A Study on an Engine Cooling Unit of Automotive Engine Test Bed

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I hereby declare that this project report entitled

"A Study on an Engine Cooling Unit of Automotive Engine Test Bed"

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ABSTRACT

In the engine test bed system, an engine cooling unit plays an important role in controlling the engine temperature and its performance lies in the capabilities of the coolant.

Currently, pure water is widely being used and as a coolant in the engine cooling unit. Generally, the coolant manages to control the temperature rise when the loads are being applied to the engine to measure the maximum torque produced at certain rpm.

But when it comes to the emission measurements, the engine tends to overheat. Therefore this research would appraise the use of an automotive radiator coolant as the replacement

ABSTRAK

Unit penyejukan enjin memainkan peranan penting dalam mengawal suhu enjin malah prestasi enjin bergantung pada keupayaan bendalir penyejuk.

Walaubagaimana pun, penggunaan air tulen sebagai bendalir penyejuk digunakan sangat meluas pada masa kini. Secara amnya, bendalir penyejuk ini digunakan untuk membantu mengawal kenaikan suhu terutama ketika beban dikenakan ke atas enjin bagi mengukur daya kilas yang terhasil pada suatu nilai rpm yang tertentu.

Akan tetapi apabila pengukuran pelepasan asap dibuat, enjin mula mengalami pemanasan lampau. Maka, kajian ini dilakukan bagi menilai keupayaan penggunaan bendalir penyejukan radiator sebagai pengganti kepada bendalir penyejukan yang sedia ada iaitu air tulen.

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$\dot{Q}$	=	Heat transfer, kW
h	=	Convection heat transfer coefficient
A	=	Surface area, m^2
T_c	=	Coolant temperature
T_w	=	Wall temperature
P_c	=	Power required
A_e	=	Effective area
A_f	=	Fin area
ip	=	Indicated power
ΔT_f	=	Temperature difference between the air and the fin
ρ_a	=	The density of air
$\eta_{thermal}$	=	Thermal efficiency

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

An internal combustion (IC) engine is a heat engine which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This IC engine converts chemical energy in fuel into mechanical energy, usually made available on a rotating output shaft. Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine and the high-pressure gas then expands against the mechanical mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine.

However (Anthony E. Schewaller, 1999), not all of the energy is converted into power for moving the vehicle because this is just about 25% is used to push the vehicle. While about 9% of the heat generated by the fuel is lost through radiation and 33% is sent out through the exhaust system. The remaining 33% must be removed by the cooling system. In the automotive engine, the cooling system is one of the more important systems. If the cooling system is not operating correctly, the engine may be severely damaged. There are three purpose of the cooling system. The first is to maintain the highest and most efficient operating temperature within the engine. The second is to remove excess heat from the engine. The third is to bring the engine up to operating temperature as quickly as possible.

In the cooling system, there are two types of system: Air Cooled System and Liquid Cooled System. The air cooled system is used more frequently for airplanes, motorcycles, and in a few older cars like the original Volkswagen Beetle, the Chevrolet Corvair and a few others. In the modern automotive system, the liquid cooled system is used as a cooling system. The liquid cooling system works by sending a liquid coolant through passages in the engine block and heads as shown in Figure 1. The liquid cooling system consists of the engine's water jacket, thermostat, water pump, radiator, fan, radiator hoses and coolant.

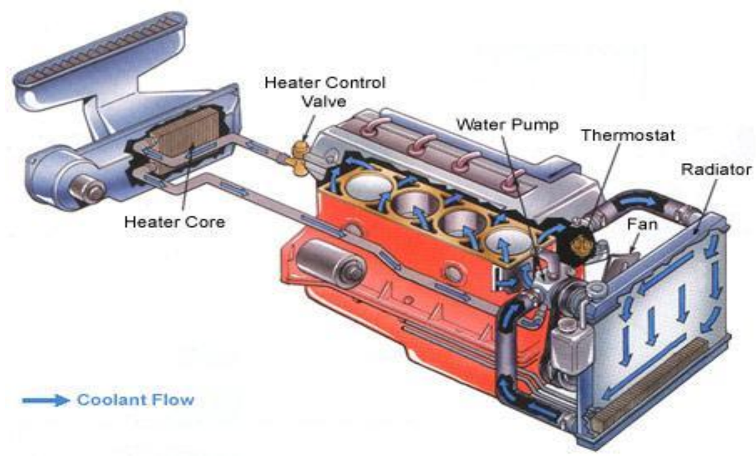

Figure 1: Schematic of automotive cooling system of liquid-cooled.
(Source: http://www.bccarnet.com/En/glossary)

The water jackets are located around the cylinder walls and combustion chambers. These water jackets allow coolant to circulate around the very hot areas, including the exhaust valve seats, as well as the relatively cooler areas of the lower cylinders. The coolant absorbs heat from the hot areas and transfers it to the colder areas in the engine or radiator. The thermostat is a temperature-controlled coolant valve. The thermostat is closed when the coolant is cold; it opens when the coolant warms up to a specific temperature where its range between 82 to 113^{o}C.

When the engine is at operating temperature, the coolant circulates through the water jackets and radiator. The excess heat absorbed by the coolant in the water jackets is passed on to the air flowing through the radiator. However, when the engine is below coolant temperature, the thermostat blocks the flow to the radiator, and the coolant would circulates through the water jackets around the engine to raise the engine temperature evenly to an efficient temperature.

In order to prevent the coolant from boiling, the cooling system is designed to be pressurized. Under pressure, the boiling point of the coolant is raised considerably. However, too much pressure will cause hoses and other parts to burst, so a relief pressure is needed in the system if it exceeds a certain point. The radiator cap is functioning to maintain the pressure in the cooling system. The cap is designed to release pressure if it reaches the specified upper limit that the system was designed to handle.

The radiator in the automotive system is most a heat exchanger that gets rid of excess engine heat. It plays a critical function in nearly all internal combustion engines. Radiator had been designed to transfer thermal energy from one medium to another for the purpose of heating and cooling. Most radiators are of fin-and-tube design. Coolant flows through tubes from the inlet tank to the outlet tank. The fins are attached to the tubes to provide the air contact area.

Coolant is the most important component in the automotive liquid cooling system. Coolant is a mixture of water and antifreeze which lowers the freezing point of water in the cooling system, prevents rust and corrosion, lubricates the water pump, and picks up heat from the engine, transferring it to the air passing through the radiator. Basically, water is the base coolant. However, it freezes at too high a temperature, boils at too low a temperature, and cause metal corrosion. Some additives had been added to improve water to make it an excellent coolant.

The antifreeze are added to water to reduce the freezing point of the mixture to below the lowest that the system is likely to be exposed to, and to inhibit corrosion in cooling systems which often contain a range of electrochemically incompatible metals such as aluminum, cast iron, copper, lead solder, etc. The main in antifreeze additives are ethylene glycol (EG) and propylene glycol (PG).

The EG and PG (Tom Birch, 2006) are the most important additive in coolant which help to make it more effectiveness. They are used as mixture with water. Even though, pure antifreeze can not be used as coolant because it has high viscosity and does not flow as well. Most manufacturers recommend a mixture of 50% of antifreeze and 50% water to get adequate corrosion protection. In half-and-half mixture, the boiling point of coolant can reach from 100°C to 106°C. By increasing the ratio of the mixture to 70/30, the boiling point will rise a further 7°C to 113°C.

In this study, dynamometer is being used to measure and compare the different of power produce by the engine on the different cooling medium. By using the dynamometer, a performance chart can be developed. When the engine is loaded with a dynamometer, a certain maximum torque and horsepower can be produced at a specific RPM. A chassis dynamometer measures power delivered to the surface of the “drive roller” by the drive wheels. The vehicle was parked on the roller, which the car then turns and the output is measured.

1.2 PROBLEM STATEMENT

In the Automotive Lab, overheating of engine occurs when there is a measurement experiment on the dynamometer. So, the experimental data has some limitation especially when the measurement of the sample taken at least 5 seconds. Currently, the engine dynamometer used water as a coolant in its cooling system.

1.3 OBJECTIVE

To appraise the capability of automotive radiator coolant as a replacement of pure water coolant that being used in the engine cooling system.

1.4 SCOPE

The scopes of the research are as follow:

a) A Long Life Radiator Coolant (Petronas brand) which has the following properties was chosen as a sample:
   i. Contain ethylene glycol
   ii. Free from amine, borax, and silicate

b) To perform the engine performance comparison as an indicator of engine temperature improvement and indicates the changes in time taken by the engine to overheat

c) Petrol engine

CHAPTER II

LITERATURE REVIEW

2.1 OVERHEAT

In an automotive system, the internal combustion engines run on heat. This heat is created when fuel and air mixture is ignited in the combustion chamber. Chemical energy in the fuel is transformed into thermal energy when the fuel burns, which produce mechanical energy to push the pistons, spin the crankshaft and drive the vehicle down the road.

According to Larry Carley (2007), most engines are designed to operate within temperature of about 195 to 220°F. A 50/50 mixture of water and ethylene glycol antifreeze in the cooling system will boil at 225°F if the cap is open. But as long as the system is sealed and holds pressure, a radiator cap rated at 15 psi will increase the boiling temperature of a coolant up to 265°F. If the concentration of antifreeze to water is upped to 70/30 (the maximum recommended), the boiling temperature under 15 psi of pressure goes up to 276°F.

Overheating can be caused by anything that decreases the cooling system's ability to absorb, transport and dissipate heat. The causes are a low coolant level, a coolant leak, poor heat conductivity inside the engine because of accumulated deposits in the water jackets, a defective thermostat that does not open, poor airflow through the radiator, a slipping fan clutch, an inoperative electric cooling fan, a collapsed lower radiator hose, an eroded or loose water pump impeller, or even a defective radiator cap.

In a paper of *How to Prevent Engine Overheating- Importance of Cooling System Maintenance* by FR Penr, if the thermostat is broken, then the fluid in the engine will recirculation in the engine and bypass the radiator. The engine will quickly overheat and can be test by feeling the temperature of the coolant return hose to the radiator. The hose should become hot within minutes of starting the car. Otherwise, according to the writer if the water pump is not operating, the engine coolant just sits in the block and heads. It does not circulate or flow to the radiator to displace its heat. No coolant heat displacement from the radiator means vehicle will quickly overheat.

2.2 CONCEQUENCES FROM OVERHEAT

Against from the written by Larry Carley (2007), if the engine overheats and exceeds its normal operating range, the elevated temperatures can cause extreme stress in the cylinder head which may result in a head gasket failure. This is especially true with aluminum cylinder heads because aluminum expands about two to three times as much as cast iron when it gets hot. The difference in thermal expansion rates between an aluminum head and cast iron block combined with the added stress caused by overheating can cause the head to wrap. This, in turn, may lead to a loss of clamping force in critical areas and allow the head gasket to leak.

Moreover, overheating can also cause pre-ignition. Hot spots develop inside the combustion chamber that becomes a source of ignition for the fuel. The erratic combustion can cause detonation as well as engine run-on in older vehicles with carburetors. Hot spots can also be very damaging and burn holes right through the top of pistons. Besides, coolant can boil out the radiator and be lost. Pistons swell inside their cylinders and can scuff or seize. Valve stems can swell in their guides and also scuff or seize. This, in turn, may damage valve train components or possibly result in damaging contact between the valve head and piston if the valve sticks open.

2.3 OVERHEAT SOLUTIONS

From the paper of *Influence of Heat Loss on the Performance of an Air Standard Atkinson*, the results show that the power output as well as the efficiency, for which the maximum power occurs, will rise with the increase of maximum cycle-temperature. The temperature-dependent specific heats of the working fluid have a significant influence on the performance. The power output and the working range of the cycle increase while the efficiency decreases with the rise of specific heats of working fluid. The friction loss has a negative effect on the performance. Therefore, the power output and efficiency of the Atkinson cycle decrease with increasing friction loss. It is noteworthy that the results obtained in the present study are of significance for providing guidance with respect to the performance evaluation and improvement of practical Atkinson cycle engine.

While in the paper *Engine Performance and Emissions of a Diesel Engine Operating on Diesel- RME (rapeseed methyl ester) Blends with EGR (exhaust gas recirculation),* the combustion of RME (biodiesel) as pure fuel or blended with diesel in an unmodified engine results in advanced combustion, reduced ignition delay and increase heat release rate in the initial uncontrolled premixed combustion phase.

Furthermore, there is another innovation that will help to solve the overheating in the engine which is Insulated Expansion Tank (IET). According to the authors of *Insulated Expansion Tank (IET) and Thermal Storage for Engine Cold Start*, the IET has two functions: 1) allows for expansion and degassing of the cooling circuit and 2) thermal storage of sensible heat. The IET is installed in the engine cooling circuit. Temperature and flow rate controls work according to the servo schematic depending on the coolant temperature inside the IET during engine cold start. The IET can transfer 150 to 200 W of thermal energy into the engine cooling circuit in a very short time; less than 30 seconds. However, the heat flux is equivalent to 18 and 24kW.

Another solution is by using a heat exchanger. From Hans J. Goettler *et al*, (1986) the use of heat exchangers resulted in average reductions of fuel consumption of 2.8% during a 7 minutes warm-up period for the engine, and of 2.2% for the automobile when tested on the above test routes. The corresponding times for the coolant in the automobile compartment heater to reach maximum temperature were reduced by 16% and 7%.

In an article titled "*Parametric studies on automotive radiators*" wrote by *C. Oliet, A. Olivia, J. Castro, and C.D. Pe'rez-Segarra* it was repeated that water is solution in the impact on the cooling capacity and the overall heat transfer coefficient, while ethylene glycol and propylene glycol report similar values (with a small advantage for ethylene glycol) for the same water content. In addition, there are significant knowledge-based design conclusions: (1) the overall heat transfer coefficient reveals almost independent of the air inlet temperature; (2) the overall heat transfer coefficient essentially depends on the coolant flow regime when coolant fluid or coolant flow arrangement are varied; (3) nozzles pressure drop can overshadow the impact of a parameter on the core coolant pressure.

By adjusting (Badih Ali Jawad *et al,* September 2004) the flow rates according to certain variable, the overall effectiveness of the system is increased and overheating problems can be eliminated. The finding also shows that this adjustment can be accomplished by incorporating a controllable electric water pump into the design. Dynamometer testing has also been conducted to show that, in addition to controlling flow rates, the use of the electric pump also possesses the potential of increasing the power output of the engine.

Wolfgang Krause and Karl H. Spies (February 1996) wrote that the conventional expansion element thermostats allow a fixing of only one coolant temperature level. This results in significantly different temperatures of the components which are near the combustion chamber depending on the load and rpm state of the engine. The fuel consumption and the emission are increased.

A new cylinder cooling system (Ken'ichi Harashina *et al*, September 1995) was designed to permit the circulation of engine lubricating oil as a coolant at high speed through grooves provided on the external periphery of the cylinder liner. Testing in an actual operating engine confirmed that the cooling system design not only provides better heat transfer and higher cooling performance but also simplifies the manufacturing of the cylinder.

2.4 COOLANT IS THE BEST SOLUTION

However, after read variety of journal and previous research, I found that coolant is the best solution for this problem. It is easy to handle coolant besides cheap and easy to find. I agreed with Larry Carley (2007), who said that one of nature's basic laws says that heat always flows from an area of higher temperature to an area of lesser temperature, never the other way around. The only way to cool hot metal is to keep it in constant contact with a cooler liquid. And the only way to do that is to keep the coolant in constant circulation.

While from previous research by *S. Rushyanarayanan* and *R. Ramprabhu*, ethylene glycol when mixed with water (in the ratio 30:70) was observed to be milky white in color, and its boiling point had been elevated to 106°C. When the cooling system operates at 1 bar (101 kPa) above atmospheric pressure, the boiling point of water increases to 120°C and hence with ethylene glycol it is expected to increase to 126°C. Maintaining the correct pH value prevents corrosion and protects the water passages. During the process of heating, it was observed that the bubble formation is significantly delayed in the ethylene glycol-water mixture (not below 95°C) unlike water, where it starts at around 80°C and in very large numbers.

CHAPTER III

METHODOLOGY

3.1 FLOWCHART