DEVELOPMENT OF AN EXPERIMENTAL SETUP OF AUTOMOBILE RADIATOR COOLING SYSTEM

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DECLARATION

I hereby declare that this project has been executed by Olayinka Daniel Adewale and Alhassan Abdulhafeez, with the report submitted to the Department of Mechanical & Mechatronics Engineering. Afe Babalola University Ado Ekiti in partial fulfillment for the award of Bachelor of Engineering (B.Eng.) degree in Mechanical Engineering.

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CERTIFICATION

I hereby certify that this project titled Experimental Setup of an Automobile Radiator Cooling System has been executed by Olayinka Daniel Adewale and Alhassan Abdulhafeez with the report submitted to the Department of Mechanical & Mechatronics Engineering, Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria. In partial fulfilment of the requirements for the award of Bachelor of Engineering (B.Eng.) degree in Mechanical Engineering.

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DEDICATION

The report is dedicated to the Almighty God, also our parents, Mr. and Mrs. Olayinka and Mr. and Mrs. Alhassan. Without whose care, support and assistance would have been possible to achieve.

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To begin, I'd like to express my gratitude to the Almighty God, who has clearly directed me through this task and provided me with the strength and health necessary to complete this program successfully.

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ABSTRACT

Automobiles, air conditioners, refrigerators, power plants, and others all employ heat exchangers. Excess heat in an automobile created during engine running is removed by the cooling system. The temperature of the engine surface is controlled by the cooling system in an automobile, ensuring the engine runs at its best. Recent advancements and developments in engine technology have prompted the creation of several ways to improve the efficiency of the engine cooling system. One of the most significant technologies in a cooling system is the coolant.

For this research, an experimental automobile radiator cooling rig was built to make evaluating the thermal properties of various cooling solutions easier. The experimental rig are of two sections, these sections are the frame which serves as the mounting point of other components and the tank which will be storing the cooling fluid. The components mounted on the frame are as follows: A double cell radiator, Two D.C automobile fans, a heating element and a pump. Other measuring equipment's were used such as a flow meter used for measuring the rate of flow within the system and 4 k-Type theromocouples which were used to measure the temperature of the cooling fluid in the tank, at the inlet of the radiator, the body of the radiator and at the outlet.

After the development of the experimental rig, performance evaluation was conducted. Three tests were conducted for the performance evaluation which involved using several mixtures of automobile coolants and water. Water was used as the cooling fluid for the first test followed by a 95.5:4.5 water to coolant ratio was used followed by a 90:10 water to coolant ratio. The result showed that the heat transfer performance of radiator is enhanced by using coolant mixed with water compared to water as the only medium for cooling. As the volume of the coolant (which contains ethylene glycol) increases the heat transfer rate and the effectiveness were much higher compared to only water.

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CHAPTER ONE

INTRODUCTION

1.1. Background of the Study.

Diesel engine

The piston is driven by combustion and expansion in an internal combustion engine in which the air is compressed to a temperature high enough to ignite the diesel fuel pumped into the cylinder. It converts the chemical energy stored in fuel into mechanical energy that can be used to power trucks, heavy tractors, locomotives and ships. Like some generator sets, a limited number of cars run on diesel. (Armstrong and Proctor 2021).

Combustion of diesel

The diesel engine is a piston cylinder device with intermittent combustion, however it only injects air into the combustion chamber on the intake stroke, unlike a gasoline engine with spark ignition. Diesel engines are generally built with compression ratios ranging from 14:1 to 22:1. Both two-stroke and four-stroke engines can be used in engines with bores (cylinder diameters) less than 600 mm (24 inches). Two-stroke cycles are virtually exclusively used in engines with bores bigger than 600 mm (Armstrong and Proctor 2021).

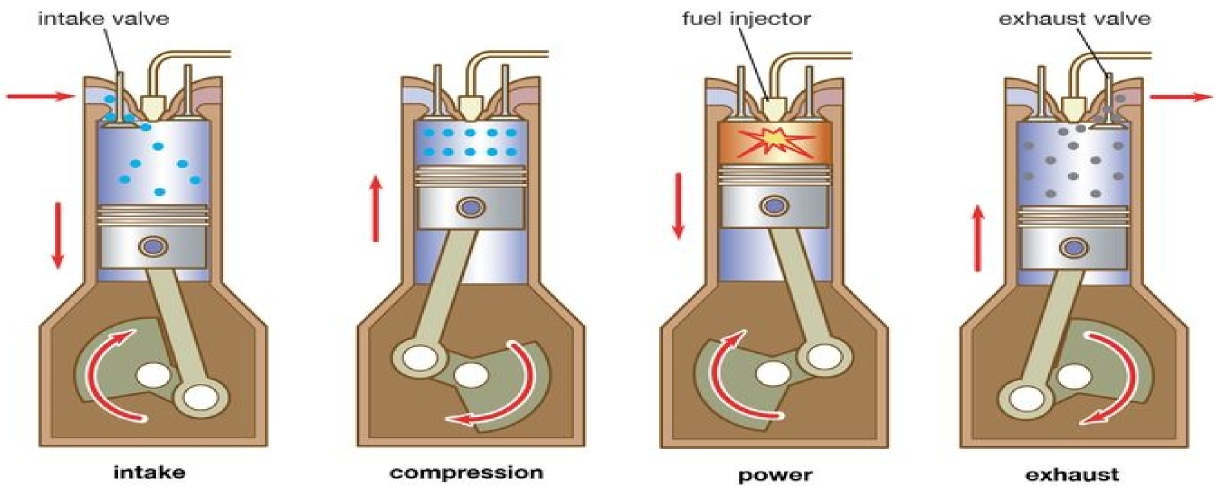

Figure 1. 1: Sequence of a four stroke engine. Source: Britannica, inc. 2020

When a car suddenly overheats, the often question is, “what went wrong?”. A breakdown in the cooling system is the usual cause. Overheating an engine causes it to self-destruct quickly, therefore good cooling system maintenance is critical to the engine's lifespan and the smooth operation of the cooling system in general. How rapidly a vehicle overheats is influenced by the type of cooling fluid utilized.

For their engines, almost all automobiles use a liquid cooling system. A typical automobile system involves the following.

A network of channels cast into the engine block and cylinder head which surrounds the combustion chamber.

Coolant is circulated throughout the engine using a centrifugal water pump which flows through those network of channels.

A radiator is made up of multiple small tubes with a honeycomb of fins to swiftly dissipate heat and gathers and cools hot liquid from the engine.

A thermostat, which maintains constant temperature by automatically varying the amount of coolant passing into the radiator and

A fan, which draws fresh air through the radiator from its surroundings.

It is vital to keep the coolant from freezing when operating at temperatures below 0 °C (32 °F). This is commonly accomplished by adding a substance that lowers the freezing point of the coolant, such as ethylene glycol. It is possible to protect the coolant from freezing down to any minimal temperature encountered by changing the amount of additive. Coolants contain corrosion inhibitors designed to make it necessary to drain and refill the cooling system only every few years (*Automobile - Cooling System | Britannica*, n.d.).

Air-cooled cylinders function at higher, more efficient temperatures, and air cooling has the critical benefit of preventing not just coolant freezing and boiling at severe temperatures, but also cooling system corrosion. When design operating temperatures are greatly increased, however, temperature control becomes more challenging, and high-temperature-resistant ceramic parts are necessary.

To raise the effective working temperature, pressurized cooling systems were utilised. In the early 1970s, partially sealed systems with coolant reservoirs for coolant expansion were introduced if the engine overheats. Specially formulated coolants that do not deteriorate over time eliminate the need for annual replacement (*Automobile - Cooling System | Britannica*, n.d.).

The engine of an automobile performs best at high temperatures. The components wear out faster, the engine releases more pollutants, and the engine is less efficient when it is cold. As a result, one of the most important roles of the cooling system is to allow the engine to warm up as rapidly as possible before maintaining a consistent engine temperature. The primary purpose of a cooling system is to keep the engine at the proper operating temperature. If the cooling system or any component of it fails, the engine may overheat, causing a variety of significant difficulties.

If the condition is severe enough, overheating can cause cylinder head gaskets to blow and engine blocks to shatter. And all of this heat has to be combated. The pistons are actually fused to the interior of the cylinders if the heat cannot be evacuated from the engine. Then you simply need to dispose of the engine and replace it with a new one. As a result, you should look after your engine cooling system and understand how it operates.

The cooling system of an internal combustion engine has a complicated cooling jacket geometry. A cooling jacket is designed to not only remove heat from the engine, but also to assist in achieving the optimal operating temperature as soon as possible.

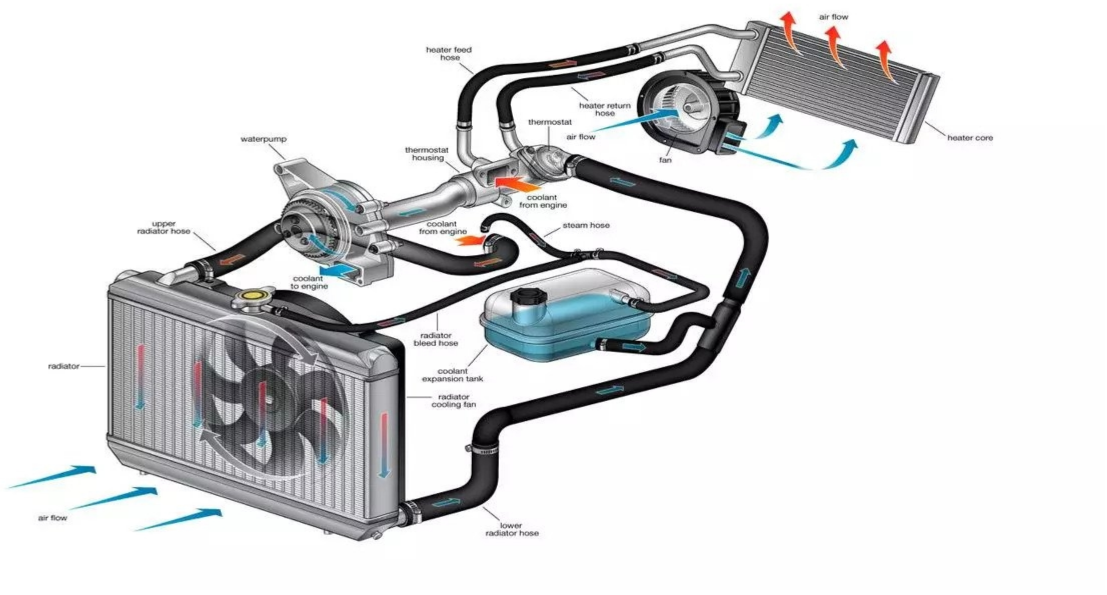

Figure 1. 2: Modern automobile cooling system. Source: Jignesh. 2017

1.2. Problem Statement

For an automobile vehicle, the radiator cooling system appears to be the finest cooling method. They are quick and efficient at lowering the engine's temperature. However, various cooling fluids exist and provide different heat transfer rate. Due to the confined space in the engine, it is difficult to analyze these various cooling fluids.

1.3. Aim and Objectives

Aim

The aim of the study is to develop an automobile radiator cooling system that will allow the ease of checking of the thermal properties of various cooling fluids.

Objectives.

The objectives of this project are to;

i. design an experimental model of an automobile radiator cooling system using solid works.
ii. fabricate the experimental radiator cooling system
iii. evaluate the performance of the developed cooling system
iv. analyze and validate the result of performance evaluation

1.4. Justification of the Study

It has been difficult to carry out the thermal properties of different available coolants in the market, which has been difficult in selecting the best cooling fluid for an automobile engine. The cooling system in an automobile engine can have various rate of heat transfer due to the type of coolant used. This coolant can be difficult to analyze due to the tight spacing within the automobile vehicle.

1.5. Scope of the Project

This project is limited to development of a small-scale working model of an experimental automobile cooling system. This working model should be able to perform the basic functions of the cooling system which includes heating the fluid and cooling the fluid and enable for convenient reading of several parameters such as the flow rate and the heat at different point in time.

CHAPTER TWO

LITERATURE REVIEW

2.1. History of Automobile

An automobile is a self-propelled ground vehicle. It is powered by an internal combustion engine and travels on wheels. An automobile's main purpose is to transport people and things from one location to another (Bellis, 2019).

The first self-powered road vehicles were powered by steam engines, and according to this definition, Nicolas Joseph Cugnot of France developed the first automobile in 1769, which was recognized as the first by the British Royal Automobile Club and the Automobile Club de France. So, why do so many history texts claim that Gottlieb Daimler or Karl Benz invented the automobile? It's because Daimler and Benz pioneered the highly successful practical gasoline-powered vehicles, which ushered in the modern era the automobiles we use today However, neither guy can claim to have invented "the" automobile.(Bellis, 2019).

People utilized bullock carriages or other animals such as camels, horses, and other animals to transport goods and people from one location to another in the early days. One major issue with using these animals is that they cannot travel vast distances or for lengthy periods of time. As a result, a machine that can fulfill these functions is required. In 1769, a French engineer Captain Nicholas Cugnot designed the first road vehicle propelled by its own power, after a considerable deal of labor by scientists. Although it is a steam engine vehicle, his design proved to be impractical.

Figure 2. 1: 1769 Cugnot three-wheeled steam vehicle. Source: Joe DeSousa

Richard Trevithick created the first steam carriage in England in 1801. The first internal combustion engine is developed in the year 1860. stroke before the gasoline bursts Nikolaus Otto and Eugen Langer employed compression stroke in that engine in 1867 to boost the engine's power. Nikolaus Otto invented the first four-stroke spark ignition engine in 1876 (Bellis, 2019).

Following this, a number of engineers (including Dugald Clerk, James Robson, and Karl Benz) created two-stroke engines. Karl Benz of Germany invented a tricycle powered by an internal combustion engine in 1880. Rudolf Diesel invented the first four-stroke compression ignition engines in 1892. In 1920, a stratified charge engine was invented that could run on both gasoline and diesel. Ricardo created a stratified charged jet fired engine. Wankel invented a rotary type internal combustion engine in 1957.

At the turn of the twentieth century, steam powered 40% of American autos, electricity 38 percent, and gasoline 22 percent. The electric automobile, in contrast to the gasoline car's unreliability, loudness, and vibration, and the steamer's complexities and thirst, had appealing selling qualities, including immediate self-start, silent operation, and low maintenance. An electric car (Camille Jenatzy's La Jamais Contente, 1899) was the first to reach 100 km/h (60 mph). In 1898, an electric, again Jenatzy's, had easily won a French hill-climb competition to test the three forms of power (Bellis, 2019).

Figure 2. 2: La Jamais Contente. Source: Alexander

Gaston Planté of France invented the storage battery in 1859–60, and Camille Faure improved it in 1881, making the electric vehicle conceivable, and the first, a tricycle, ran in Paris in 1881. Other three-wheelers followed in London (1882) and Boston (1883). The first American battery-powered automobile, manufactured by William Morrison in Des Moines, Iowa, in 1890, with a top speed of 14 miles per hour (23 kilometers per hour). The absence of battery-charging infrastructure limited the electric car's popularity. Even in cities, few private residences were wired with electricity prior to 1910, and community charging stations and battery exchange programs failed to take off. The problem had been solved by 1912, and the electric had reached its peak. There were 20 businesses in the business, and 33,842 electric automobiles were registered in the United States, the country where they were most popular. Another application of battery power, the electric self-starter, did more than anything to doom the electric automobile by removing the feared hand crank and allowing women to operate internal-combustion engine cars. Furthermore, the electric has never been well-suited to other applications showing of its modest speed (15–20 miles per hour, or 24–32 kilometers per hour), short range (30–40 miles, or roughly 50–65 kilometers), and long recharging time By 1920, the electric car's heyday in America had passed, though a few manufacturers continued to provide them on a limited basis until World War II. However, the war prompted tests with small electric automobiles in fuel-strapped France, as well as widespread usage of electric vehicles for milk delivery in Britain, which lasted the rest of the century (Breeze, 2018).

2.2. Automobile Cooling System

What is a cooling system?

The purpose of a vehicle's engine cooling system is to keep the engine cool while simultaneously keeping it heated enough to ensure efficient and clean operation. System components include a radiator which dissipates heat, a fan or fans which ensure appropriate airflow for radiator cooling, a thermostat valve that opens when the desired operating temperature is attained, and a water pump (or coolant pump) to circulate coolant through the engine, hoses and other components (Nolan, 2017). When the automobile is switched off and the engine cools, the coolant expands and exits the cooling circuit, and then returns when the car is turned off and the engine cools. The cooling system also incorporates elements of the cabin’s ventilation system, because engine heat is used to warm the car’s interior (Nolan 2017).

Despite significant improvements, gasoline engines are still inefficient at converting chemical energy into mechanical power. The majority of the energy in gasoline (about 70%) is converted to heat, and the cooling system's purpose is to remove that heat. In fact, a car's cooling system loses enough heat to heat two average-sized houses when traveling down the freeway. The cooling system's principal function is to prevent the engine from overheating by transferring heat to the air, but it also has several other significant functions (Nice, 2021).

Your car's engine performs best when it's warm. Components wear down faster when the engine is cold, and the engine is less efficient and produces more pollutants. Another crucial function of the cooling system is to allow the engine to heat up rapidly and maintain a steady temperature. Fuel is always burning inside your car's engine. The heat from this combustion mostly escapes through the exhaust system, although some of it heats up the engine. When the coolant temperature is at 200 degrees Fahrenheit, the engine runs best (93 degrees Celsius)(Nice 2021).

Cooling system of an internal combustion engine

Air (gaseous fluid) or a liquid coolant pumped via a pump through a heat exchanger (radiator) cooled by air are used to cool most internal combustion engines. In the water cooling system of cooling engines, the cylinder walls and heads are provided with a jacket through which the cooling liquid can circulate (John, 2022).

An internal combustion engine's cooling system keeps the various engine components at temperatures that promote long life and proper operation.

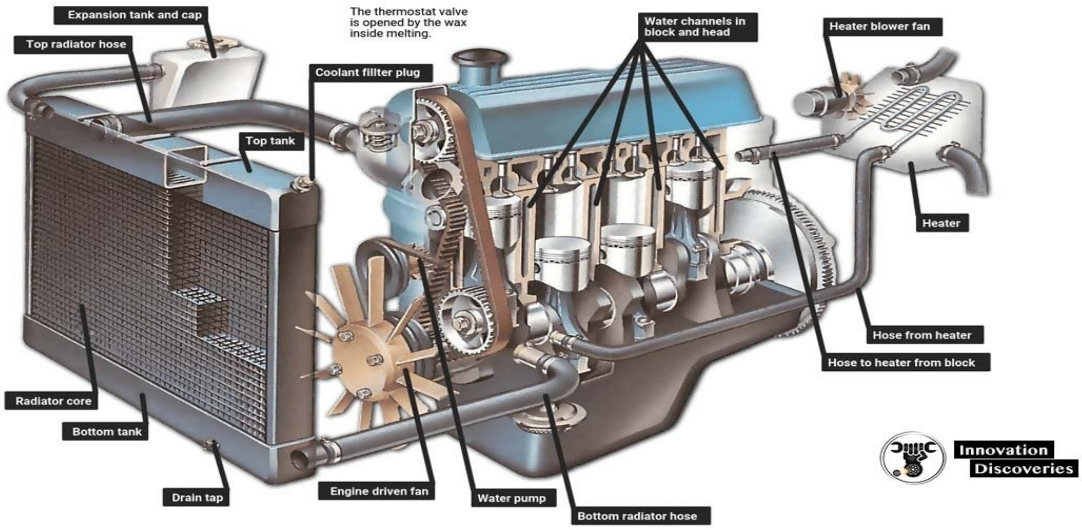

Figure 2. 3: A typical automobile cooling system.

2.3. Automobile Liquid Coolants

In automotive internal combustion engines, liquid coolants (typically a half-and-half mixture of water and ethylene glycol (EG) based antifreeze) are used to regulate heat. The coolant prevents corrosion in the cooling system and also removes waste heat from the engine. Water is employed because of its ability to absorb and carry heat efficiently, but it doesn't guard against corrosion and has a limited operating range due to its freezing and boiling temperatures (32 degrees F and 212 degrees F). Using a spring-loaded radiator or a coolant reservoir lid to pressurize the cooling system can raise the temperature at which water boils. Water must be blended with something else to lower the temperature at which it freezes for cold-weather operation. When ethylene glycol is mixed in equal parts with water, the freezing point drops to -34 degrees F and the boiling temperature rises to 265 degrees F. (with a 14 PSI cap).

Why not use ethylene glycol only as a cooling medium? It transfer heat 15 to 20% less efficiently than water, and while it boils at 386 degrees Fahrenheit, it only freezes at 10 degrees Fahrenheit, which is insufficient for freezing protection in cold climes.

2.4. REQUIREMENTS OF EFFICIENT COOLING SYSTEM

The ability to remove around 30% of the heat generated in the combustion chamber is one of the two basic criteria of an efficient cooling system. Too much heat removal reduces the engine's thermal efficiency.

When the engine gets hot, the cooling system should evacuate the heat quickly also he cooling should be done slowly when the engine is first started so that the various functioning parts achieve their operational temperatures quickly.

How Does A Car Cooling System Work?

A cooling system circulates liquid coolant via passageways in the engine block and heads to keep the engine cool. The coolant absorbs heat from the engine as it passes through these channels. After cooling, the fluid returns to the engine to absorb more heat. Liquid cooled and air cooled cooling systems are the two types of cooling systems found on automobiles.(Nice 2021)

AIR COOLING SYSTEM

In this form of cooling system, the heat that is delivered to the engine's outer parts is radiated and taken away by a stream of air drawn from the atmosphere. Fins around the cylinder and cylinder head increase the contact area, making air cooling more efficient.The fins are metallic ridges that form during the casting of the cylinder and cylinder head. The amount of heat removed by air-cooling is determined by the following factors: The overall area of the fin surfaces, the cooling air velocity and volume, and the temperature of the fins and cooling air.

Low-horsepower tractors, motorcycles, scooters, small vehicles, and tiny aircraft engines all use air cooling since the machine's forward motion provides enough velocity to cool the engine. Air cooling is also used in some small industrial engines. Individual cylinders are frequently employed in this system to provide sufficient cooling area via fins while a blower is used to supply the air.

Figure 2. 4: Air cooling system. Source: Saif. 2019

Air cooled engines have the following advantages:

The design of air-cooled engine is simple and less complex compared to water cooling system.

It is lighter than water-cooled engines due to the lack of water jackets, radiators, circulating pumps, and the weight of the cooling water.

It is less expensive to produce, it requires less attention and upkeep, the cooling technique is especially useful in areas with extreme climate conditions, such as the arctic, or where water is scarce, such as deserts and there is no possibility of frost damage, such as cylinder jacket or radiator water tube splitting.

Disadvantages of Air-cooling system

Air Cooling Systems also has some drawbacks, including:

Increased noise during operation and the low heat transfer coefficient of the air reduces the efficiency of the operation.

Liquid cooling system

On liquid-cool system, the cooling system circulates a fluid through pipes and tunnels in the engine. This liquid absorbs heat as it flows through the heated engine, cooling it. After leaving the engine, the fluid flows through a heat exchanger, also known as a radiator, which transfers heat from the fluid to the air passing through the radiator. On liquid-cool system, the cooling system circulates a fluid through pipes and tunnels in the engine. This liquid absorbs heat as it flows through the heated engine, cooling it. After leaving the engine, the fluid flows through a heat exchanger, also known as a radiator, which transfers heat from the fluid to the air passing through the radiator. Liquid cooling system serves two purposes in the working of an engine; It takes away the excessive heat generated in the engine and saves it from over-heating and it keeps the engine at working temperature for efficient and economical working.

There are two types of liquid cooling systems: thermosyphon and pump cooling.

Thermo-Syphon Water Cooling System

Because heated water is lighter than cold water and cold water is heavier, hot water rises and cold water sinks. This design elevates the radiator above the engine to allow for simple water flow towards the engine. The heat is transported to the water jackets, where the circulating water convectively removes it. As the radiator heats up, the water jacket rises to the top. The hot water rises and is replenished by cold water from the radiator, causing the system to circulate. This aids in maintaining the engine's operating temperature. This system does not have a pump. The difference in densities between hot and cold water causes water to circulate. However, the rate of cooling in these cooling systems is slow. Because we need to keep the water level at a specified level, its use is restricted nowadays. It's easy to build and inexpensive. The system's shortcoming is that cooling is solely dependent on temperature and is unaffected by engine speed (Bellis 2019).

Disadvantages of Thermo-Syphon System

The rate of circulation is very slow

Circulation begins only when there is a significant temperature difference.

When the water level goes below the top of the radiator's delivery pipe, circulation stops. As a result of these factors, this system is no longer in use.

Pump circulation system

The water circulation in this cooling system is accomplished using a centrifugal pump. The rate of water flow is increased thanks to this pump. The pump is also driven by a crankshaft belt. The designer may install the radiator in any convenient location. Operation Cooling water flows upward from the cylinder head to the radiator's top tank, then down through the radiator core to the bottom tank in this system. With the help of the water pump, which circulates the water, it goes from the bottom tank to the cylinder block water jackets via the lower radiator line. Water enters the engine through the center of the pump's input side. A belt from the crankshaft drives the circulating pump. The flow of coolant increases as the engine speed rises.

Water-Cooling System advantages

A water-cooling system has the following advantages:

We notice a significant heat transfer rate in various types of cooling, The cooling system is employed when the engine's size or power is greater, Higher Thermal Conductivity, There is plenty of water and because liquid has a high enthalpy of vaporization, water cooling is more efficient.

Water-Cooling System Disadvantages

The following are some of the drawbacks of water-cooling systems:

Corrosion can occur within the radiator, piping, or storage.

Scaling reduces the heat transmission rate with time, necessitating regular cleaning and maintenance.

This form of cooling system is used in all modern engines (cars, buses, trucks, and so on).

2.5. The cooling system consists of the following components:

2.5.1 Water Pump

The water pump is situated between the engine block and the engine fan in rear-wheel-drive cars. The water pump is situated at the rear of the engine in a few front wheel drive automobiles. The water pump circulates the coolant using centrifugal force and is made out of a fan shaped impeller positioned in a round shaped chamber with curved intake and exit tubes. Because of the curving portions, the chamber is known as a scroll. When the coolant temperature rises, the centrifugal design causes the vehicle to increase engine speed.

The water pump circulates the coolant using centrifugal force and is made out of a fan-shaped impeller positioned in a round chamber with curved intake and exit tubes. Because of the curving portions, the chamber is called a scroll. When the coolant temperature begins to rise, the centrifugal architecture causes the vehicle to increase engine speed. Once the coolant has cooled in the radiator, the water pump returns it to the cylinder block, heater core, and cylinder head. The liquid ultimately makes its way back to the radiator to cool off.

Figure 2. 5: Water Pump. Source: Larry 2017

2.5.2. Radiator

A heat exchanger, such as a radiator, is a form of heat exchanger. Its purpose is to transfer heat from the hot coolant flowing through it to the air blown by the fan.

Radiators made of aluminum are used in the majority of modern automobiles. Brazing tiny aluminum fins to flattened aluminum tubes creates these radiators. The coolant circulates through a series of parallel tubes from the input to the outlet. The heat from the tubes is transferred to the air passing through the radiator by the fins.

A turbulator is a sort of fin that is occasionally added into the tubes to increase the turbulence of the fluid passing through them. Only the fluid directly touching the tubes would be cooled if the fluid went very smoothly through the tubes. The quantity of heat transferred to the tubes from the fluid going through them is determined by the temperature difference between the tube and the fluid it comes into contact with. As a result, if the fluid in contact with the tube cools rapidly, less heat is delivered. By creating turbulence inside the tube, all of the fluid mixes together, maintaining the temperature of the fluid touching the tubes high enough to extract more heat, and all of the fluid inside the tube is successfully employed.

A transmission cooler is normally found within a tank on each side of a radiator. The gearbox cooler functions similarly to a radiator within a radiator, except that instead of exchanging heat with the air, the oil exchanges heat with the radiator's coolant.

2.5.3. Thermostat

The thermostat is a small mechanism that lies between the engine and the radiator in any liquid-cooled vehicle engine. In most autos, the thermostat is roughly 5 cm (2 inches) in diameter. Its job is to prevent coolant from flowing to the radiator until the engine has reached operating temperature. Coolant does not flow through the engine when it is cold. The thermostat opens when the engine reaches operational temperature (mostly around 200 degrees Fahrenheit, 95 degrees C). The thermostat reduces engine wear, deposits, and pollutants by allowing the engine to warm up as rapidly as possible. Its valve opens roughly an inch as it heats up.

Figure 2. 6: Car Thermostat. Source: wuling. 2021

The thermostat's secret is hidden in the little cylinder on the device's engine side. The wax in the cylinder melts at 180 degrees Fahrenheit (Different thermostats open at different temperatures, but a common temperature is 180 degrees Fahrenheit /82 degrees Celsius).

Thermostat Failure

The thermostat is rather straightforward and rarely creates issues, but when it does, the consequences can be severe. The thermostat sticking shut is the worst case situation, which can occur if the wax element has been damaged by past overheating, corrosion, or age. If it becomes stuck shut, coolant will not be able to circulate between the engine and the radiator, causing the engine to overheat.

The steady flow of coolant via the thermostat will keep the engine from reaching normal operating temperature if the thermostat fails to close, which can happen if the sensor element binds up, the return spring breaks, or a piece of rust or debris jams it open. This can result in a significant increase in fuel consumption, little or no heater output, and cylinder attrition. It's a thermostat that serves as a coolant valve, allowing it to travel through the radiator only when a specified temperature is reached. The thermostat is made of paraffin wax, which expands and closes at a specific temperature. The cooling system uses a thermostat to maintain the internal combustion engine's regular operating temperature. The thermostat is activated when the engine reaches normal operating temperature. The coolant can then be injected into the radiator.

2.5.4. Coolant Recovery Tank

A coolant recovery tank, also known as an overflow reservoir, allows coolant to expand without being driven out of the radiator. The tank also allows the radiator to be refilled when the engine cools, ensuring that the radiator is always full. As the engine heats up, the coolant expands due to the increased temperature. The rise in temperature is accompanied by a rise in pressure. The radiator pressure cap, which relies on a spring to keep the radiator fill hole sealed. The spring's force is overcome when the pressure hits roughly 15 psi, and the cap rises. The aperture of a tube is visible as the cover rises.The coolant is pumped through the tube into the recovery tank under pressure.

The procedure is reversed as the engine cools. A vacuum sucks coolant back into the radiator instead of pressure pulling it out. This maintains the proper level of coolant throughout a wide range of engine temperatures.

A dipstick in the recovery tank can be used to check the coolant level. The dipstick comes in a variety of temperatures, from hot to cold. When the engine is cold, the coolant level should be at the "cold" mark, and when the engine has reached operating temperature, it should be at the "hot" mark.

It prevents a radiator system that is slightly overfilled from venting onto the ground. When used in conjunction with a standard radiator, an expansion tank contributes only a tiny quantity of additional coolant to the system. If this tiny amount of extra coolant isn't enough to cool down an overheating engine, there's another issue with the cooling system that needs to be addressed.

2.5.5. Cooling Fan

The cooling fan is only required when the engine temperature exceeds a predefined level or when the cooling system is under greater stress (as when running your air conditioner). Running the fan the remainder of the day would be a waste of electricity, therefore it is turned off. Most front-wheel-drive vehicles with transverse-mounted engines, as well as many late-model rear-wheel-drive vehicles, have electric cooling fans. Electric fans are used on front-wheel-drive cars since they do not require a belt drive and may be positioned regardless of where the engine is located.Furthermore, electric fans use less energy to operate (for better fuel economy and performance), are quieter, and provide more precise cooling control. A mechanical belt-driven fan, on the other hand, can require anywhere from 5 to 15 horsepower, depending on engine speed and fan size. It's still a lot of lost power, even with a fan clutch to reduce drag at higher speeds.

At highway speeds, airflow via the radiator is usually sufficient, thus a fan isn't required. As a result, the fan is normally only turned on when the car is stuck in traffic or traveling at a slower speed.

The electric fan is regulated by a temperature switch in the radiator or engine on older models. The switch closes and energizes a relay that supplies voltage to run the fan when the coolant temperature exceeds the switch's rating (usually 195 to 235 degrees F). The fan will continue to run until the coolant temperature falls below the switch's opening point. Most electric fans are also set to turn on when the air conditioner is turned on. A separate fan for the A/C condenser is found in many automobiles (dual fan systems). When the air conditioner is turned on, one or both fans turn on.

The engine control module controls fan operation in contemporary automobiles with digital engine controls. The coolant sensor, as well as, in many situations, the vehicle speed sensor, are utilized to decide when the fan should be turned on.

2.5.6. Hoses

Radiator hoses must be the proper size, material, and in good working order. When the thermostat is fully open, the upper and lower radiator hoses must be large enough to accommodate the maximum flow of coolant. A part of the coolant is diverted to and from the heater core via the smaller heater hoses. For high-pressure, high-temperature systems, the hoses must also be made of the appropriate material. When servicing a cooling system, look for any signs of damage on the hoses because of the extreme heat in the engine compartment, the rubber substance of the hoses becomes brittle and cracks.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Materials

Light duty Radiator : It is a heat exchanger specifically designed to efficiently cool the engine block to prevent overheating in a light-duty engine. In this project work, it functions as a heat exchanger when we are simulating the heat transfer process in a light-duty engine. The radiator used is a double cell radiator which can take a maximum of 2.5 liters within it.

Figure 3. 1: Image of the radiator used.

Mild steel: Mild steel is a ferrous metal made of iron and carbon. It's a low-cost material with properties that make it suitable for a variety of engineering applications. Mild steel was selected for this project due to its low cost and machinability. A 2-inch square pipe and 1mm sheet of mild steel was used in the fabrication of the experimental rig. The 2-inch square pipe was used in the fabrication of the framework while the 1mm sheet Was used in the fabrication of the chassis of the reservoir tank

Figure 3. 2: Chassis for the experimental rig built with 2-inch square mild steel pipe.

Figure 3. 3: Construction of the reservoir tank using a 1mm mild steel sheet.

Centrifugal Water Pump: The centrifugal pump was used to pump the cooling fluid from the radiator throughout the system. The centrifugal pump has the following specifications:

i. Product Brand: STRONGDAB 60

ii. Max flow rate: 30 L/min

iii. Frequency: 50Hz

iv. Power: 0.5 HP

v. Current: 2.5A

vi. R.P.M: 2850

Figure 3. 4: Water Pump

Flow Meter: A flow meter was used to determine and record the flow rate of flow of the various fluids flowing through the pipes while the fluid was circulated through the system by the pump. The flow meter chosen had these following specifications; Model: K24, Max working pressure: 20 bar and Flow range: 10-100L/Min

Figure 3. 5: Flow meter

Heating Element: A heating element was used to heat up the fluids in the reservoir tank to a certain temperature. It simulated to imitate the heat produced by the automobile engine. The heating element had a specification on

Figure 3. 6: Heating Element

Type K Thermocouple: Four (4) type k thermocouples were used to measure and record the temperatures at four specific points on the experimental setup. The thermocouples had a specification of temperature range between -50°C to 750°C.

Figure 3. 7: Type K Thermocouple

Fan: Two fans were used to direct air towards the heat exchanger (radiator) to allow for heat exchange to occur thereby resulting in the cooling of the fluids in the radiator.

Metallic pipes, Plastic Pipes and Flexible hoses: Metallic pipes and flexible hoses were connected to the various compartments of the experimental rig to enable the various fluids to flow through it from one part to another.

Clips and tapes: Clips and tapes were used to fasten various equipment and enable them to be firm

3.2. Methods

The experimental rig is devoted to the design of the radiator cooling system of an automobile vehicle. The rig requires a constant loop of flow of cooling fluid from the radiator to the reservoir tank. The cooling fluid is forced into the reservoir through the pump which which is then heated up by the heating element within the reservoir. This is to simulate the transfer of heat of the engine to the cooling fluid passing through it by means of conduction. This cooling fluid then experiences a rise in temperature and then goes back into the radiator. As the cooling fluid passes through the radiator it looses some of its heat. Finally it becomes cool and makes it back up to the reservoir tank for reheating.

3.3. Design Specifications

In the design of the experimental rig a list of criteria were considered which guided the process of the development of the rig. The criteria considered in designing the experimental rig included the manufacturability, performance, serviceability and economic concerns.

When designing the experimental rig, the temperature was taken into consideration by selecting materials that could withstand the increase in temperature of the heated water. The performance of the rig was a high priority. The main criteria was that the rig must be able to

3.4. Design Calculations

Length of tank = 400mm

Breadth of tank = 400mm

Height of tank = 350mm

Max Volume of the Tank = 400 x 400 x 350 = 56 liters

Volume of water used for experiment = 25 Liters

Volume of coolant (ethylene glycol) used for first test = 1.2 Liters

Volume of coolant (ethylene glycol) used for second test = 2.8 Liters

Calculating the concentration (x) of coolant (ethylene glycol) for 1.2 Liters with 25 Liters of water

Total fluid = 1.2 Liters + 25 Liters = 26.2 Liters

$$X = \frac{1.2 \times 100}{26.2} = 4.5\%$$

Calculating the concentration (x) of coolant for 2.8 Liters with 25 Liters of water

Total fluid = 2.8 Liters + 25 Liters = 27.8 Liters

$X = \frac{2.8 \times 100}{27.8} = 10.07\%$

Nomenclature

K = Thermal Conductivity, W/m-K

C_p = Specific heat j/kg-K

Q = Heat transfer by coolant, Watt

N_u = Nusselt number

m = Mass flow rate of coolant kg/s

T = Temperature, K

H = Convective heat transfer

A_s = Surface Area of Coolant tube, m^2

Estimation of Nussellt number (N_u)

Coolant heat transfer is estimated as follows:

$Q = mC_p(T_{in} - T_{out})$

According to Newton's law of cooling

$Q = hA_s(T_b - T_\omega)$

Therefore: $N_u = \frac{hD}{K} = \frac{mC_p(T_{in} - T_{out})\ D}{A_e(T_b - T_\omega)K}$

Mass flow rate = Density of the fluid x Volume flow rate

Where m is nanofluids mass flow rate.

C_p is specific heat of the coolant, K is thermal conductivity of coolant.

A_s is the surface area of the oval tubes of radiator.

T_{in} and T_{out} are the inlet and outlet coolant temperature respectively .

T_b is the bulk tempertature which is average of inlet and outlet temperature of the coolant.

T_w is the tube surface temperature. N_u is the coolant side Nusselt number for the radiator.

3.5. Experimental Setup

The experimental setup took place in three (3) phases namely

i. Design of the experimental rig
ii. Construction of the experimental rig
iii. Performance evaluation

3.5.1. Design of Experimental Rig:

The entire models were designed with the use of solidworks. These includes the third angle projection of the reservoir tank and framework. With the isometric and exploded view of the assembled parts. This drawings can be seen in the appendix.

3.5.2 Construction of experimental Rig.

Frame:

The construction and welding of the framework of the experimental rig was started using a 2-inch square pipe mild steel to construct the framework. The framework had the following dimensions: Length: 857mm, Breadth: 948mm, Height: 775mm

Then proceeded to constructing and welding the reservoir tank using a 1mm mild steel sheet. Mild steel was used in place of galvanized steel due to the cost of the material. The sheet was later painted to avoid rust and corrosion since the tank will contain various fluids at various times. The reservoir tank had the following dimensions: Length: 400mm, Breadth: 400mm, Height: 350mm.

The tank has 3 different outlets. Two large outlets and one in which the heating element will be inserted through. The heating element was attached to the side of the tank which will be responsible for heating the water inside the tank. Two metallic pipes were attached to the two large outlets which serve as the inlet passage for the fluid to flow from the pump into the tank and the other which allows the heated water to into the radiator for cooling.

Tank Cover

A cover with a handle was also constructed for the reservoir tank. We also used the 1mm mild steel sheet for the cover. The cover had the following dimensions

Length: 401mm

Breadth: 401mm

Height: 30mm

3.5.3. Assembling of the experimental rig

The reservoir tank was attached to the top right corner of the framework by welding the sides of the frame and the tank together.

The pump was mounted on the base at the bottom left corner of the framework with aid of bolt and nuts.

A plastic pipe was then attached to the inlet of the pump and was connected to the pipe welded to the outlet of the tank

The radiator (Heat exchanger) was placed steadily in front of the frame and bolted to the frame with a bolts and nuts.

Two fans were attached behind the radiator at very close proximity to ensure direct impact of the radiator

The flowmeter was attached between pump and the inlet pipe of the tank with the help of plastic elbow pipes. A flexible hose was then attached to the other side of the pump and the outlet of the radiator.

Figure 3. 8: Experimental Rig

3.5.4. Performance Evaluation

The performance evaluation of the system with the following fluids

Water

Water + Coolant (4.5% concentration)

Water + Coolant (10.07% concentration)

3.6. Experimental Procedure

The first fluid used was water. Twenty-five (25) liters of water was poured into the reservoir and stirred properly to make the temperature even.

Then the first thermocouple was inserted into the tank and was switched on and the ambient temperature of the fluid was recorded.

The control panel was then connected to the outlet socket and the control panel turned on.

The switch for the heating element was turned on and the water was allowed to boil till it reached 60°C.

All the type K thermocouple were connected at the specific points as stated above were turned on.

Once the temperature reached 60°C. The fan and the pump were switched on and the fluid was allowed to circulate through the system.

The pumping machine pumped the fluid through the system from the radiator through the flow meter to the reservoir tank and back into the radiator.

The first reading was taken immediately after all components were turned on.

After the fluid had circulated for about five (5) minutes the temperature readings indicated by the four (4) type k thermocouples were recorded.

The fluid was allowed to continue flowing for another five (5) minutes then the temperature readings were taken again.

The entire process was repeated for the second fluid water + coolant (4.5% concentration).

The overall process again repeated for the third fluid water + coolant (10.07% concentration).

Table 3. 1: Bill of Engineering Measurements and Evaluation

S/N	Components	Specification	Quantity	Unit Price(N)	Price
1	Radiator		1	sourced	sourced
2	Centrifugal Water Pump	2.5Ah (230V) 0.5HP	1	25,000	25,000
3	Fan				10,000
4	Flowmeter		1	45,000	45,000
5	Thermocouple		2	15,000	30,000

6	Ball Gauge		1	2,500	2,500
7	Square Pipe	(2 x 2)inch	3	6,000	18,000
8	Galvanized Pipe		1	8,000	8,000
9	Clips and Tapes		5	200	1000
10	Elbow		5	500	2,500
11	Metal Sheet	Mild Steel	1	18,000	18,000
	Total				160,000

CHAPTER FOUR

RESULT AND DISCUSSION

After the completion of the experimental rig, the following results were achieved and the data log is presented in the tables corresponding to the various cooling fluid. Using these data, the performance is determined and plotted

4.1. Results

The cooling fluid data log below indicates the performance of the experimental setup that has been tested on different cooling system. The experimental rig was tested on three different types of cooling fluid: Water, Water + coolant, + water + Nano fluid.

4.2. Constant variable for tests

Density of water = 1kg/L

Density of ethylene glycol = 1.12kg/L

Density of water and ethylene glycol mixture (4.5% concentration) = 0.83 Kg/L

Density of water and ethylene glycol mixture (10.07% concentration) = 0.91 Kg/L

Specific heat capacity of water = 4190J/kgK

Specific heat capacity of water and ethylene glycol (4.5% concentration) = 4320J/kgK

Specific heat capacity of water and ethylene glycol (10.07% concentration) = 4240J/kgK

Air velocity = 5.3m/s

From the reading below,

T1 is the temperature of the fluid inside the reservoir tank

T2 is the temperature of the fluid going into the radiator

T3 is the temperature of the radiator walls

T4 is the temperature of the fluid exiting the radiator.

Heat transfer rate $Q = mc_L(T_2 - T_4)$

4.3. Readings for light duty radiator

Table 4. 1: Experimental reading of water

SI No.	Coolant	Volume flow rate (L/min)	Mass flow rate (kg/min)(Density of fluid x Volume flow rate)	T1 (°**C**)	T2(°**C)**	T3(°**C)**	T4(°**C)**	Heat transfer rate (W)
1	water	70.6	70.6	60	59.1	55.6	51.7	17844.37
2		65.5	65.5	40.9	40.2	37.4	37.1	14183.99
3		54.8	54.8	34.9	34.7	34.5	33.0	6481.93

Solution:

1) Mass flow rate = density x Volume flow rate
   = 1 x 70.6 = 70.6 kg/min
   = 1.17667 kg/s

   Heat Transfer $(Q) = mc_L(T_2 - T_4)$

   = 1.17667 x 4190 x (59.1 – 51.7) = 17844.372 W

2) Mass flow rate = density x Volume flow rate
   = 1 x 65.5 = 65.5 kg/min
   = 1.092 kg/s

   Heat Transfer $(Q) = mc_L(T_2 - T_4)$

   = 1.092 x 4190 x (40.2 – 37.1) = 14183.988 W

3) Mass flow rate = density x Volume flow rate

= 1 x 54.8 = 54.8 kg/min
= 0.91 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 0.91 x 4190 x (34.5 – 33.0) = 6481.93 W

Table 4. 2: Experimental reading of water and coolant (4.5%) concentration

SI No.	Coolant	Volume flow rate (L/Min)	Mass flow rate (kg/min)	T1 (°**C**)	T2(°**C**)	T3(°**C**)	T4(°**C**)	Heat transfer rate (W)
1	Water + coolant (4.5% concentration)	83.2	69.06	60	49.6	45.6	35.9	68061.6
2		72.3	60.01	42.7	41.9	39.7	34.7	31108.67
3		61.5	51.05	37.5	37.2	35.9	35.3	6985

Solution:

1) Mass flow rate = density x Volume flow rate
= 0.83 x 83.2 = 69.056 kg/min
= 1.15 kg/min

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 1.007 x 4320 x (49.6 – 35.9) = 68061.6 W

2) Mass flow rate = density x Volume flow rate
= 0.83 x 72.3 = 60.009 kg/min
= 1.00 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 1.00 x 4320 x (41.9 – 34.7) = 31108.666 W

3) Mass flow rate = density x Volume flow rate
= 0.83 x 61.5 = 51.045 kg/min
= 0.851 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 0.851 x 4320 x (37.2 – 35.3) = 6985.008 W

Table 4. 3: Experimental reading of water and coolant (10.07% concentration)

SI No.	Coolant	Volume flow rate (L/Min)	Mass flow rate	T1 (°C)	T2(°C)	T3(°C)	T4(°C)	Heat transfer rate (W)
1	Water + coolant (10.07% concentration)	73.3	66.70	60	57.7	47.9	35.4	104952.7
2		64.6	58.79	45.9	45.6	40.8	36.5	37812.32
3		59.3	53.96	40.3	40.2	38.1	34.7	20985.67

Solution:

1) Mass flow rate = density x Volume flow rate
= 0.91 x 73.3 = 66.703 kg/min
= 1.11 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 1.11 x 4240 x (57.7 – 35.4) = 104952.72 W

2) Mass flow rate = density x Volume flow rate
= 0.91 x 64.6 = 58.786 kg/min
= 0.98 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

= 0.98 x 4240 x (45.6 – 36.5) = 37812.32 W

3) Mass flow rate = density x Volume flow rate
= 0.91 x 59.3 = 53.963 kg/min
= 0.8999 kg/s

Heat Transfer (Q) = $mc_L(T_2 - T_4)$

$= 0.8999 \times 4240 \times (40.2 - 34.7) = 20985.668$ W

4.4. Performance of the Experimental rig

Heat transfer of water coolant at 60°C and 5.3m/s air flow rate

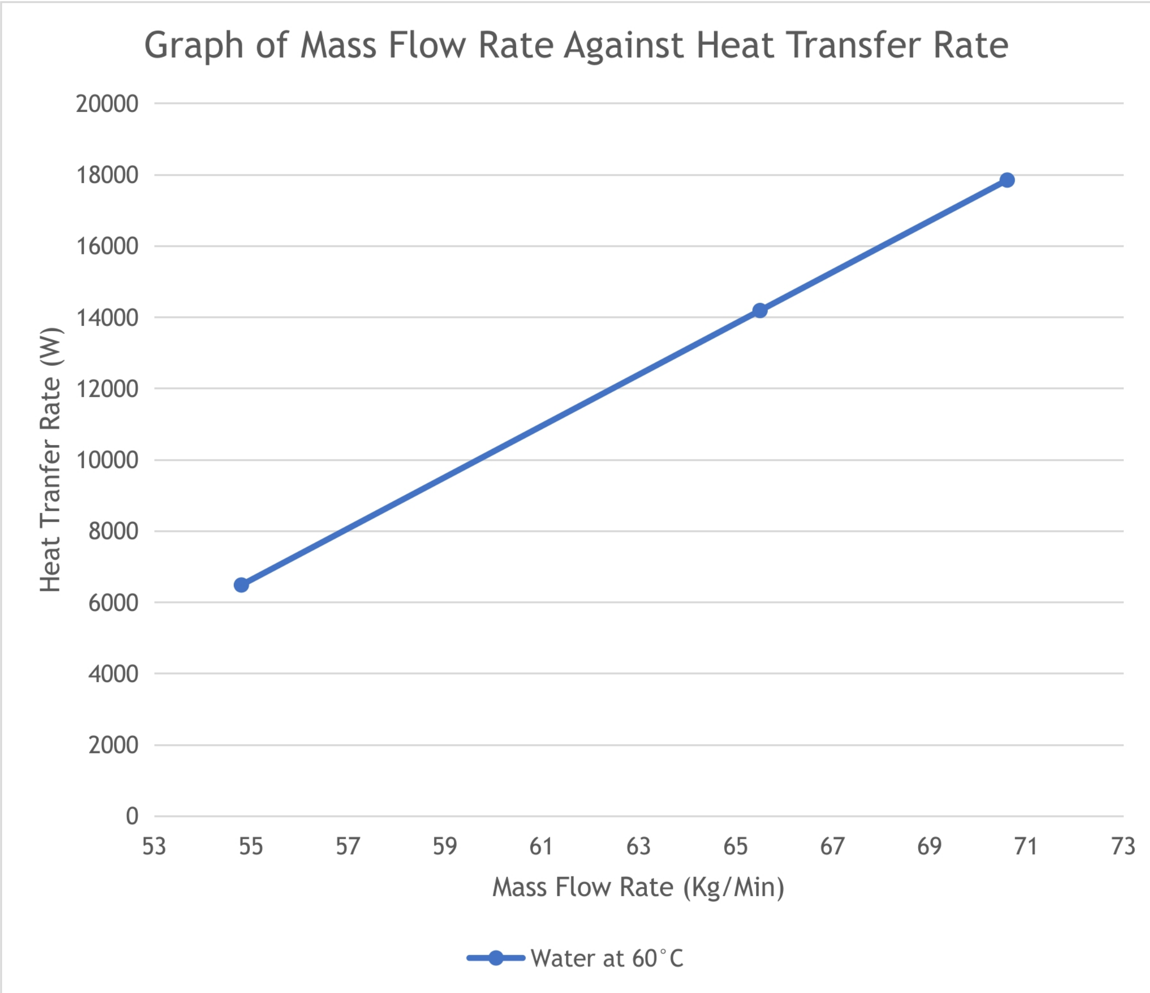

Figure 4. 1: Heat transfer rate on water

The graph shows the variation of heat transfer to the mass flow rate of mixture of water

Heat transfer rate for water and ethylene glycol (4.5% concentration) mixture coolant at 60°C and 5.3m/s air flow rate.

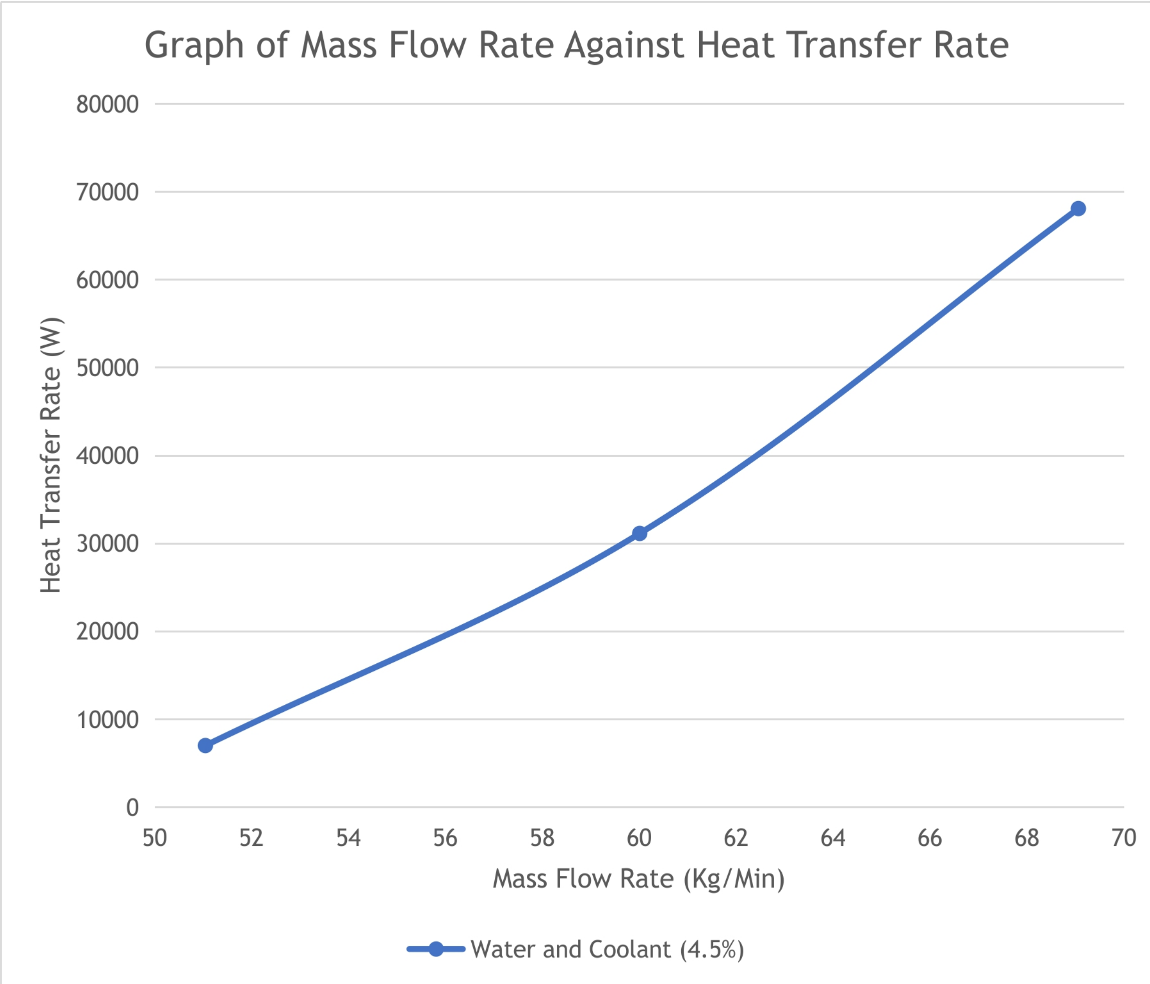

Figure 4. 2: Heat transfer using water and coolant (4.5% concentration) mixture

The graph shows the variation of heat transfer to the mass flow rate of mixture of wate and 4.5% concentration of coolant.

Heat transfer rate for water and ethylene glycol (10.07% concentration) mixture coolant at 60°C and 5.3m/s air flow rate

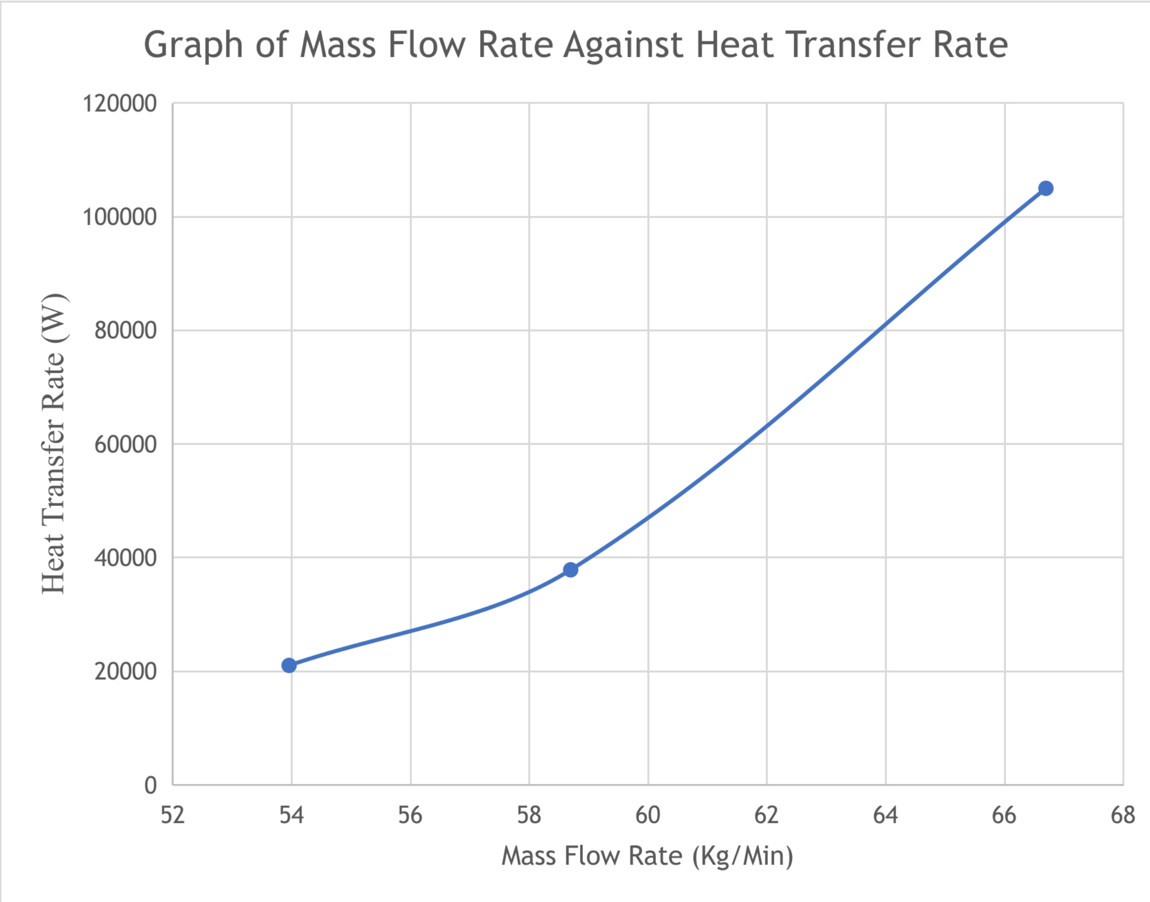

Figure 4. 3: Heat transfer rate using water and coolant (10.07% concentration)

The graph shows the variation of heat transfer to the mass flow rate of mixture of water and 10.07% concentration of coolant.

Heat Transfer for Different Coolants at Temperature 60°C at air velocity

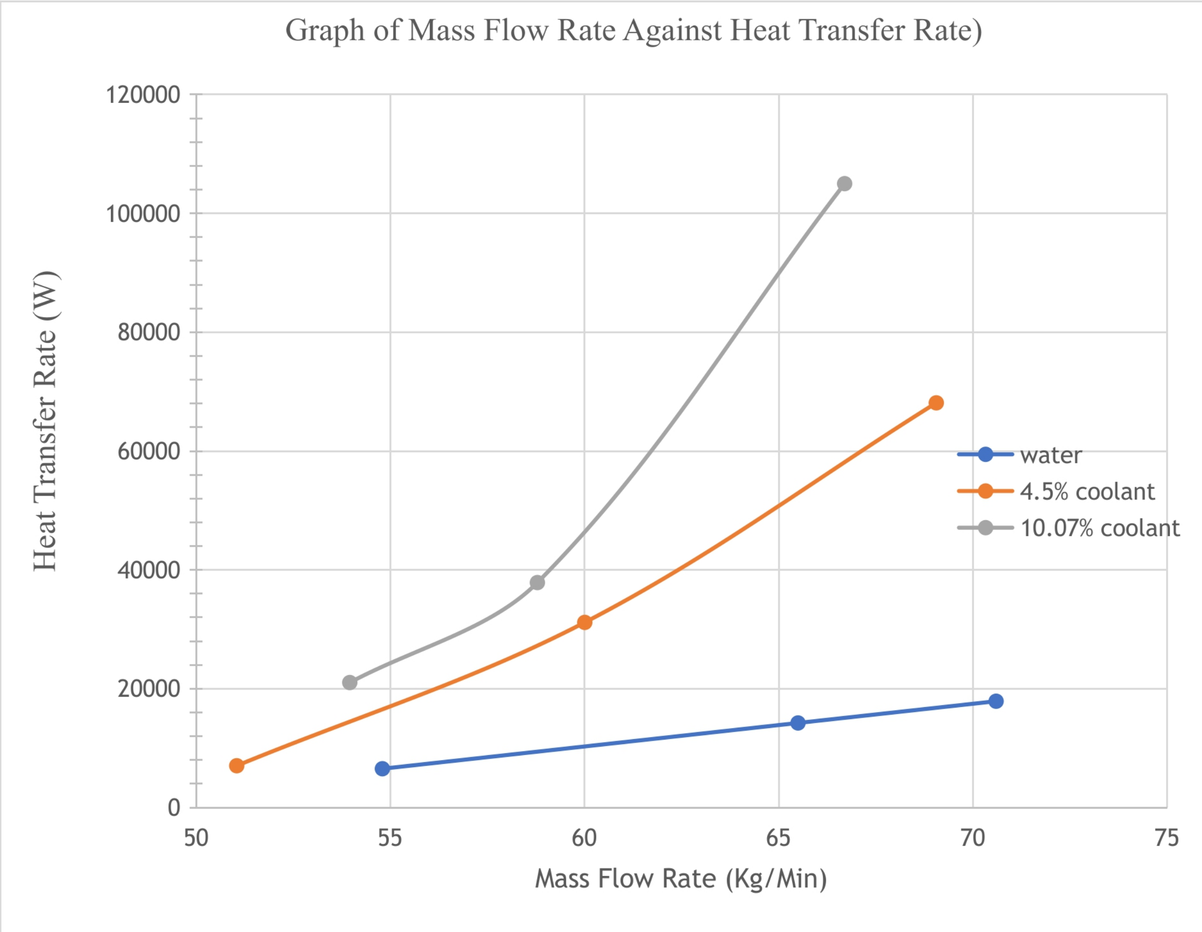

Figure 4. 4: Graph of heat transfer on different cooling fluids

Figure 4.4 shows the heat transfer of the different coolants, the graph shows that water, ethylene glycol (automobile coolant) (10.07% concentration) mixture coolant has the highest heat transfer rate. The water and coolant (ethylene glycol) (4.5% concentration) had the second best. Water had the lowest heat transfer rate. As the volume fraction of coolant(ethylene glycol) increased and compared to pure water and, the heat transfer rate and effectiveness were much higher.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The experimental rig has been demonstrated and has proved and proved to be able to get the readings of the thermal properties of the cooling fluid. An automobile cooling system are generally simple mechanisms in theory, yet the process from theory to manifestation is not as easy as it may seem. The automobile radiator cooling system is a marvelous cooling system which regulates the temperature of the engine at various conditions. The design has been adapted to a multitude of machines such as Industrial generators.

5.2. Recommendation

This project focused on a basic experimental automobile cooling system that makes it determine the analysis of the thermal properties of various coolants. The future advancement of the project may be:

i. To add a drainage to the tank to make it easier for changing the coolant.

ii. Addition of a control valve to regulate the flow rate.

In addition, more tests should be carried out, with a varieties of concentration of ethylene glycol and nano-fluids.

5.3. Contribution to knowledge

This study shows the workings and principles behind the radiator cooling system of an automobile cooling system. It also aids in the selection of cooling fluid in the market that will aid in the efficiency of the engine by checking the heat rate of the various cooling.

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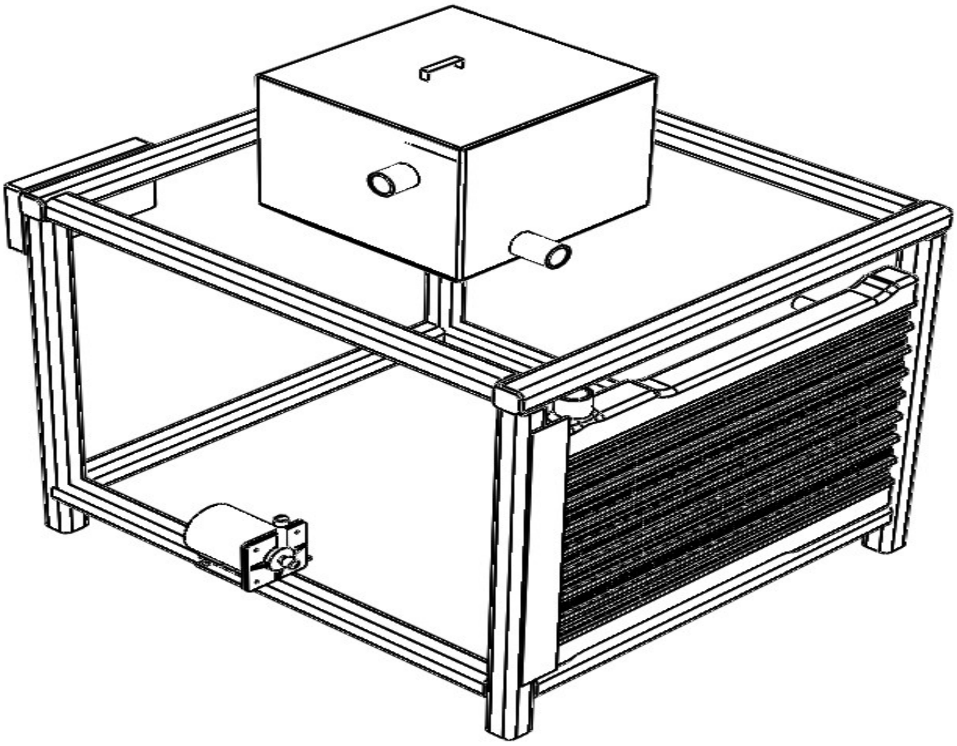
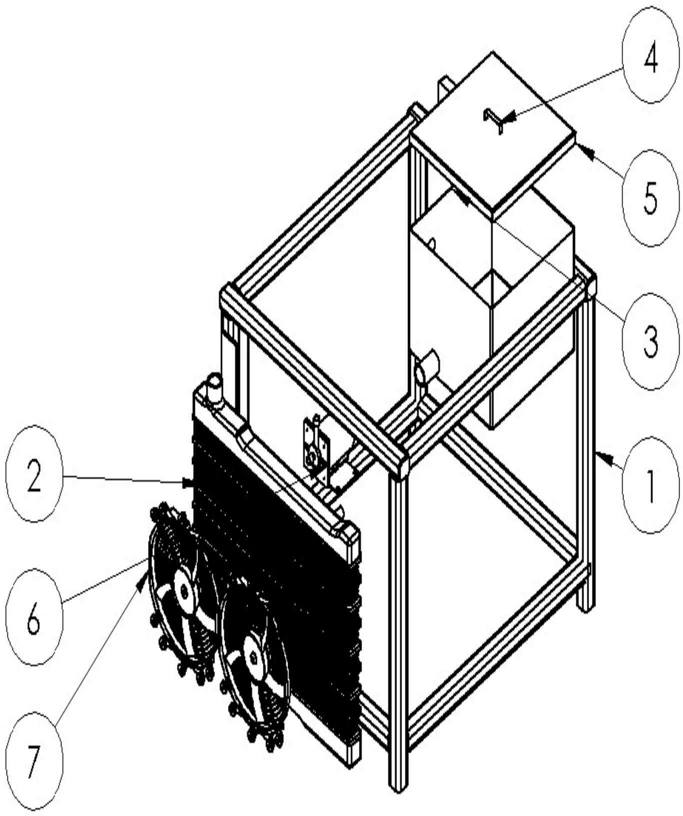
APPENDIX





ITEM NO.	Part	QTY.
1	frame	1
2	radiator_assembly	1
3	tank	1
4	control panel	1
5	tank cover	1
6	Water Pump	1
7	fan	2