LPM of flowrate was used. The temperature remain constant when it reached nine minutes which is

63.27 °C. When 8 LPM of flowrate was used the temperature remain constant at 61.87 °C when it reached eight minute and the lowest temperature gained when the 4 LPM of flowrate is used. For figure 4.5, 75 % of mud was used, it show the similar pattern with others experiment. The highest temperature gained when 12 LPM of flowrate was used. The temperature remain constant when it reached to the nine minutes which is 67.76 °C. Then, the 8 LPM flowrate was used it remain constant at 66.94 °C. The lowest temperature gained when the 4 LPM of flowrate was used which is 65.61 °C.

From the experiment, it can be observed that, when the coolant flowrate is increased, the temperature of water out from the radiator will be increased. The highest temperature obtained for the coolant at the out from the radiator was obtained when 12 LPM of coolant were used in the radiator. This is because the specific heat capacity is high for the coolant. So, if it is required to increase the cooling capacity with the mixture then its mass flow rate is to be increased [10].

4.2.2 RESULT OBTAIN WITH DIFFERENT PERCENTAGE OF MUD

As shown in Figure 4.6, 4.7 and 4.8, the temperature of coolant out from the radiator increase with the increase of the percentage area covered. There were also the corresponding increase temperature of the coolant into the radiator when the percentage of area covered increased. This experiment is used three different flowrate which is (4 LPM, 8 LPM, and 12 LPM). There were similarity trend between three experiments.

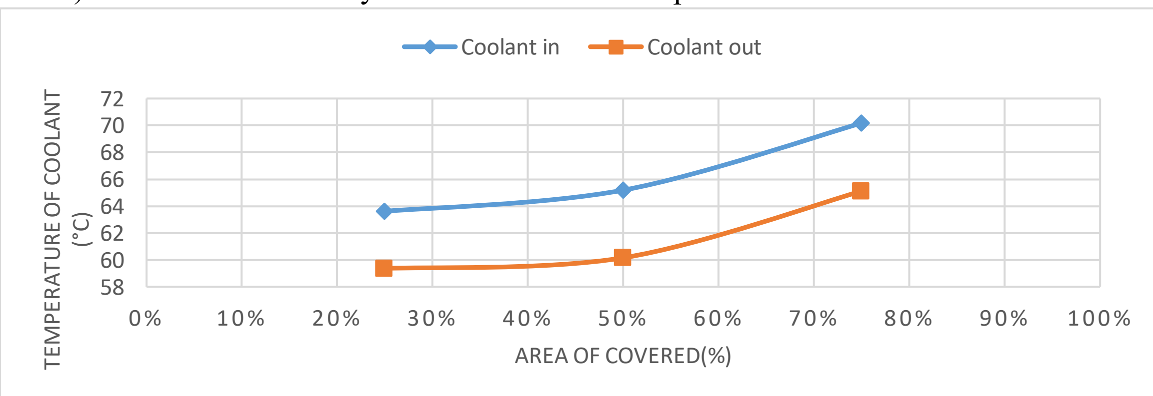


Figure 4.6: Graph of temperature versus area of covered using 4 LPM

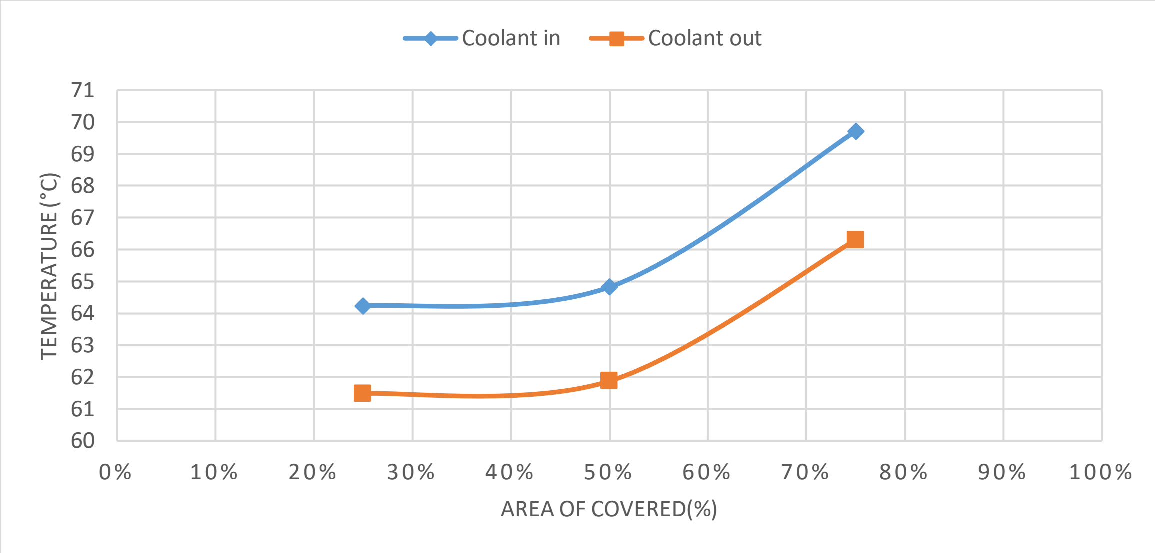


Figure 4.7: Graph of temperature versus area of covered using 8 LPM

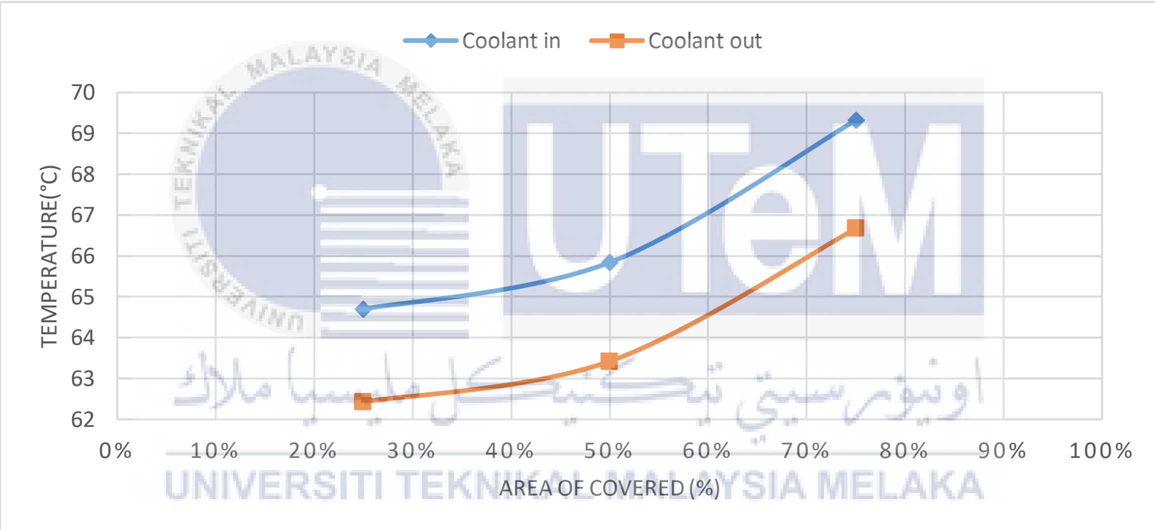


Figure 4.8: Graph of temperature versus area of covered using 12 LPM

The first point in the graph means 25 % of area covered, the second point is referred to the 50 % of area covered and for the third point is referred to the 75 % of area covered by mud. The lowest temperature obtained for coolant at inlet and outlet is when 25 % mud used as covering material. The highest temperature obtained for the coolant at the inlet and outlet of the radiator was obtained when 75 % of the radiator is covered with the mud.

This was because of the inability of the coolant from removing enough heat from the walls of the radiator. When the surface area of the radiator is decreased by mud, so in this way it will reduced the amount of air going through the radiator for reasons for cooling the coolant, and it will cause the increased of temperature of inlet and outlet of the radiator[1].

4.2.3 RESULT OBTAIN WITH CLEAN CONDITION

After completing the experiment, all the dirt will be cleaned using a brush. Then, a post-cleaning experiment has been conducted to study the significance of the proposed cleaning method. As shown in Figures 4.9 and 4.10, comparing the temperature of the inlet and outlet of three condition which is the model, with dirt and clean condition with using 12 LPM of flowrate.

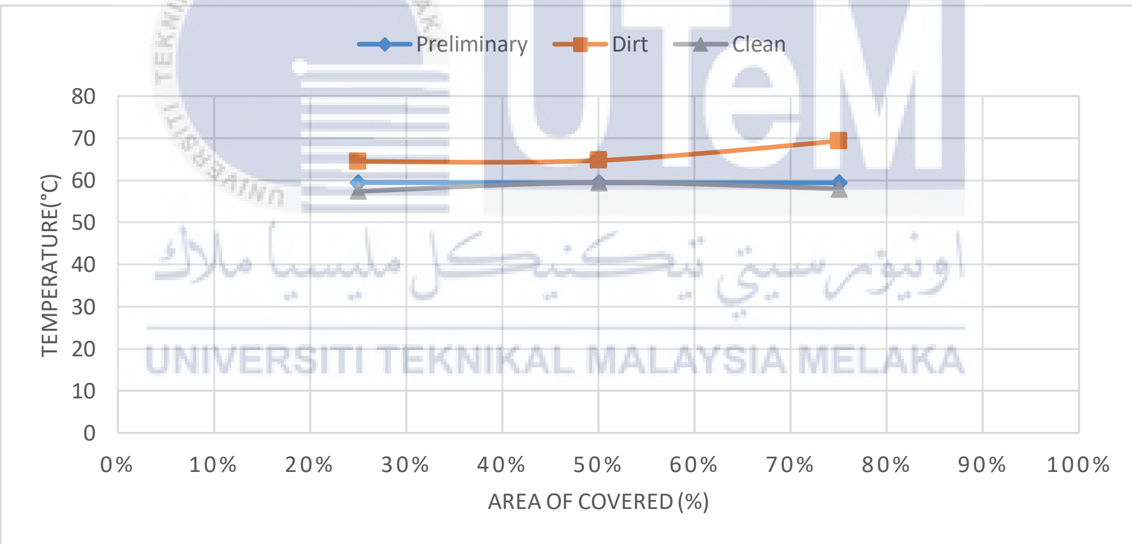


Figure 4.9: Graph of temperature of coolant inlet versus area of covered with clean condition

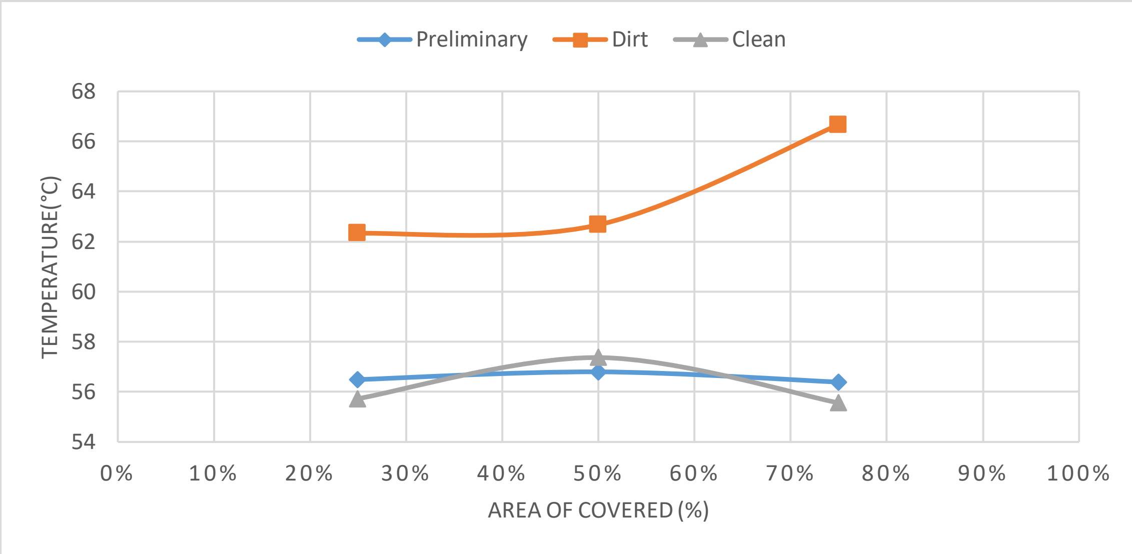


Figure 4.10: Graph of temperature of coolant outlet versus area of covered with clean condition

The highest temperature of inlet and outlet is when the dirt is covered the surface of the radiator for 75 % about 70 °C for inlet and 66.48 °C for outlet. It was generally observed that as the area of the radiator covered was increased, the temperature of the coolant from the radiator also increased considerably. This can be explained by the fact that the effective heat transfer area was reduced, thereby reduced the quantity of air going through the radiator for reason of cooling the coolant [1].

Radiator and cooling system is significant and should be clean with the goal for it to run smoothly and perfectly. There are regular conditions in any case, which diminish the efficiency of internally and externally, subsequently decreasing the performance. Right when dust and dirt gathering, brushing down of the approach air side of the core faces is recommended. A sensitive kind of brush is recommended so as not to harm or distort the copper fins [17].

Therefore, when the dirt was removed by using the brush, it show that the temperature for both inlet and outlet is decreased. The temperature is return near to the preliminary condition. It can be observed the temperature of clean condition is remain constant even though the percentage of area covered is increased. This can be explained by the fact that the effective heat transfer area was increased, indirectly it will increased the quantity of air going through the radiator for purpose of cooling of the coolant. This phenomenon was expected because as the effective transfer area of the radiator is increased, more temperature is going out and thereby affecting the temperature of the coolant and hence the performance of the engine.

4.3 SILT AS COVERING MATERIAL

The experiment was conducted using silt as covering material for the radiator. There are three parameter used in the experiment which are flowrate, percentage of dirt and clean condition.

4.3.1 RESULT OBTAIN WITH DIFFERENT FLOWRATE

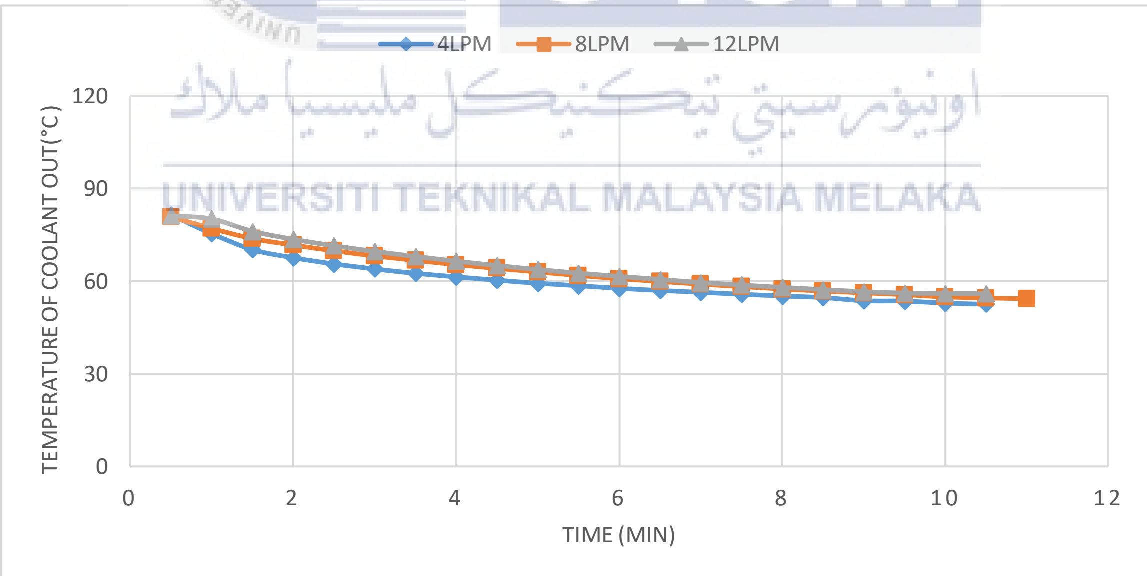


Figure 4.11: Graph of temperature coolant out from radiator using 25 % of silt with different flowrate

By referring to Figure 4.11 above this experiment was using 25 % of silt. The maximum temperature obtained for the coolant out from radiator was achieved when the 12

LPM of flowrate was used. The temperature remain constant when it reached nine minutes which is 56.78 °C. When 8 LPM of flowrate was used the temperature remain constant at 54.89 °C and the lowest temperature gained when the 4 LPM of flowrate is used. The temperature remain constant at 53.66 °C.

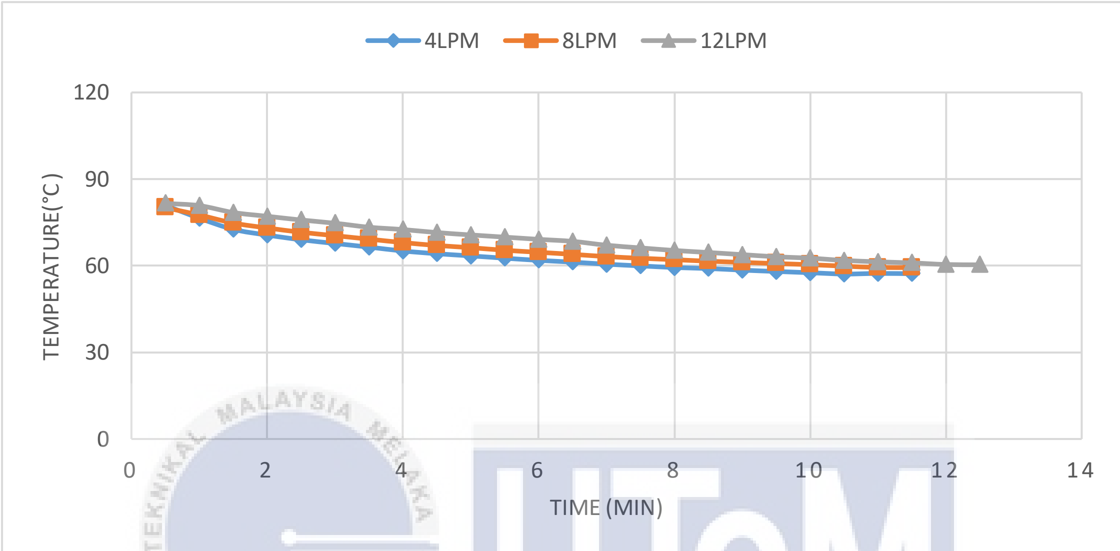


Figure 4.12: Graph of temperature coolant out from radiator using 50 % of silt with different flowrate

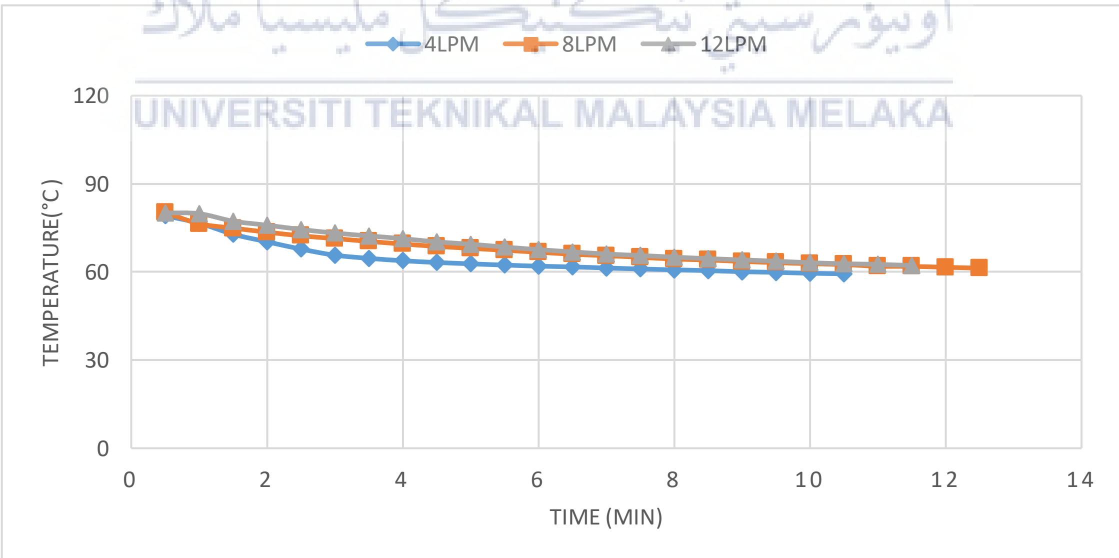


Figure 4.13: Graph of temperature coolant out from radiator using 75 % of silt with different flowrate

By referring to Figure 4.12 above this experiment was using 50 % of mud. The maximum temperature obtained for the coolant out from radiator was achieved when the 12

LPM of flowrate was used. The temperature remain constant when it reached ten minutes which is 61.283 °C. When 8 LPM of flowrate was used the temperature remain constant at 59.85 °C when it reached ten minute and the lowest temperature gained when the 4 LPM of flowrate is used. For figure 4.13, 75 % of mud was used, it show the similar pattern with others experiment.

The highest temperature gained when 12 LPM of flowrate was used. The temperature remain constant when it reached to the 63.15 °C. Then, when the 8 LPM flowrate was used it remain constant at 61.94 °C. The lowest temperature gained when the 4 LPM of flowrate was used which is 59.38 °C.

From the experiment, it can be observed that, when the coolant flowrate is increased, the temperature of water out from the radiator will be increased. The highest temperature obtained for the coolant at the out from the radiator was obtained when 12 LPM of coolant were used in the radiator. This is because the specific heat capacity is high for the coolant. So, if it is required to increase the cooling capacity with the mixture then its mass flow rate is to be increased [10].

4.3.2 RESULT OBTAIN WITH DIFFERENT PERCENTAGE OF SILT

As shown in Figure 4.14, 4.15 and 4.16, the temperature of coolant out from the radiator increase with the increase of the percentage area covered. There were also the corresponding increase temperature of the coolant into the radiator when the percentage of area covered increased. This experiment is used three different flowrate which is (4 LPM, 8 LPM, and 12 LPM). There were similarity trend between three experiments.

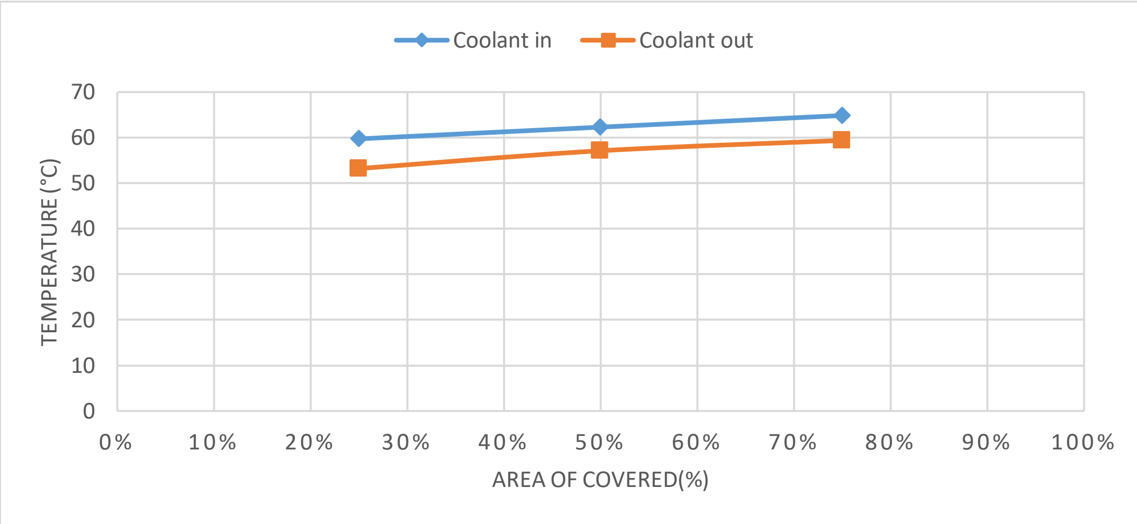


Figure 4.14: Graph of temperature versus area of covered using 4 LPM

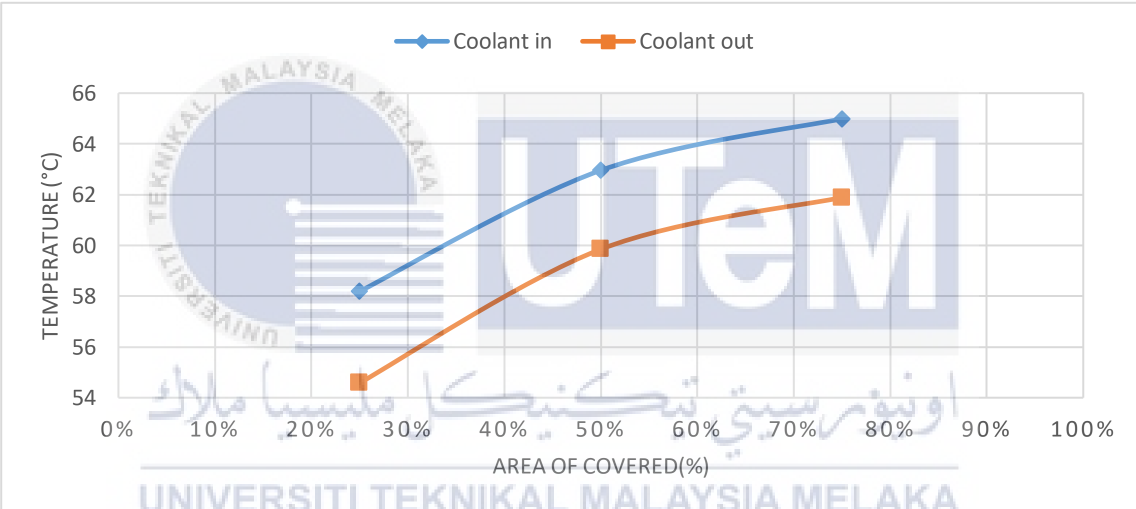


Figure 4.15: Graph of temperature versus area of covered using 8 LPM

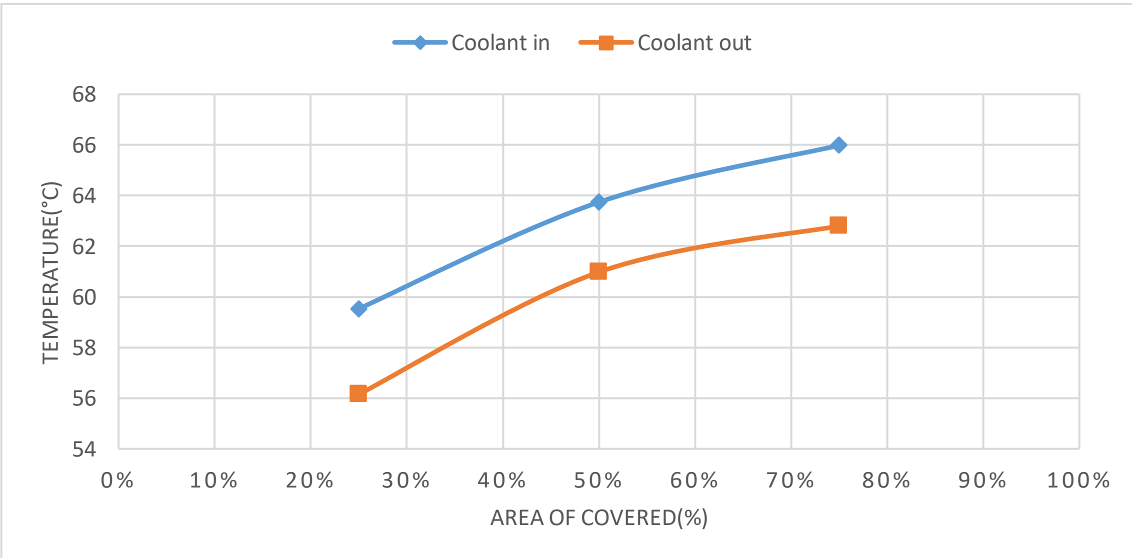


Figure 4.16: Graph of temperature versus area of covered using 12 LPM

The first point in the graph means 25 % of area covered, the second point is referred to the 50 % of area covered and for the third point is referred to the 75 % of area covered by silt. For 4 LPM coolant flowrate the lowest temperature obtained for coolant at inlet and outlet is when 25 % mud used as covering material which is 59.73 °C for inlet and 53.21 °C. The highest temperature obtained for the coolant at the inlet and outlet of the radiator was obtained when 75 % of the radiator is covered with the silt which is 64.86 °C for inlet and 59.38 °C for outlet.

Other than that, for 8 LPM coolant flowrate the lowest temperature obtained for coolant at inlet and outlet is when 25 % silt used as covering material which is 58.19 °C for inlet and54.28 °C. The highest temperature obtained for the coolant at the inlet and outlet of the radiator was obtained when 75 % of the radiator is covered with the silt which is 64.99°C for inlet and 61.89 °C for outlet. For 12 LPM it show the same trend with others experiment. The lowest temperature obtain when 25 % of silt used as covering material which is 59.53 °C for inlet and 56.15 °C for outlet. The highest temperature obtain when 75 % used as covering material which is 65.98 °C for inlet and 62.8 °C for outlet.

It can be observed that the highest temperature obtain when 75 % of silt was used. This was because of the inability of the coolant from removing enough heat from the walls of the radiator. When the surface area of the radiator is decreased by mud, so in this way it will reduced the amount of air going through the radiator for reasons for cooling the coolant, and it will cause the increased of temperature of inlet and outlet of the radiator [1].

4.3.3 RESULT OBTAIN WITH CLEAN CONDITION

After completing the experiment, all the dirt will be cleaned using a brush. Then, a post-cleaning experiment has been conducted to study the significance of the proposed cleaning method. As shown in Figure 4.17 and 4.18, comparing the temperature of the inlet and outlet of three condition which is the model, with dirt and clean condition with using 12 LPM of flowrate.

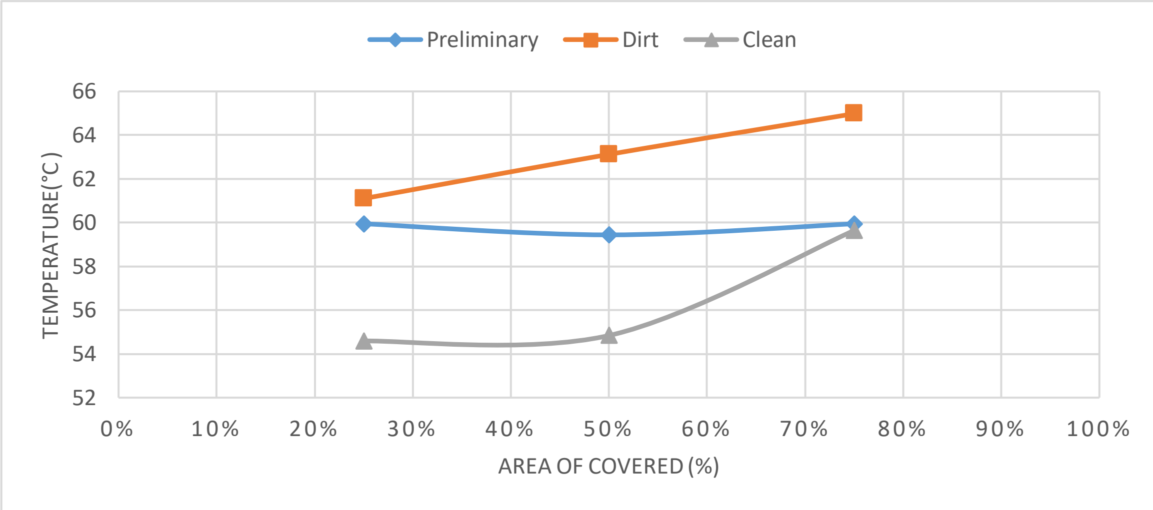


Figure 4.17: Graph of temperature of coolant inlet versus area of covered with clean condition

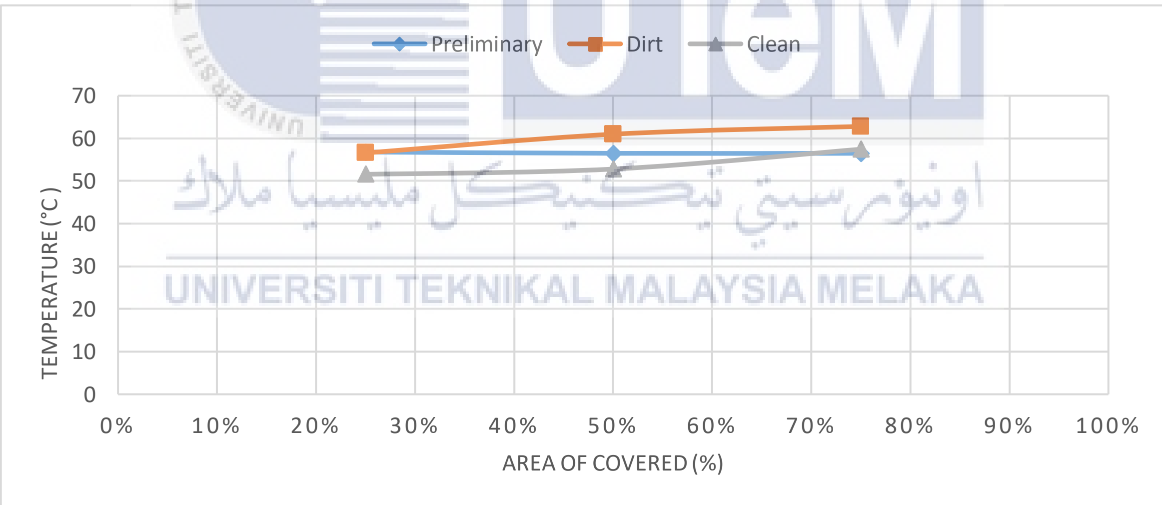


Figure 4.18: Graph of temperature of coolant outlet versus area of covered with clean condition

The highest temperature of inlet and outlet is when the dirt is covered the surface of the radiator for 75 % about 65 °C for inlet and 61.48 °C for outlet. It was generally observed that as the area of the radiator covered was increased, the temperature of the coolant from the radiator also increased considerably. This can be explained by the fact that the effective heat transfer area was reduced, thereby reduced the quantity of air going through the radiator for reason of cooling the coolant [1].

Radiator and cooling system is significant and should be clean with the goal for it to run smoothly and perfectly. There are regular conditions in any case, which diminish the efficiency of internally and externally, subsequently decreasing the performance. Right when dust and dirt gathering, brushing down of the approach air side of the core faces is recommended. A sensitive kind of brush is recommended so as not to harm or distort the copper fins [17].

So, when the dirt was removed by using the brush, it show that the temperature for both inlet and outlet is decreased. The temperature is return near to the preliminary condition. It can be observed the temperature of clean condition is remain constant even though the percentage of area covered is increased.

4.4 COMPARISON BETWEEN MUD AND SILT RESULT

This section show the experiment result and analysis when mud and silt was used as the covering material. It also show the model temperature both of the dirt was used. From the cases that used dirt as covering material, it show that the temperature of coolant inlet and outlet from radiator increased when the area of covered is increased.

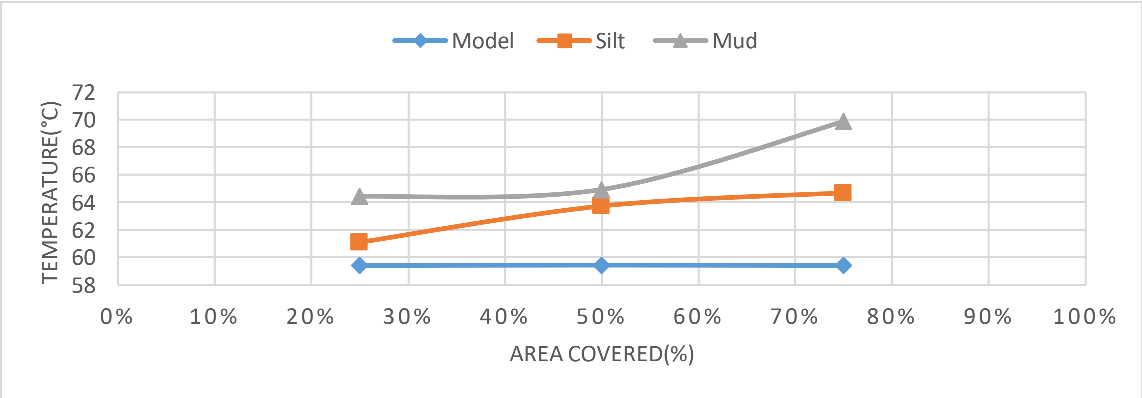


Figure 4.19: Variation of the temperature water inlet to the radiator with the area of radiator covered.

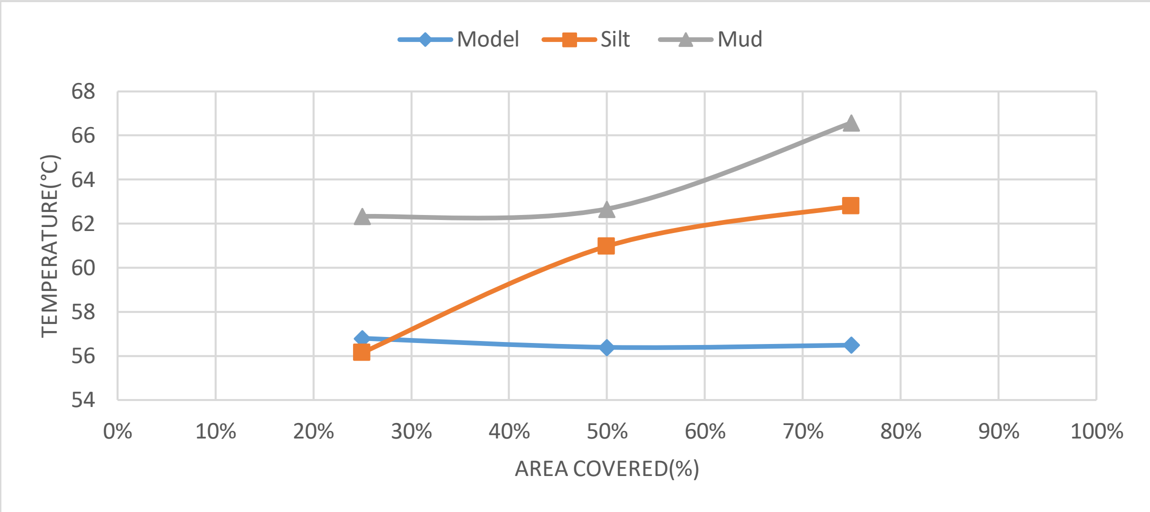


Figure 4.20: Variation of the temperature water outlet from the radiator with the area of radiator covered.

As shown in Figures 4.19 and 4.20 above, the experiment used mud was compared to that obtained using silt, it was observed that the coolant temperature into the radiator was higher when mud was used as the cover material than when silt was used. From the Figure 4.18 , it shown that when 25 % of dirt was used the temperature of mud is higher than silt which is 61.1 °C for mud and 59.41 °C for silt. Then, when the area of covered is increase to the 50 %, the graph show mud is high than silt. Temperature for mud is 64.94 °C and 63.74 °C for silt.

The highest temperature gained when it comes to 75 % of area covered by both dirt. The temperature of mud is 68.89 °C higher than the silt which is 64.7 °C. Besides, it show that the temperature both of the dirt is high than the model. The model temperature was taken before the experiment with dirt was run. The model temperature's was remain constant. The model was able to anticipate the heat transfer process very well [3]. For the Figure 4.19, it show the same pattern with the inlet. The mud was always have higher temperature compared to the silt at all the percentage area of dirt covered the radiator.

This could be clarified by the way that mud stuck strongly on the radiator surface compared the silt. Because silt is loose, pocket of air space was observed on the covered radiator surface. This brought about some amount of air going through the air spaces to help in the cooling of the coolant to a lower temperature than when mud was used. Since less temperature was remove from the coolant, the resultant temperature of the coolant got from the radiator was additionally observed to be higher for mud than silt [3].

4.5 LIMITATION

There are a few limitations in this experiment, which are the heat loss to the surrounding cannot control due to environment factor. There is also no insulator within the pipeline, this will cause the rate of heat transfer to surround high. This experiment that used galvanise pipe which has high thermal conductivity compared to PVC pipe is also one of the limitation in this experiment. There is also a few leaking that has been detected throughout this experiment. The leaking that has been detected at the connector of the coolant out from the small hole between the connector. This is because the usage of different type of connector (PVC) and pipe (Galvanise steel).

Next, the speed of the fan is not fix because of the battery and it will that cause the rate of heat transfer also not fixed. Then, different ambient temperature during the experiment run. The experiment was run from morning to afternoon. Where the different reading of ambient temperature. When in the morning, the rate of heat transfer high because temperature different between surrounding and liquid coolant is large. Different condition happens at afternoon where the temperature different is low because small different of temperature different between liquid coolant with surrounding. This happen because afternoon is hotter than morning.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the experiment was successfully conducted on the test rig. Two different types of dirt were used as covering material to cover the surface of the radiator namely silt and mud. It was observed that the temperature at the inlet and outlet of the radiator increased when the percentage of the covered area was increased. It was also observed that the highest temperature gained in both cases when 75% of dirt was used to cover the surface of the radiator. This is because the effective transfer area of the radiator is reduced, less heat is taken out and thereby affecting the temperature of the coolant and hence the performance of the engine.

It also found that the temperature at inlet and outlet of the radiator were high when the mud was used as covering material compared to the silt. It can be said that the mud is a better covering material compared to the silt. Other than that, the temperature of the inlet and outlet will be decreased after when the post-cleaning experiment was done. All the dirt will be removed using a brush. It shows that, in both cases, the temperature will be decreased near the preliminary condition. This is due to the effective heat transfer area was increased, whereby increased the amount of heat going through the radiator for purpose on the cooling of the coolant.

From the analysis, it can be concluded that the dirt that accumulates on the surface of the radiator will decrease the performance of the radiator. Mud that accumulate on the surface of the radiator will have higher temperature of the coolant compared to the silt. If this problem persists, overheating will occur and indirectly will damage the engine.

5.2 RECOMMENDATION

As a recommendation for future research, the test rig needs to be improved to minimize the heat loss. This is to make sure the data and result that obtained is more accurate and validate. Other than that, the fan needs to be at the constant speed during the experiment to get more accurate heat transfer of the radiator. Furthermore, the experiment needs to be conducted with the different weight of the dirt to cover the surface of the radiator, to get more data to interpret. A future researcher can study about the cleaning method on the radiator and it effect such as wash the radiator using warm water and get the data to prove that the method is proven.

REFFERENCES

[1] Y. Singh and N. K. Singh, "Dirt analysis on the performance of an engine cooling system," *J. Energy South. Africa*, vol. 24, no. 4, pp. 44–50, 2013.

[2] A. M. Hussein, H. K. Dawood, R. A. Bakara, and K. Kadirgamaa, "Numerical study on turbulent forced convective heat transfer using nanofluids TiO2in an automotive cooling system," *Case Stud. Therm. Eng.*, vol. 9, no. November 2016, pp. 72–78, 2017.

[3] S. D. Oduro, "Assessing the Effect of Dirt on the Performance of an," vol. 2, no. 3, 2009.

[4] V. For and O. French, *Internal combustion engine*, vol. 21. 1859.

[5] A. Kaleli, G. Kaltakkiran, A. Dumlu, and K. K. Ayten, "Design and control of intelligent cooling system for IC engine," *Proc. 2017 Int. Conf. Eng. Technol. ICET 2017*, vol. 2018–Janua, pp. 1–3, 2018.

[6] V. A. Romanov and N. A. Khozeniuk, "Experience of the Diesel Engine Cooling System Simulation," *Procedia Eng.*, vol. 150, pp. 490–496, 2016.

[7] F. Micali, M. Milanese, G. Colangelo, and A. de Risi, "Experimental investigation on 4-strokes biodiesel engine cooling system based on nanofluid," *Renew. Energy*, vol. 125, pp. 319–326, 2018.

[8] R. Paul Linga Prakash, M. Selvam, A. Alagu Sundara Pandian, S. Palani, and K. A. Harish, "Design and modification of radiator in I.C. engine cooling system for maximizing efficiency and life," *Indian J. Sci. Technol.*, vol. 9, no. 2, pp. 1–7, 2016.

[9] M. L. M. Tasuni, Z. A. Latiff, H. Nasution, M. R. M. Perang, H. M. Jamil, and M. N. Misseri, “Performance of a water pump in an automotive engine cooling system,” *J. Teknol.*, vol. 78, no. 10–2, pp. 47–53, 2016.

[10] J. P. Yadav and B. R. Singh, “Study on Performance Evaluation of Automotive Radiator,” *SAMRIDDHI A J. Phys. Sci. Eng. Technol.*, vol. 2, no. 2, pp. 47–56, 2015.

[11] T. T. Wang, A. Jagarwal, J. R. Wagner, and G. Fadel, “Optimization of an Automotive Radiator Fan Array Operation to Reduce Power Consumption,” *IEEE/ASME Trans. Mechatronics*, vol. 20, no. 5, pp. 2359–2369, 2015.

[12] J. Chastain, J. Wagner, and J. Eberth, “Advanced engine cooling - Components, testing and observations,” *IFAC Proc. Vol.*, vol. 43, no. 7, pp. 294–299, 2010.

[13] N. R. D *et al.*, “CFD analysis of axial flow fans for radiator cooling in automobile engines,” *Proc. Int. Conf. Mech. Eng. Mech. 2007, Vols 1 2*, no. 724, pp. 1864–1869, 2007.

[14] Danny bender, “How important is your radiator cap,” *DANNYSENGINEPORTAL.COM*, 2010. .

[15] N. A. C. Sidik, M. N. A. W. M. Yazid, and R. Mamat, “A review on the application of nanofluids in vehicle engine cooling system,” *Int. Commun. Heat Mass Transf.*, vol. 68, pp. 85–90, 2015.

[16] S. M. Peyghambarzadeh, S. H. Hashemabadi, S. M. Hoseini, and M. Seifi Jamnani, “Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators,” *Int. Commun. Heat Mass Transf.*, vol. 38, no. 9, pp. 1283–1290, 2011.

[17] H. Road and L. Vic, “Radiator Maintenance 45,” no. iii, 2001.

[18] I. Ismail and T. S. Murugesu, “A study of formation damage caused by oil-based mud in dynamic condition,” vol. 43, no. October, pp. 85–94, 2007.

[19] U. T. Management, “Sand, clay.”

[20] Carpark.com, cooling system, retrieved from https://www.carparts.com/classroom/coolingsystem.htm 10 December 2018

[21] Internal combustion engine, overview, retrieved from https://vehiclemaintenanceandrepairs.com/internal-combustion-engine-101/ 10 December 2018

[22] Id carid, radiator components, retrieved from https://www.carid.com/radiators.html 10 December 2018

[23] Id carid, overview, retrieved from https://www.carid.com/radiators.html 10 December 2018

[24] Retrieved from http://thermostat.rehabacation.com/auto-thermostat-installation/ 10 December 2018

[25] Retrieved from https://repairpal.com/engine-cooling-fan , 10 December 2018

[26] Dannys engine portal, how important is your radiator cap, retrieved fromhttps://dannysengineportal.com/how-important-is-your-radiator-cap/