FLUID PROPERTIES OF AUTOMOTIVE ENGINE COOLING SYSTEM

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DECLARATION

I declared that this project report entitled "Fluid Properties of Automotive Engine Cooling System" is the result of my own work except those that were cited in the references.

Signature : ……………………………..

Name of Supervisor : ……………………………..

Date : ……………………………..

SUPERVISOR'S APPROVAL

I hereby declared that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature : ………………….

Name of Supervisor : ………………….

Date : ………………….

DEDICATION

To my beloved father, Idris Bin Husin and

Loving mother, Roiyati Binti Mohamad

ABSTRACT

Car cooling system is one of the most important components in the automotive engine system. The function of this cooling system is to control engine temperature from overheat. A typical car can produce enormous amount of heat ignite by the combustion of fuel in cylinder to drive the wheels. If it is not controlled, it can destroy an engine in a minute. A few components that influence cooling system are; i) size of radiator, ii) type of coolant, iii) speed of fan, and iv) radiator fin. This factor will affect the rate of temperature released to the surrounding. The experiment was performed to study the major properties of coolant that influence cooling system and to differentiate properties behaviour between various type of coolant. The result stated that the coolant with 88.86% water and 11.42% antifreeze is the best because of the factor that influence the heat transfer and ability to increasing the boiling point and lowering the freezing point.

ABSTRAK

Sistem penyejukan kereta adalah salah satu komponen yang paling penting dalam sistem enjin kenderaan. Fungsi sistem penyejukan ini adalah untuk mengawal suhu enjin daripada terlalu panas. Engin kereta boleh menghasilkan sejumlah besar haba yang menyala oleh pembakaran bahan api dalam silinder untuk memacu roda. Jika ia tidak dikawal, ia boleh memusnahkan enjin dalam masa yang singkat. Beberapa komponen yang mempengaruhi sistem penyejukan adalah; i) saiz radiator, ii) jenis penyejuk, iii) kelajuan kipas, dan iv) sirip radiator . Faktor ini akan mempengaruhi kadar suhu yang dilepaskan ke kawasan sekitarnya. Ujikaji di makmal dilakukan untuk mengkaji sifat-sifat utama penyejuk yang mempengaruhi sistem pendinginan dan membezakan kelakuan sifat antara pelbagai jenis penyejuk. Hasilnya menyatakan bahawa penyejuk dengan 88.86% air dan 11.42% antibeku adalah yang terbaik kerana faktor yang mempengaruhi pemindahan haba dan keupayaan untuk meningkatkan titik didih dan menurunkan titik beku.

ACKNOWLEDGEMENT

The completion of this Final Year Project could not have been possible without the participation and assistance of so many people whose names may not all be enumerated. I am very thankful for their aspiring guidance, invaluable constructive criticism and friendly advice during the project work. Their contributions are sincerely appreciated and gratefully acknowledged.

Among others, I would like to express my sincere gratitude to my final year project supervisor, ADZNI BIN MD. SAAD, whose contribution in intriguing suggestion and encouragement, helped me to coordinate my project especially in writing this report. I am indebted to him for all the knowledges, wisdoms and experiences that he shared during my studies.

Finally, it is impossible to name everyone who helped, guided and encouraged me when I am working on my thesis. I am taking this opportunity to thank all of them especially to my family and friends for their constant understanding and encouragement.

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LIST OF ABBREVIATIONS

PVC	Polyvinyl Chloride
RPM	Rotation Per Minutes

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Engine of a vehicle produces heat during combustion process. Engineers have to come out with a solution to cool down the engine by inventing a liquid called the coolant or also known as the antifreeze. Coolant are circulated around the engine block. It is generally a mixture of glycol and water where it is used to maintain or control the raising temperature of the engine. Researchers that had studied the properties of the coolant indicated that an ideal coolant has high thermal capacity and low viscosity. Coolant is also a non-toxic, chemical inert, and it will not cause corrosion in the cooling system. And the most important thing is, the cost to buy a coolant is super affordable.

There is other type of coolant that is used as the cooling agent which is water. Based on the observation, many people use water as a coolant substitution. This is mainly because it is cheaper and easier to find compare to the coolant. Unfortunately, water has a lot of down sides such as the corrosive behaviour, which can shorten the engine life. Water also does not posses antifreeze capability as compared to coolant.

Therefore, coolant is an important substance to maintain the temperature of the engine. One of the most conducted research in this area is how to reduce the taken time for the engine to cool down with the help of the coolant. Without the coolant, almost all conventional engines for modern cars and motorcycles will overheat and increase the tendency to break.

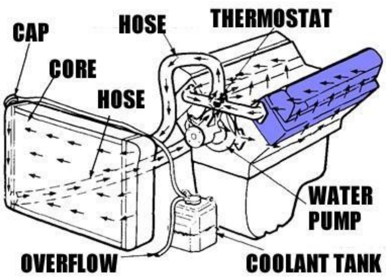


Figure 1: Circulation of coolant in engine

1.2 PROBLEM STATEMENT

Based on the scenario of a local manufactured car, the radiator fan keeps on rotating because the engine temperature is too high. In order to lower down the temperature, the fan has to suck air into the radiator fin and push the hot air out from the radiator. It will cool down the coolant inside the radiator. Therefore, the selection of good coolant is critical in order to regulate the temperature of engine during operation. The burning of engine fuel inside the cylinder increases the temperature up to 4500°F which can absolutely damage the engine without proper cooling system.

1.3 RESEARCH STATEMENT

Based on the problem statements described in the previous section, the objectives of the research are:

i. To determine the major properties of coolant that influence the vehicle cooling system

ii. To differentiate the properties behaviour between various type of coolant.

1.4 SCOPE OF RESEARCH

The scope of this project involves the experimental testing in laboratory environment to study the fluid properties of the coolant.

1.5 GENERAL METHODOLOGY

Table shows the Gantt generated for the following FYP 1 and 2

Task	Duration														
FYP 1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Introduction to FYP															
Initial Work and Brainstorming															
Article and Gantt chart Submission															
Introduction and Methodology															
Research on Coolant															
Progress Report Submission															
Literature Review															
Literature Review Submission															
Conceptual Project															
Presentation															
FYP 1 Submission															
FYP 2															
Experiment															
Result and Analysis															
Conclusion and Recommendation															
Presentation															
FYP 2 Submission															

Table 1: Gantt Chart for FYP 1 and FYP 2

The actions that need to be carried out in order to achieve the objectives of this project are listed as below:

1. Literature Review.

   Journals, articles, books, and videos are studied as research materials for the project.

2. Observation, Surveys and Data Collection.

   The car behaviour when the cooling system that is not functioning well is observed. Automotive mechanic is referred to illustrate the cause of the problem.

3. Experimental Testing

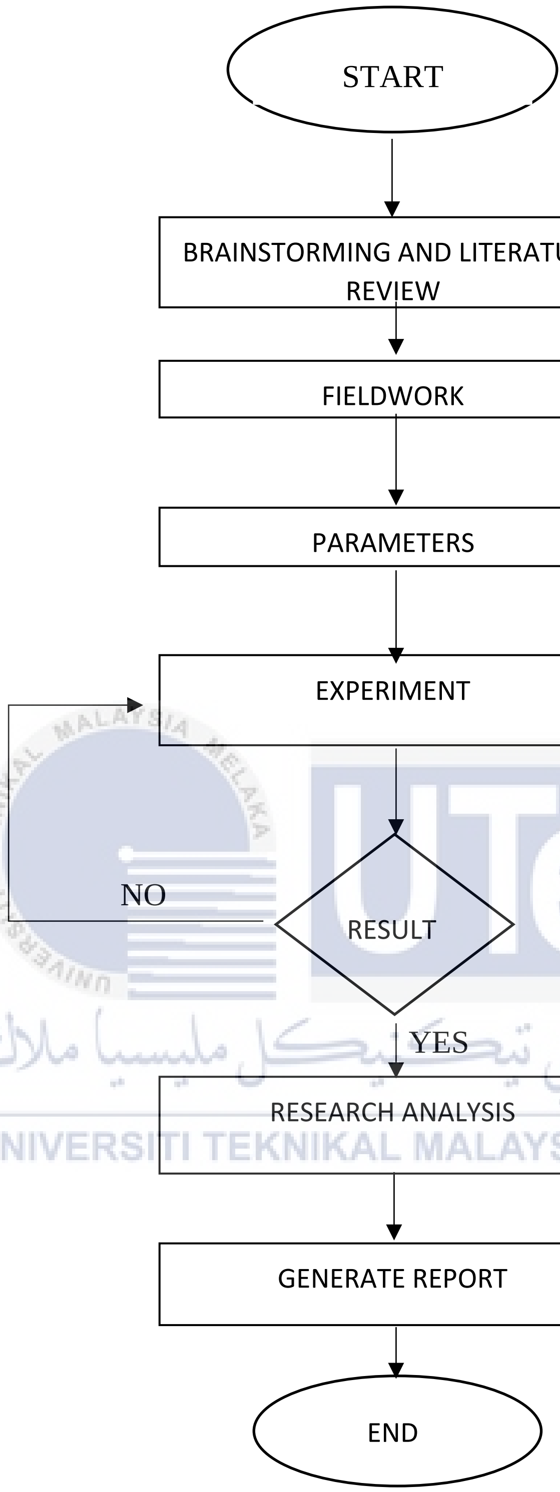
   Experiment is conducted to collect data.

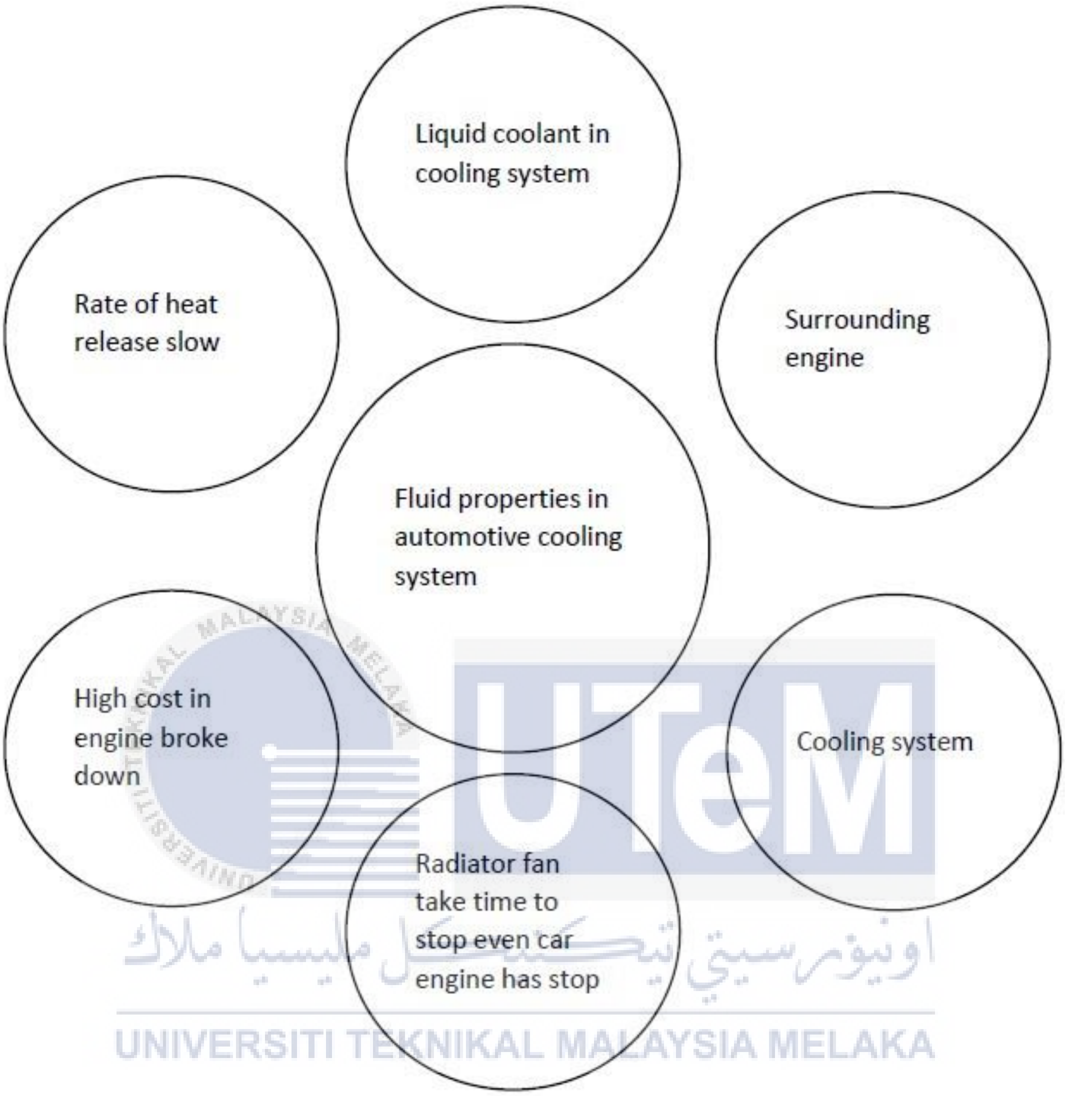
4. Analyse the results and provide the recommendation for improvement.

   Analysis is presented on how to reduce the time for the automotive engine to cool down. All solutions are proposed based on the analysis of the project.

5. Report Writing.

   A report will be written and submitted at the end of this project.


START
BRAINSTORMING AND LITERATURE REVIEW
FIELDWORK
PARAMETERS
EXPERIMENT
NO
RESULT
YES
RESEARCH ANALYSIS
GENERATE REPORT
END


Liquid coolant in cooling system
Rate of heat release slow
Surrounding engine
Fluid properties in automotive cooling system
High cost in engine broke down
Cooling system
Radiator fan take time to stop even car engine has stop

CHAPTER 2

2 LITERATURE REVIEW

2.1 ENGINE

A modern vehicle design consists of many integrated systems that are required to function properly. Cooling system is one of the subsystem that works to support the operation of vehicle powertrain system. Automotive engine was invented in 1878 by Karl Benz [1]. The components of the engine consist of cylinder block, piston, cylinder head, connecting rod, crankshaft, oil sump, crankshaft, valve, spark plug, injector, push rod, manifold, piston rings, gasket, piston pin, and engine bearing. The function of the engine is to propel the car by converting the chemical energy to mechanical energy [2]. The process of converting energy happened when the mixture of fuel and air exploded inside the combustion chamber. This explosion causes the piston to move which can be translated as mechanical energy.

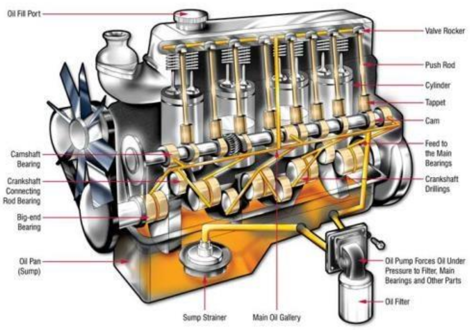


Figure 2: The engine component

2.2 COOLING SYSTEM

The combustion process of the engine is not only helps to move the car, but also leads to produce massive amount of heats that can damage the engine. Cooling system was invented to regulate the temperature of the engine. The fuel burns inside the cylinders can reach the temperature above 4500°F (2500ºC) [3]. In even a more efficient engine, only 20 to 25 percent of this heat energy is used to drive a car. The remaining of 30 to 35 percent must be carried away by the cooling system to keep the engine oil from evaporating and the engine components from become jam or melt. The first honeycomb radiator was designed by Wilhelm Maybach for Mercedes 35hp. It was the first successful cooling system for a vehicle. Later on, engineers came out with improved design of radiator that was suitable with a larger engine capacity. In general, there are three type of cooling systems which are the air cooling, oil cooling and liquid cooling. These three types of cooling are used to remove the heat from the engine block and engine head. With air as the coolant, the heat is removed by using the fin that attached to the cylinder wall. By using water as the coolant, the heat is removed by the fluid that filled the internal cooling passages. Both of these fluids have various advantages and disadvantage. For the air-cooled system, this system is noisier because there is no water jacket to absorb the combustion sound. It uses fins to increase the heat transfer rate. For the water-cooled system, it usually uses a single loop where the water pump circulates the coolant to the engine block, and then to the engine head. The coolant then flows to radiator or heat exchanger and back to the pump [4].

Conventional car uses liquid cooling system. This is because this type of cooling is more efficient than air cooling. Oil cooling is usually used in the motorcycles engine. This system consists of reservoir, radiator fin, fan, coolant, hose, thermostat, heater core.

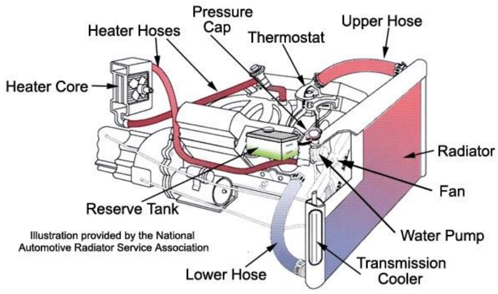


Figure 3: The cooling system

2.2.1 FUNCTION OF COOLING SYSTEM

Generally, the function of cooling system is to control the engine temperature. It removes excess heats produced by the internal combustion engine to keep the engine in safe temperature range [5]. In cold winter, the cooling system provides an interior cabin heat to warm up the car.

2.3 COOLING PART

2.3.1 Coolant

The main component in cooling system is coolant. Coolant is a liquid that is used as a heat transporter. Commonly called as antifreeze, it is a special formulated liquid that flows around the cylinder through the hollow passages in metal engine block called water jacket. Coolant absorbs heat from combustion and release the heat to atmosphere. Coolant is generally consisting of a 50-50 mixture of glycol and water. Glycol is an organic compound, which is mainly used in polyester fibres and ion as a raw material in antifreeze formulation. Ethylene glycol is a common chemical used in many commercial and industrial applications including antifreeze coolant [6]. Ethylene glycol helps keeping the engine from freezing in the winter and acts as a coolant to reduce overheating in the summer. A spring-loaded radiator cap keeps the cooling system under about 14 pounds per square inch (97kPa) of pressure, which raises the boiling point of a 50-50 mixture of water and antifreeze from 226°F (108ºC) to 263°F (128ºC). The freezing point of the same mixture would be -34°F (36ºC). Antifreeze concentrations of up to 70 percent can be used and produce a boiling point of 274°F (134ºC) and freezing point of -85°F (-65ºC) in a 14-psi pressurized system. More than 70 percent antifreeze will raise the freezing point rather than lowering it [7]. However, ethylene glycol is a toxic material that can cause birth defect, reproductive damages or even death if ingested and requires very specific handling. Ethylene glycol antifreeze has a sweet odour and flavour, and that makes it dangerously appealing to animal and child. An alternative antifreeze is based on propylene glycol. Propylene glycol antifreeze is significantly less toxic than ethylene glycol. Another method of removing heat that is commonly used is by substituting water as coolant. It is used as a method of heat removal from component and industrial equipment. The advantage of using water is inexpensive and non-toxic. It also has high specific heat capacity, density, and thermal conductivity. This allows water to transmit heat over greater distance with mush less volumetric flow and reduce temperature difference. In contrast, water also accelerates corrosion of metal part. When the corrosion occurs, it may cause the crucial component like thermostat to break down and affects the cooling system performance. Another disadvantage is water has low boiling point and high freezing point as compared to antifreeze coolant.

Figure 4: The antifreeze coolant

2.3.2 Reservoir

Reservoir in a vehicle cooling system can be identified as a clear plastic bottle that is located near the radiator. The function of this part is to hold the excess or overflowing cooling agent used in the system [8]. Reservoir has an important role in cooling system as it keeps the system full and free of air bubbles, so it can operate at full potential. Reservoir is also the first place that able to notice a leak. The trapped air bubbles in the cooling system restricts the coolant to reach and cool that section. It can cause the temperature to exceed the safe operating temperatures, which can cause a blown head gasket, warped head, damaged valves or piston, cracked engine block, a blown radiator or bursting hoses.

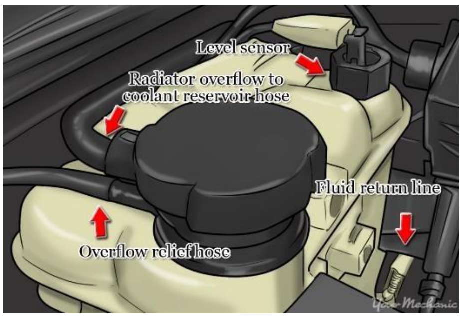


Figure 5: The coolant reservoir

2.3.3 Thermostat

Any liquid-cooled car engine is equipped with a small device that called thermostat [9]. It sits between the engine and the radiator. In most cars, thermostat is about 2 inches (5 cm) in diameter. Its function is to block the flow of coolant to radiator until the engine is fully warming up. There is no coolant flow through engine when the engine is cold. When the engine reaches its operating temperature (200°F, 95°C) the thermostat opens. By letting the engine to warm up as quick as possible, the thermostat reduces engine wear, deposits and emission. The thermostat works by maintaining the coolant in pre-set temperature. When the temperature falls below the pre-set temperature, thermostat will block the coolant flow to the radiator. It forces the fluid to bypass through directly back to the engine. Coolant repeats this circulation until it reaches the accurate temperature, when the thermostat opens the valve and allows the coolant to flow back to the radiator. Thermostat is an automatic device of temperature control (control the supply of electricity or gas to heating apparatus). It works by sensing the surrounding temperature (switch on the heating when air temperature falls below the thermostat setting and switch it off once the desired temperature is reached). It sends the coolant either through or bypass the radiator, or the combination of both. The thermostat is composed of formulated wax and powdered metal pellet that contains in a heatconducting copper cup equipped with piston inside rubber boot. The heat causes the wax pellet to expand and force the piston outwards, which open the valve of the thermostat. The pellet senses the temperature changes and opens and closes the valve to control the coolant temperature and flow. Thermostat is also designed to reduce coolant flow velocity when it opens [10]. It helps to stop overheating which is resulted from the coolant moving too quick through the engine and unable to absorb enough heat. Thermostat can be placed at several locations; most common spots are in front of the engine and at the top of the engine block. Heat element fits into a recess in the block where it exposes to the hot coolant. The top of the thermostat is covered with water outlet housing, which holds it in place and provide connection to upper radiator hose.

There are two basic type of thermostats that functioning in the same manner but each has different distinction. The first type of thermostat is the reverse poppet thermostat. It opens against the flow of coolant from the water pump. The coolant that is under water pump pressure is used to help the reversed poppet thermostat to stay close when cooling. The valve is self-aligning and self-cleaning. The next type of thermostat is balance sleeved thermostat. It eliminates pressure shocks by allowing the pressurized coolant to circulate around its working part. It provides stability to coolant temperature during most difficult operating conditions by reducing the pressure shock. Thermostat authorises the fast warm-up of the engine after it starts. Slow warm-up process causes moisture condensation in the combustion chamber that finds its way into the crankcase and causes sludge formation. The thermostat keeps the coolant above minimum required temperature for efficient engine performance. The thermostat must start to open at specified temperature – normally 3°F above or below its temperature rating. It must fully have opened at 20°F above "start to open" temperature. It must permit the passage of specified amount of coolant when fully open and leak not more than the specified amount when it fully closed. One of the side effect of using water as coolant is it can increase the rate of corrosion in the thermostat. When the corrosion occurs, it may cause the system to be stuck. So, it increases the probability of the engine to overheat.

Figure 6: The thermostat

2.3.4 Radiator

Radiator is a heat exchanger that transfers heat from the engine to the air that passing through it. It is constructed with a series of tubes and fins to increase the surface area that maximize the heat exposure of the coolant as much as possible. This help to maximizes the potential of heat being transferred to the air. Inlet tank on the radiator contains baffle to distribute the coolant. The efficiency of the radiator is influenced by the basic design of the radiator, the area and thickness of the radiator core, the amount of coolant going through the radiator and the temperature of the cooling air. The efficiency of the radiator can be greatly increased by increasing the difference between the temperature of coolant and the outside air flowing through it. This can be only done by rising the temperature of the coolant. There are two radiator designs which are the cross flow and down flow. For the cross-flow radiator, the coolant enters from one side, travels through tubes and exits on the opposite side. For the down-flow radiator, the coolant enters from the top of the radiator and drawn downwards by the gravity. The cross-flow radiator is mostly used in large-engine or late-model cars. Because of the coolant flows through the fan air stream, it provides maximum cooling performance. There are two type of radiator core construction, which are the honeycomb or cellular and tube and fin [11]. There are also two types of radiator core construction material; the copper or brass, soft solder coolers and the vacuum-brazed, aluminium core cinched to nylon tank. The aluminium type is less costly, lightweight and thin. It makes the aluminium core radiators more popular to be used in newer vehicle models.

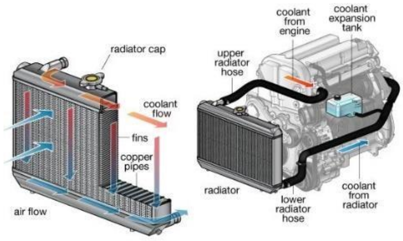


Figure 7: The radiator

2.3.5 Radiator Fan

The efficiency of cooling system is based on the amount of heat being removed from the system and transferred to the surrounding air. The system needs air at highway speed that rams through the radiator in order to maintain the sufficient cooling. At low and idle speed, the system needs additional air. This air is delivered by the fan. Usually, the fan is shrouded to maintain the efficiency by causing the flow to pass through the radiator. Shrouding allows the fan to be placed relatively far from radiator. It allows the engine to set back in the car while radiator is left near the front of the vehicle. Fan may be made of steel, nylon, or fiberglass, and precisely balanced to prevent damage to water pump bearing and seal. The fans that are usually found in cars are five-or six-blade and only necessary at idle and low speed operation. Various design concepts are used to limit the fan`s operation at higher speed. Fans are also very noisy at high speeds [12]. In latest model application, to save power and reduce the noise level, conventional belt-driven, water-pump-mounted engine coolant fan has been replaced with the electrical driven fan. The fan and water pump are mounted to the radiator shroud and not connected mechanically of physically to the engine. The fan is electrically controlled by either, an engine coolant temperature switch or sensor and air-conditioner switch.

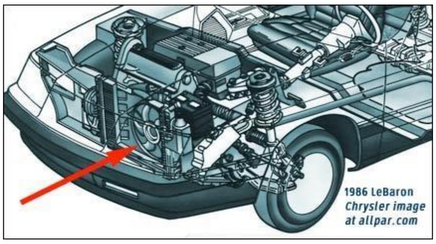


Figure 8: The radiator fan

2.3.6 Heater Core

Heater core is a radiator-like device that is used in heating the cabin of vehicle [13]. It is one of the main component in automotive heating, ventilation and air-conditioning (HVAC) system. Heater core can be used in vehicle that has liquid-cooled engine. Air-cooled engine requires different method of heating generation. Heater core is a small radiator that is located under dashboard of vehicle and contains of conductive aluminium or brass with cooling fins to increase the surface area. The hot coolant that passes through the heater core gives off heat before returning to the engine cooling circuit. The operation of heater core is also same as the radiator. Hot coolant passes into the inlet, then moves through the tubes and passes back out through the outlet. When the electric blower motor forces air through the core, the heat is transferred from hot coolant to the air by convection. Since heater core is an essential small radiator that performs the same basic function, the heater core can be used as a secondary radiator. When the engine is overheat, turning on the heater may help to cool it down. Clogging is one of the common issue in heater core since it is made up of small piping that has many bends and kinks.

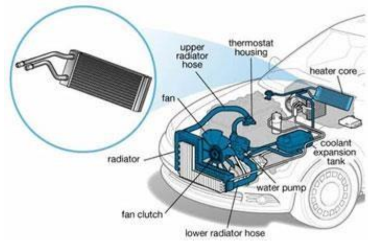


Figure 9: The heater core component

2.3.7 Hoses

Hoses works to carry the coolant between different components of the system. Most of the automobiles have upper and lower radiator hose and two heater hoses. Some of the design may also have a by-pass hose. Majority of the cooling system hoses are made up of butyl or neoprene rubber and wire reinforced is used to connect metal tubing between engine and radiator. Normally, radiator hoses are designed with expansion bends to protect radiator connection from excessive engine motion and vibration. Upper radiator hose is subjected to the roughest service life of any hose in the cooling system. It absorbs more engine motion than other hoses. It is also exposed to the coolant at the hottest stages and it insulates by the hood during hot soak time. These conditions make the upper hose has the highest probability to fail. The deterioration of the hoses begins from the inside. The piece of deteriorated hose can circulate through the system until it finds the place to rest. The common resting place is the radiator core, which can cause clogging. Any external bulging or cracking of hoses is definite sign of failure. Hoses can become either very soft and spongy or very hard and brittle when the host life is nearly end. When one hose fails to operate, all of the other hose should be carefully inspected. Most of all original radiator hoses equipment are of the moulded, curved design. The aftermarket products are available in this type or of a wire inserted flex type. The flex type hose allows greater vehicle coverage per part number but may not design for cars that required radical bends and shapes. Lower radiator hoses are normally wire reinforce to prevent collapse due to the suction of the water pump. All cooling system hoses are basically installed in the same way.

Figure 10: The hoses for cooling system

2.4 FLUID PROPERTIES

2.4.1 Density

Density or more precisely known as volumetric mass density of substance is a mass per unit volume [14]. Mathematically, density is known as mass divided by volume. It is an essential measurement of how tightly matter is crammed together. This principle of density was discovered by Archimedes, the Greek scientist. In coolant, the higher the density the lower the thermal conductivity. It happens because when the density is high, the heat is difficult to be transferred. Formula for density is:

$$\rho = \frac{m}{V} \tag{1}$$

Where:

ρ is density, kg/m^3 m

is mass in kg

V is volume in m^3

2.4.2 Conduction

Conduction process is a process of transferring heat from hot area of a solid object to the cold by the collision of particle [15]. Conduction occurs in solid, liquid and gas. Solid object transfers energy efficiently because the molecules in solid are packed and closer together. Conduction of heat occurs when the increase in temperature of molecules causes vibration and movement that passes the heat energy to the surrounding. Generally, a good conductor of heat is also a good conductor of electricity. The material that can be classified as good conductor allows the flow of charge particle and electrical energy can pass through them.

Formula for thermal conductivity is:

$$Q = -K \frac{\Delta T}{\Delta X} \tag{2}$$

Where:

Q is heat transfer rate in Joules
K is thermal conductivity in W/(m.K)

ΔT is the temperature change in unit Kelvin ΔX

is the distance between two points

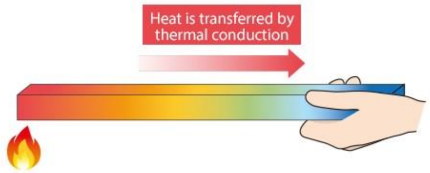


Figure 11: The conduction process

2.4.3 Thermal Conductivity

Thermal conductivity can be described as the transport of energy through a body of mass as the result of temperature gradient, in form of heat. According to thermodynamic second law, heat flows in the direction of the lower temperature. Thermal conductivity is material-specific property that is used to characterize the heat transportation capability. The unit for thermal conductivity is joules per meter kelvin (W/(m.K) [16]. Thermal conductivity of tubing materials is described as the amount of required energy to increase the temperature of the liquid inside the tubing to the same temperature on the exterior of the tubing. It can be simply stated as the rate in which heat is transferred through material. Different materials contain different thermal conductivity rates, based on molecular structure. The rate of heat flow through tubing material is depended by the amount of energy presents in the system.

2.4.4 Heat Transfer

Heat is a form of energy that flows from high temperature to low temperature. Conduction, convection and radiation are three modes of heat transfer. In term of thermodynamic system, heat transfer is a movement of heat across boundary of system due to temperature difference between system and surrounding. Heat transfer can also take place within the system due to temperature difference at various points inside the system. The difference in temperature is considered to be 'potential' that causes the flow of heat, which is called flux. Unit of heat transfer is joules per square meter kelvin (W/m^2.K). Heat transfer in cooling system is used to cool circulating coolant liquid of water and a mixture of antifreeze coolant like Ethylene Glycol [17].

$$Q = hA(T2 - T1) \tag{3}$$

Where:

Q is heat transfer rate in Joules h is heat

transfer coefficient in W/(m^2.K)

A is the surface area where the heat transfer takes place, m^2

T2 is temperature of the surrounding fluid, K

T1 is temperature of the solid surface, K

2.4.5 Ideal Gas Law

Ideal gas law describes the relationship between measurable properties of an ideal gas [18]. The law relates the temperature, pressure, volume, and number of particle of gas. Pressure (P) and volume (V) are inversely proportional, while pressure and volume are directly proportional to temperature (T) and number of particle [19]. The equation is shown below:

$$pV=mRT \tag{4}$$

Where:

p is pressure in N/m^2

V is volume in m^2 m

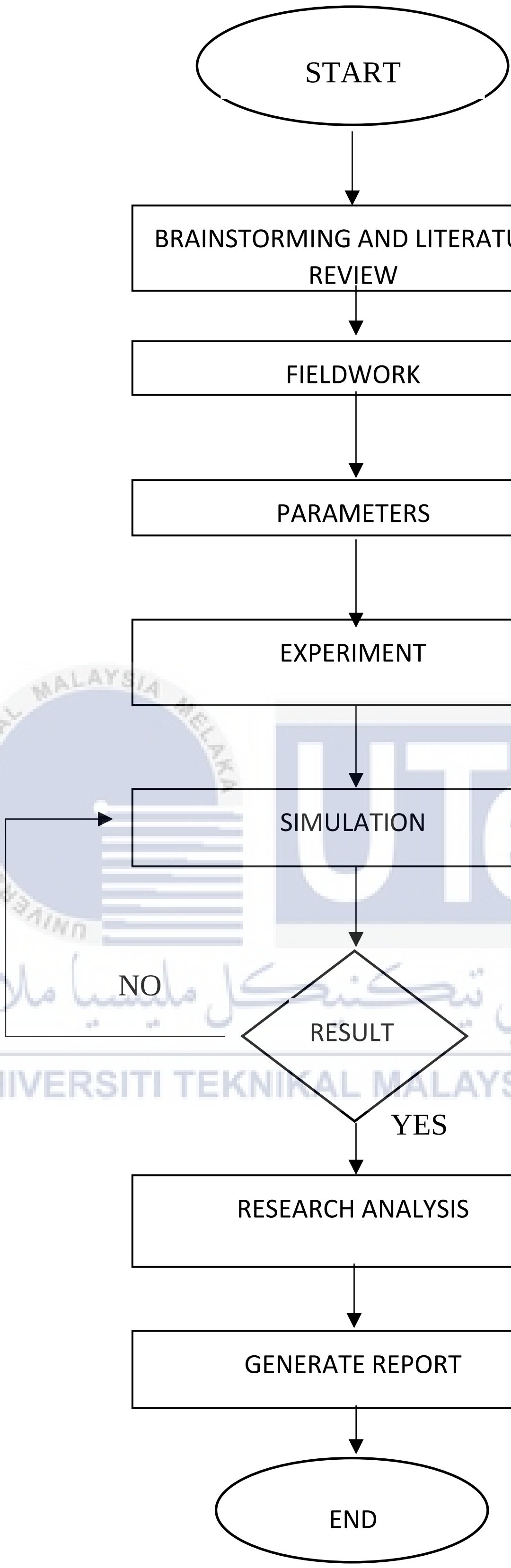
is mass

R is gas constant in J $K^{-1}mol^{-1}$

T is temperature in K

CHAPTER 3

3 Methodology



3.1 Experiment

The method that is used in this study is experimental testing. The process was carried out by using cooling system experimental jig that is available in workshop at Fasa B. This system is in a good conditions and not used by other students. The experiment was conducted three times by using different coolant compositions; 100 percent water, 94.33 percent water with 5.57 percent antifreeze, 88.86 percent water with 11.42 percent antifreeze and 83.29 percent water with 16.71 percent antifreeze.

The first experiment was conducted by using 100 percent water as coolant. The cooling system was filled with the water, and the pump and heater were started. When the temperature achieved maximum value, the fan was turned on until it reached a desired value. This step was repeated for the second time to have different value. Lastly, when the fluid reached the maximum value, the heater was turned off, but the fan was not turned on. A thermal sensor was used to collect the coolant reading at reservoir and inlet radiator hose. The reading was taken in every 5 minutes to get accurate reading. The data was plotted in a graph.

The experiment was repeated by using 94.33 percent water with 5.57 percent

antifreeze. The cooling system was filled with the coolant mixture, and the pump and heater were started. When the temperature achieved maximum value, the fan was turned on until it reached a desired value. The step was repeated for the second time to have different value.

Lastly, when the fluid reached maximum value, the heater turned off, but the fan was not turned on. A thermal sensor was used to collect the coolant reading at reservoir and inlet radiator hose. The reading was taken in every 5 minutes to get accurate reading. The data was plotted in a graph.

Next, the experiment was repeated by using 88.86 percent water with 11.42 percent antifreeze. The cooling system was filled with the coolant mixture, and the pump and heater were started. When the temperature achieved maximum value, the fan is turned on until it reached a desired value. The step was repeated for the second time to have different value. Lastly, when the fluid reached maximum value, the heater turned off, but the fan was not turned on. Thermal sensor was used to collect the coolant reading at reservoir and inlet radiator hose. The reading was taken in every 5 minutes to get accurate reading. The data was plotted in a graph.

Lastly, the experiment was repeated using 83.29 percent water with 16.71 percent antifreeze. The cooling system was filled with the coolant mixture, and the pump and heater were started. When the temperature achieved maximum value, the fan is turned on until it reached a desired value. The step was repeated for the second time to have different value. Lastly, when the fluid reached maximum value, the heater turned off, but the fan was not turned on. Thermal sensor was used to collect the coolant reading at reservoir and inlet radiator hose. The reading was taken in every 5 minutes to get accurate reading. The data was plotted in a graph.

CHAPTER 4

4 RESULT AND ANALYSIS

4.1 INTRODUCTION

The experimental set up is to replicate the cooling process in an automotive cooling system. The heater in the reservoir system replicates the heat that was produced by the car engine. The flow rate of the experiment was maintained at 31.8 LPM and with a pressure of 0.5 bar. The speed of the motor was also maintained at 2900 rpm. The 6.325 L of coolant fluid was composed by 4 different compositions which were 100% water, 94.33% water with 5.57% coolant, 88.86% water with 11.14% coolant, and 83.29% water with 16.71% coolant composition. For each composition, the experiment was repeated 3 times to simulate 3 different conditions. All the data was recorded once in every 5 minutes within 90 minutes of total time. The recorded data were plotted in a Temperature vs Time graph. The temperature was manually controlled by switching the fan (on and off). This action was being done to simulate the function of thermostat [20]. The fan was switch on when a desired or maximum temperature was achieved. This action allowed the increment of heat transfer to the surrounding. In the thermostat, a similar process occurred when the engine reaches the maximum operating temperature. The fan was turned off when it achieved a certain desired temperature.

Figure 12: Experimental set-up

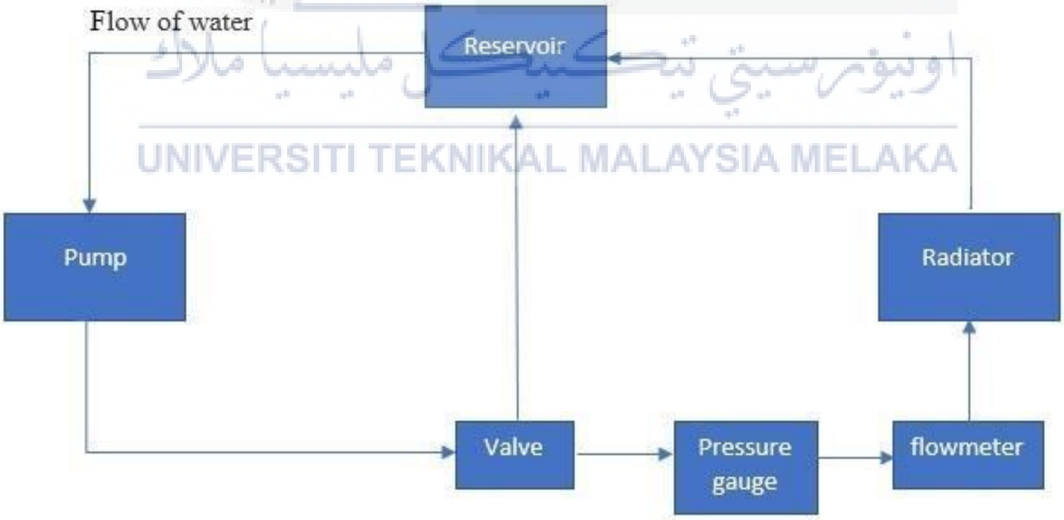


Figure 13: Schematic diagram of experiment

4.2 RESULTS AND DISCUSSION

4.2.1 COOLANT COMPOSITION OF 100% WATER

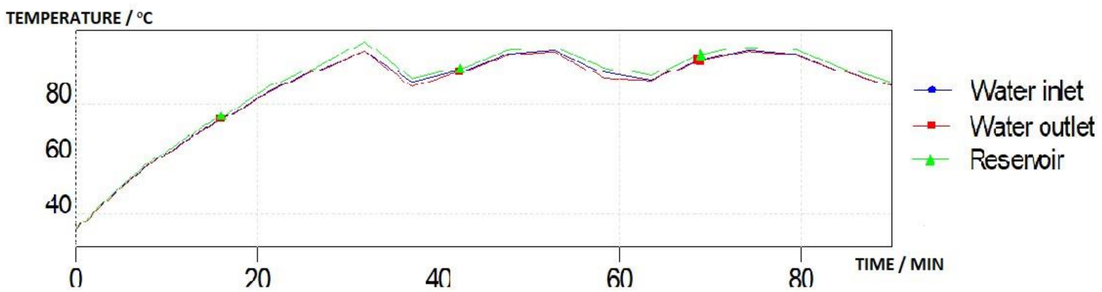


Figure 14: Coolant temperature with 100% water composition

By referring to Figure 14, this experiment was conducted with the coolant composed of 100% water. This coolant composition was used as a benchmark for this experiment because no coolant was added. By using this fluid, the minimum temperature that was recorded was around 28.51 degree Celsius. It was recorded when the fluid was used in the morning. The maximum temperature in this experiment was recorded at 98.1 degree Celsius. While, the average temperature reservoir was at 79.48 degree Celsius. When the water was being flowed out, the temperature recorded was 78.15 degree Celsius and when the water was being inserted the temperature recorded was 78.66 degree Celsius. The reason behind these changes of temperature was because of several factors. The reading of temperature in the reservoir was higher because a heater was placed there. The temperature of reservoir when the water was being flowed out was lower than when the water was being flowed in was due to the heat loss to the surrounding temperature when it entered the radiator. Next, the temperature at reservoir was higher than the temperature when water was being flowed in because there was heat loss in the pipe and there was also small leakage detected between the connector.

Figure 15: First segment of 100% water composition graph

The first segment of graph increases and non-linear due to the amount of heat transfer of the molecules in order to break the inter-molecular bond [21]. The first half of the graph has a high rate of heat transfer but for the next half of the graph, the rate of heat transfer decreases because a lot of bonds have already been broken.

Figure 16: Second segment of 100% water composition graph

In the second segment of the graph, the maximum peak temperature is achieved by the system. It represents the engine warm-up routine of the car in the morning where the engine temperature is low [22].

Figure 17: Third segment of 100% water composition graph

The linear decreasing pattern at segment 3 occurs when the fan is switched on. This is due to the temperature different between the fluid and surrounding because of the rate of heat transfer. This factor increases the rate of heat transfer and also increases the heat release to the surrounding.

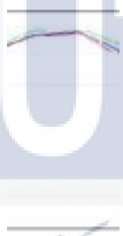


Figure 18: Fourth segment of 100% water composition graph

The peak of segment 4 represents the condition when the car engine is cooling down (heat is still present in engine). After the system achieves the lower temperature, the fan is switched off. The temperature different decreases and also the rate of heat transfer decreases. Then, the heat in the engine (reservoir) increases.

Figure 19: Fifth segment of 100% water composition graph

The step and process in segment 3 were repeated and recorded in segment 5. The time to reach the lower temperature limit of the system in a different conditions are obtained.

Figure 20: Sixth segment of 100% water composition graph

Segment 6 represents the car engine at optimum temperature. When the maximum temperature is achieved, the heater that acts as the heat produced by the engine is turned off while the radiator fan is not switched on. This process replicates the process when the driver switches off the engine after driving. Convection process occurs naturally without any involvement of external factor.

4.2.2 COOLANT COMPOSITION OF 94.33 % WATER AND 5.57 % ANTIFREEZE

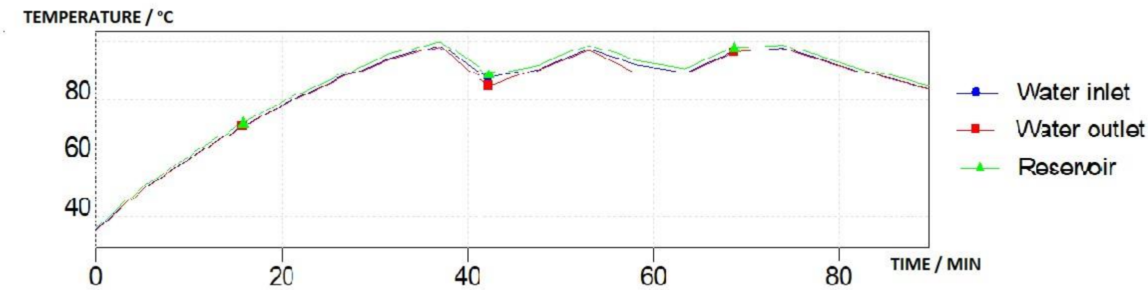


Figure 21: Coolant temperature with 94.33% water and 5.57% antifreeze

By referring to Figure 15, this experiment uses coolant composition of 94.33% water and 5.57% antifreeze. By using this fluid, the minimum temperature that was recorded was around 30.85 degree Celsius. It was recorded when the fluid was used in the afternoon. The maximum temperature in this experiment was recorded at 102.5 degree Celsius and the average reservoir temperature was 95.35 degree Celsius. When the water was being flowed out, the recorded temperature was 81.41 degree Celsius and when the water was being inserted, the recorded temperature was 81.81 degree Celsius. The reason of the change of temperature was because of several factors. The temperature reading in the reservoir was higher because a heater was placed there. The reservoir temperature when the water was being flowed out was lower than when the water was being flowed in was due to the heat loss to the surrounding when it entered the radiator. The temperature at reservoir was higher than the temperature when water was being flowed in because there was heat loss in pipe and there was also small leakage detected between the connector.

Figure 22: First segment of 94.33% water and 5.57% antifreeze composition graph

The first segment of graph increases non-linearly because of the amount of heat transfer to the molecules in order to break the inter-molecular bond [21]. For the first half of the graph, it has a high rate of heat transfer but for the next half of the graph, the rate of heat transfer decreases because there are a lot of bond that already being broken.

Figure 23: Second segment of 94.33% water and 5.57% antifreeze composition graph

In segment 2, the maximum peak temperature is achieved by the system. It represents the the engine warm-up routine of the car in the morning where the engine temperature is low [22].

Figure 24: Third segment of 94.33% water and 5.57% antifreeze composition graph

The linear decreasing pattern in segment 3 happens when the fan is switched on. This is due to the temperature different between the fluid and surrounding because of the rate of heat transfer. This factor increases the rate of heat transfer and increases the heat release to the surrounding.

Figure 25: Fourth segment of 94.33% water and 5.57% antifreeze composition graph

The peak of segment 4 represents the condition when the car engine is cooling down (heat is still present in engine). After the system achieves the lower temperature, the fan is switched off. The temperature difference decreases so that the rate of heat transfer decreases. Then, the heat in the engine (reservoir) increases.

Figure 26: Fifth segment of 94.33% water and 5.57% antifreeze composition graph

The step and process in segment 3 were repeated in segment 5 to record the time taken to reach the lower limit of the system temperature at different conditions.

Figure 27: Sixth segment of 94.33% water and 5.57% antifreeze composition graph

Segment 6 represents the engine at optimum temperature. When the maximum temperature is achieved, the heater that acts as the heat produced by the engine, is turned off while the radiator fan is not switched on. This process replicates the process when the driver switches off the engine after driving. Convection process occurs naturally without any involvement of external factors.

4.2.3 COOLANT COMPOSITION OF 88.86% WATER AND 11.42% ANTIFREEZE

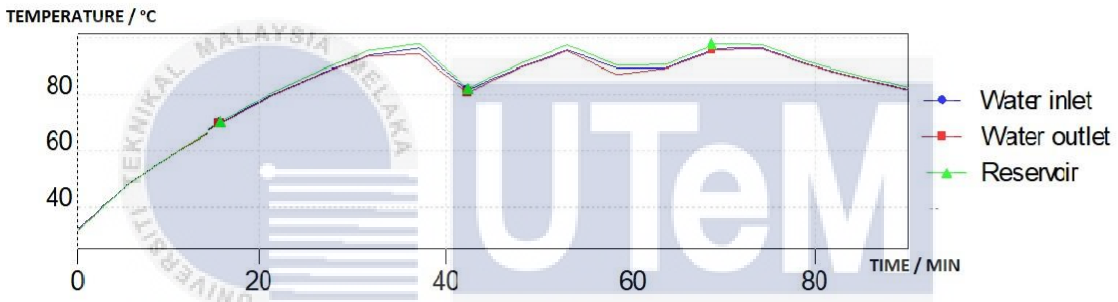


Figure 28: Coolant temperature with 88.86% water and 11.42% antifreeze

By referring to Figure 16, this experiment uses coolant composition of 88.86% water and 11.42% antifreeze. By using this coolant mixture, the minimum temperature that was recorded was around 32.82 degree Celsius. It was recorded when the fluid was used in the afternoon. The maximum temperature in this experiment was recorded at 99.66 degree Celsius and the average reservoir temperature was 81.47 degree Celsius. When the water was being flowed out, the recorded temperature was 78.87 degree Celsius and when the water was being inserted, the recorded temperature was 80.34 degree Celsius. The reason of this change of temperature was because of several factors. The reading of temperature in the reservoir was higher because a heater was placed there. The temperature of reservoir when the water was being flowed out was lower than when the water was being flowed in was due to the heat loss to the surrounding temperature when it entered the radiator. The temperature of reservoir was higher than the temperature when water was being flowed in because there was heat loss in pipe and there was also a small leakage detected between the connector.

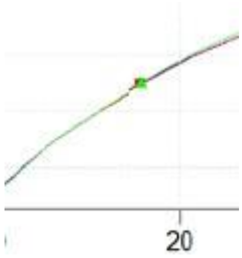


Figure 29: First segment of 88.86% water and 11.42% antifreeze composition graph

The first segment of the graph increases non-linearly because the amount of heat transfer to the molecules in order to break the inter-molecular bond [21]. For the first half of the graph, it has a high rate of heat transfer but for the next half of the graph, the rate of heat transfer decreases because there are a lot of bond that already being broken.

Figure 30: Second segment of 88.86% water and 11.42% antifreeze composition graph

In the segment 2, the maximum peak temperature is achieved by the system. It also represents the engine warm-up routine in the morning where the engine temperature is low [22].

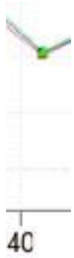


Figure 31: Third segment of 88.86% water and 11.42% antifreeze composition graph

The linear decreasing pattern in segment 3 happen when the fan is switched on. This is due to the difference of temperature between the fluid and surrounding because of the rate of heat transfer. This factor increases the rate of heat transfer and increases the heat release to surrounding.

Figure 32: Fourth segment of 88.86% water and 11.42% antifreeze composition graph

The peak of segment 4 represents the condition when the car engine is cooling down (heat is still present in engine). After the system achieves the lower temperature, the fan is switched off. The temperature difference decreases so that the rate of heat transfer decreases. Then, the heat in the engine (reservoir) increases.

Figure 33: Fifth segment of 88.86% water and 11.42% antifreeze composition graph

The step and process in segment 3 were repeated in segment 5 to take the time to reach the lower limit of temperature in the system for different conditions.

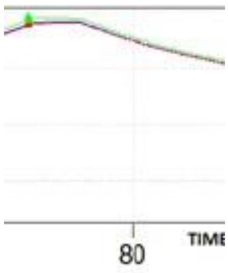


Figure 34: Sixth segment of 88.86% water and 11.42% antifreeze composition graph

Segment 6 represents the car engine at optimum temperature. When the maximum temperature is achieved, the heater that act like the heat produce by the engine, is turned off while the radiator fan is not switched on. This process replicates the process when the driver switches off engine after driving. Convection process occurs naturally without any involvement of external factor.

4.2.4 COOLANT COMPOSITION OF 83.29% WATER WITH 16.71% ANTIFREEZE

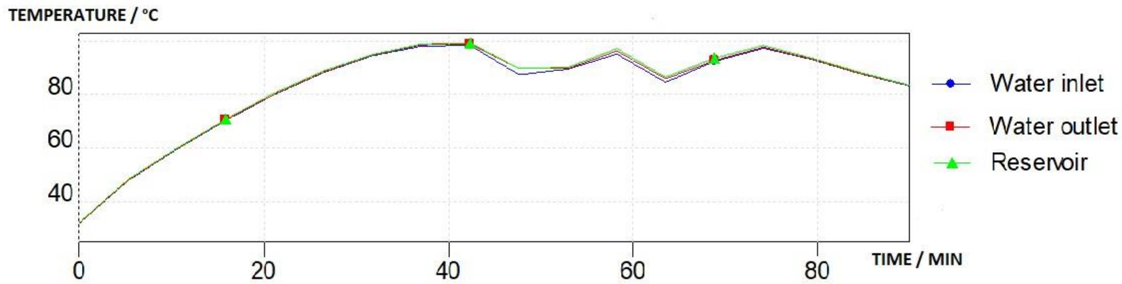


Figure 35: Coolant temperature with 83.29% water and 16.71% antifreeze

By referring to Figure 17, this experiment uses coolant composition of 83.29% water and 16.71% antifreeze. By using this coolant mixture, the minimum temperature that was recorded was around 28.69 degree Celsius. It was recorded when the fluid was used in the morning. The maximum temperature in this experiment was recorded at 98.41 degree Celsius and the average reservoir temperature was 80.34 degree Celsius. When the water was being flowed out, the recorded temperature was 79.98 degree Celsius and when the water was being inserted, the recorded temperature was 79.54 degree Celsius. The reason of this change of temperature was because of several factors. The reading of temperature in the reservoir was higher because a heater was placed there. The temperature of reservoir when the water was being flowed out was lower than when the water was being flowed in due to the heat loss to the surrounding temperature when it entered the radiator. The temperature at reservoir was higher than the temperature when water was being flowed in because there was heat loss in pipe and there was also small leakage detected between the connector.

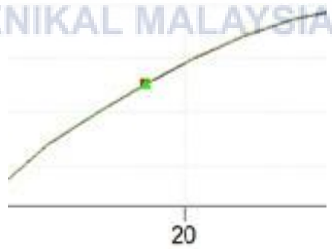


Figure 36: First segment of 83.29% water and 16.71% antifreeze composition graph

The first segment of graph increases non-linearly because the amount of heat transfer to the molecules in order to break the inter-molecular bond [21]. For the first half of the graph, it has a high rate of heat transfer but for the next half of the graph, the rate of heat transfer decreases because there are a lot of bond that already being broken.

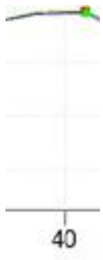


Figure 37:Second segment of 83.29% water and 16.71% antifreeze composition graph

In the segment 2, the maximum peak temperature is achieved by the system. It also represents the engine warm-up routine in the morning where the engine temperature is low [22].

Figure 38: Third segment of 83.29% water and 16.71% antifreeze composition graph

The linear decreasing pattern in segment 3 happens when the fan is switched on. This is due to the difference of temperature between the fluid and surrounding because of the rate of heat transfer. This factor increases the rate of heat transfer and also increases the heat release to surrounding.

Figure 39: Fourth segment of 83.29% water and 16.71% antifreeze composition graph

The peak of segment 4 represent the condition when the engine is cooling down (heat is still present in engine). After the system achieves the lower temperature, the fan is switched off. The temperature difference decreases so that the rate of heat transfer decreases.

Then, the heat in the engine (reservoir) increases.

Figure 40: Fifth segment of 83.29% water and 16.71% antifreeze composition graph

The step and process in segment 3 were repeated in segment 5 to take the time to reach the lower limit of temperature in the system for different condition.

Figure 41: Sixth segment of 83.29% water and 16.71% antifreeze composition graph

Segment 6 represents the car engine at optimum temperature. When the maximum temperature achieved, the heater that acts like the heat produce by the engine is turned off while the radiator fan is not switched on. This process replicates the process when the driver switches off engine after driving. Convection process will occurs naturally without any involvement of external factor.

4.3 LIMITATION

There are a few limitations in this experiment in which the motor RPM is fixed so that the coolant flow rate cannot be controlled. Next, the lid of the reservoir is not fully closed that causes the pressure drop. As referring to equation (4), although the increment of temperature increases the pressure, but in this case the decrement of volume and mass causes the pressure to decrease due to the lid is not fully closed. Volume and mass decrease because of the fluid has change to vapour due to the occurrence of evaporation process. Besides, in this experiment, the heat loss to the surrounding cannot be controlled due to environmental factor. There is no insulator on the pipeline which causes the high rate of heat transfer to the surroundings. This experiment uses galvanise pipe which has high thermal conductivity as compared to PVC pipe. It is also one of the limitation in this experiment [23].

There is also a few leakages had been detected throughout this experiment. The leakage is detected with the occurrence of small hole at the connector of the coolant. This is because of the usage of different type of connector (PVC) and pipe (Galvanise steel). Next, the speed of the fan is fixed that causes the rate of heat transfer is also fixed.

The reading of thermocouple is also inaccurate because of the placement of the sensor that touches the wall. There is also a wire error, due to different length of wire that causes the different rate of heat transfer throughout this single wire [24]. The calibration of thermocouple also plays an important role in temperature sensoring [25]. Next is the difference of ambient temperature during the experiment. The experiment was run from morning to afternoon which causes the different reading of ambient temperature. In the morning, the rate of heat transfer was high because of the temperature difference between surrounding and liquid coolant is large. Different condition happens in the afternoon where the temperature different is low. This condition occurs because is hotter in the afternoon compared to the morning.

The limitation of the experiment is also because of the variation of the used. The experiment was run by using 3 different types of coolant. This is due to the financial and time constraint. More data can be retrieved if more coolant is used. Another limitation is the inaccurate volume of each composition. This happened because of the leakage at the connector and the evaporation occurs at reservoir. Another limitation is the wire and plug for the heater are always burn and melt. This is because the heater consumes power that can not be handled by the cable and causes overheating process occur. The same condition happens to the plug, which easily melting due to the overpower.

4.4 COMPARISON

There are several disadvantages and advantages when using the different type of compositions. For the first composition of 100% water, the advantages are this composition is very cheap and easily available. This composition also has a high rate of heat transfer since the viscosity is only 1.002 cP at 68 ℉ [26] and toxic-free. On the other hand, the disadvantages of this fluid are it has high freezing point and lower melting point. Corrosion can easily occur if user uses only water as coolant. This is because, pure water does not have additive like anti-corrosion to counter corrosion process occurrence and it consumes more time to change it regularly.

The second type of composition is water that with mixed with coolant. The advantages of this composition are it reduces the rate of corrosion because of the anticorrosion additive.

Besides, this composition can lower the freezing point of fluid and increases the boiling point of the fluid. It also stops the water from being foamy. One of the disadvantages of this composition is, it has low heat transfer rate as compared to 100% water.

For the case of using 100% antifreeze as coolant, the disadvantages are it is very expensive and hard to find. It also has poor heat transfer due to losses of 35% heat transfer ability [27]. Besides, this fluid has high viscosity that makes it hard to flow through small tubes in radiator which causes the lost of its heat transfer ability. This fluid also lost the additive abilities because it has no water molecules within its composition.

CHAPTER 5

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion of the research, user cannot use too much antifreeze in the coolant. Although antifreeze can increase the boiling point and lower the freezing point, it reduces the heat transfer rate due to change in viscosity. It is the best to use small amount of coolant to increase the melting point and lowering the boiling point based on the surrounding temperature. Last but not least, a coolant that contains antifreeze can reduce the time taken for corrosion to happen.

5.2 RECOMMENDATION

As a recommendation for the research, the experimental set-up to needs to be improved to minimise the heat loss. All of the improvements are able to produce more accurate and reliable data. Furthermore, the experiment needs to be conducted with various composition of coolant in order to get more data for analysis. Other than that, simulation can be conducted by using ANSYS in order to get clearer understanding of heat transfer process.

CHAPTER 6

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CHAPTER 7

7 APPENDIX

Time	Water inlet	Water outlet	Reservoir
Minutes	°C	°C	°C
0	30.66	30.64	30.85
5	37.28	37.16	37.73
10	50.82	50.65	51.24
15	63.08	62.87	63.91
20	74.29	74.06	75.35
25	84.13	83.88	85.68
30	91.82	91.55	93.16
35	98.64	98.65	102.52
40	87.56	85.69	88.68
45	91.42	91.18	92.39
50	97.58	97.2	98.92
55	98.84	98.35	100.19
60	90.84	88.85	92.88
65	88.23	88.05	89.77
70	95.65	95.4	97.38
75	98.88	98.45	100.72
80	97.54	97.3	99.19
85	91.14	91.05	92.58
90	86.02	85.93	87.39

Table 3: Coolant temperature with 100% water composition

Time	Water inlet	Water outlet	Reservoir
Minutes	°C	°C	°C
0	32.41	32.27	32.82
5	38.12	38.03	39.15
10	49.83	49.72	50.52
15	60.84	60.7	61.83
20	71.06	70.9	72.19
25	80.14	79.94	81.27
30	87.61	87.37	88.46
35	94.03	93.74	95.48
40	98.25	97.78	99.66
45	87.32	84.8	88.92
50	90.69	90.47	91.9
55	96.74	96.33	98.48
60	91.99	89.49	93.25
65	89.64	89.42	90.87
70	96.27	95.9	97.72
75	97.54	97.2	98.62
80	92.41	92.27	93.31
85	87.69	87.55	88.6
90	83.9	83.78	84.91

Table 2: Coolant temperature with 94.33% water and 5.57% antifreeze

Time	Water inlet	Water outlet	Reservoir
Minutes	°C	°C	°C
0	29.87	29.03	28.51
5	34.9	34.79	34.71
10	47.38	47.25	47.26
15	59.11	58.95	59.05
20	69.79	69.62	70.27
25	79.45	79.26	80.17
30	87.2	86.98	88.49
35	93.92	93.64	95.64
40	96.47	94.43	98.1
45	81.64	80.67	82.23
50	89.17	88.94	90.38
55	95.81	95.45	97.62
60	89.47	87.05	90.53
65	89.5	89.21	90.66
70	96.32	95.9	97.98
75	96.52	96.2	97.81
80	90.55	90.34	91.55
85	85.81	85.63	86.67
90	81.7	81.51	82.54

Table 4: Coolant temperature with 88.86% water and 11.42% antifreeze

Time	Water inlet	Water outlet	Reservoir
Minutes	°C	°C	°C
0	28.43	28.49	28.69
5	35.03	35.12	35.4
10	47.74	47.86	48.17
15	59.56	59.69	59.94
20	70.36	70.49	70.79
25	80.07	80.22	80.62
30	88.28	88.44	88.91
35	94.57	94.81	95.02
40	98.17	98.63	98.94
45	98.46	98.97	99.4
50	87.48	89.8	89.85
55	89.55	89.79	90.23
60	95.18	96.35	97.25
65	84.62	85.96	86.55
70	92.49	92.79	93.67
75	97.41	97.8	98.41
80	93.15	93.31	93.65
85	87.73	87.86	88.22
90	83.24	83.37	83.53

Table 5: Coolant temperature with 83.29% water and 16.71% antifreeze

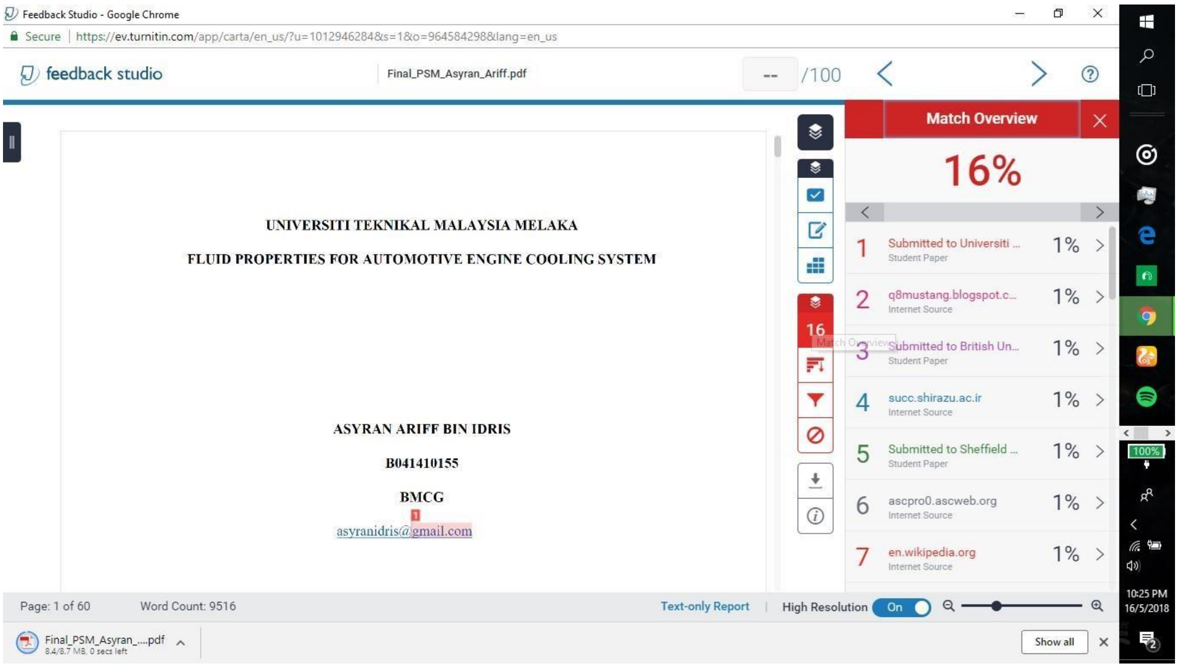

Figure 42: Result plagiarism from Turnitin software