FLUID FLOW CHARACTERISTIC IN CURVED TUBE HEAT EXCHANGER BY NUMERICAL METHOD

SYAZWAN BIN ZAINUDDIN

This thesis is submitted to Mechanical Engineering Faculty in partial fulfillment of the requirements for the award of Bachelor Degree in Mechanical Engineering (Thermal-Fluid)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

Dis 2012

DECLARATION

"I hereby declared that this report is a result of my own work except for the works that have been cited clearly in the references."

Signature : ……………………………………

Name : Syazwan Bin Zainuddin

Date : ……………………………………

Special dedicate to

My beloved mother Che Sariah Binti Ahmad

My father Zainuddin Bin Mohd Noor

My supervisor Dr. Mohd Yusoff Bin Sulaiman

ACKNOWLEDGEMENT

Assalamualaikum .. I give thanks to Allah swt for His blessings and grace, can I run the program and complete the *Projek Sarjana Muda II* report without hindrance and can solve everything very well when I was 15 weeks at the plant.

I am grateful and would like to express my sincere gratitude to my supervisor Dr. Mohd Yusof Bin Sulaiman for his genius ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct. I appreciate his consistent support from the first day I was start this project to these concluding moments. I am truly grateful for his commitment to this project. I also sincerely thanked him for the time spent proofreading and correcting my many mistakes. My sincere thanks also to my partner study and all friends who helped me for provided assistance at various in many ways throughout the project and his views and tips are useful indeed. My special thanks to my parent and family which is support me to achieve my goals and given me the strength to continue my studies up to this level.

ABSTRACT

Due to the enormous heat generated in the internal combustion engine of a motor vehicle, a cooling system must be included. For compact and aerodynamic cars design affect the air flow rate through the radiator and need the design of compact radiator. The radiator is device used to cool the engine. In any cooling system of a motor vehicle, a redesigned the radiator can give the better performance. This report examines fluid flow characteristics in curved tubes heat exchanger by numerical method. This project will investigate the result for the curved tube radiator and compare to result from existing radiator. The method of this study for the collecting data and analyze by numerical method. By using the Computational Fluid Dynamic (CFD) software the modeling of fluid flow in tube was developed for computation simulation. Aided by the developed software, the characteristic of fluid flow will be investigated. Besides that, this study will be carried out by using experimental data for evaluating the working performance of different types of radiator. Therefore, performance data of automotive radiator were acquired and analyzed to improve available radiator performance.

Performance data of curved tube radiator such as velocity, mass flow rate, pressure, temperature, air flow rate were acquired to find out the effect of the operating parameter to radiator performance. The heat dissipation rate of the radiator increased as air flow rate and surface tube are increase. Meanwhile, the expected result for the performance of a curved tube radiator associates with more heat dissipation and compact design and can be used in automotive cooling in the future.

ABSTRAK

Oleh kerana haba yang besar terhasil di dalam enjin pembakaran dalaman kenderaan motor, sistem penyejukan harus disertakan. Bagi reka bentuk kereta kompak dan aerodinamik mempengaruhi kadar aliran udara melalui radiator dan memerlukan reka bentuk radiator padat. Radiator adalah alat yang digunakan untuk menyejukkan enjin. Dalam mana-mana sistem penyejukan kenderaan bermotor, direka semula radiator boleh memberikan prestasi yang lebih baik. Laporan ini mengkaji ciri-ciri aliran cecair dalam tiub melengkung penukar haba dengan kaedah berangka. Projek ini akan mengkaji hasil untuk radiator tiub melengkung dan membandingkan hasil dari radiator yang sedia ada. Kaedah kajian ini untuk mengumpul data dan menganalisis dengan kaedah berangka. Dengan menggunakan Bendalir Komputeran Dynamic (CFD) perisian model aliran bendalir dalam tiub telah dibangunkan untuk simulasi pengiraan. Dibantu oleh perisian yang dibangunkan, ciri-ciri aliran bendalir akan disiasat. Selain itu, kajian ini akan dijalankan dengan menggunakan data eksperimen untuk menilai prestasi kerja jenis radiator. Oleh itu, data prestasi radiator automotif telah diperolehi dan dianalisis untuk meningkatkan prestasi radiator ada.

Data prestasi radiator tiub melengkung seperti halaju, kadar aliran jisim, tekanan, suhu, kadar aliran udara telah diperolehi untuk mengetahui kesan parameter operasi untuk prestasi radiator. Kadar pelesapan haba radiator meningkat kadar aliran udara dan permukaan tiub adalah peningkatan. Sementara itu, hasil yang dijangka bagi pelaksanaan yang melengkung rakan radiator tiub dengan pelesapan haba yang lebih banyak dan reka bentuk yang kompak dan boleh digunakan dalam penyejukan automotif di masa hadapan.

CONTENTS

LIST OF FIGURE

CHAPTER I

INTRODUCTION

1.1 Background

The vehicle needs to have a radiator in order to dissipate the excessive heat produced by the combustion of fuel inside the engine’s cylinders. In order to fit into the car hood, have a compact size and design but still capable of transferring massive amount of heat energy from the engine to the surrounding air without the engine being overheated. This problem in automotive industry requires the innovative solutions. One innovative solution is redesigned the rectangular radiator with the circular radiator design. The circular radiator design to enhance the greater heat transfer with reduces the costing and more efficiency. The data to be gathered in this research may provide the better characteristic of performance between the existing radiators. The research reported in this project aims to the work is conducted using numerical method by Computational Fluid Dynamic (CFD) Software to models supported by validation studies. By using CFD to study complex fluid flows, the project demonstrates the capabilities of CFD in modeling such flows and the potentials it offers in this area of research, while also highlighting some of its current limitations. It also highlights the need for further research in areas where information is lacking. (Versteeg and Malalasekera, 1996) state the Computational Fluid Dynamics (CFD) is the use of computer-based simulation to analyze systems involving fluid flow, heat transfer and associated phenomena such as chemical reaction a numerical model is first constructed using a set of mathematical equations that describe the flow. These equations are then solved using a computer programmer in order to obtain the flow variables throughout the flow domain. Since the advent of the digital computer, CFD has received extensive attention and has been widely used to study various aspects of fluid dynamics. The development and application of CFD have undergone considerable growth, and as a result it has become a powerful tool in the design and analysis of engineering and other processes. In the early 1980s, computers became sufficiently powerful for general-purpose CFD software to become available.

1.2 Problem Statement

Optimize the design of the existing car radiator to radiator rounded design requires a more detailed analysis of fluid flow in the tube, cooling capacity, heat transfer rate, size, air flow, pressure, and cost.

a. The heat transfer rate must be higher than the existing radiator. At the same time can drain the radiator fan air through all the tubes.
b. Ensure the size of the smaller circular radiator for space saving in the front of the engine in the car.
c. This study aims to study and analyze the characteristic flow in circular tube heat exchanger.

1.3 Objective of the Study

The objectives of this study are:

i. To investigate the characteristic fluid flow in curved tube radiator by using the Computational Fluid Dynamic (CFD) software.
ii. The numerical results are to be compared with experimental observations of automotive radiator. The experimental data are to be correlated with the numerical parameter of temperature, pressure, and velocity and dimensional.
iii. The characteristic parameters the curved tube radiators are to be determined.

1.4 Scope of the Study

From of this project, the experimental study has been carried out for performance radiator tests by two different type of radiator which square and circular radiator. The scopes of this study are:

i. By using the transparent plastic tubes, metal tubes, conduct flow measurements using laboratory equipment.
ii. Also, design the suitable configuration of the typical automotive radiator. Involve the Computational Fluid Dynamic (CFD) software to conduct the numerical modeling.

CHAPTER II

LITERITURE REVIEW

2.1 INTRODUCTION

Ng EY et al described that the high complexity of vehicle front end design, arising from consideration of aerodynamics, and compact, cause the air flow velocity profile at the radiator face to be highly distorted, leading to potentially reduce airflow volume for heat dissipation (figure 1). Consequently, the heat transfer area of radiator may be poorly utilized. It is emphasized that the radiator cooling air flow plays a key role in the heat transfer process, since the overall heat transfer coefficient of a radiator is predominantly influenced by the air-side heat transfer coefficient. Therefore the several factor that make measurement the air flow very difficult. The factors are the compactness of engine compartment. Next, the air velocity, pressure and temperature field in engine compartment is complexity. Also, the laminar flow of air flow velocity through the radiator.

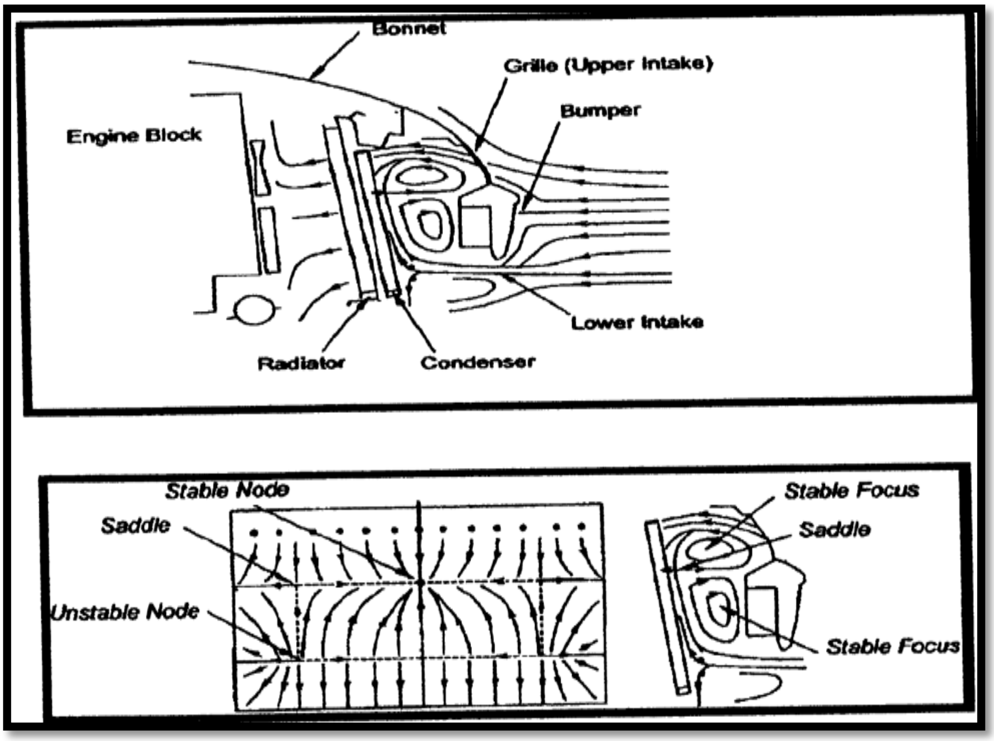

Figure 2.1: under hood air flow profile in typical passenger car (reprint from NG).

From the figure 2.1, observation that air flow shown the non-uniform distributed over the radiator.

Maddiptla, Sridhar, Guessous, Laila describe that the radiator quadrangular use, but ventilation fan only in the circle. Cause the edges radiator low velocity airflow. Velocity of air generated by the fan is not constant along its axial direction. It is found to be almost zero at the centre and gradually increases at the rate of square of the radius towards the periphery

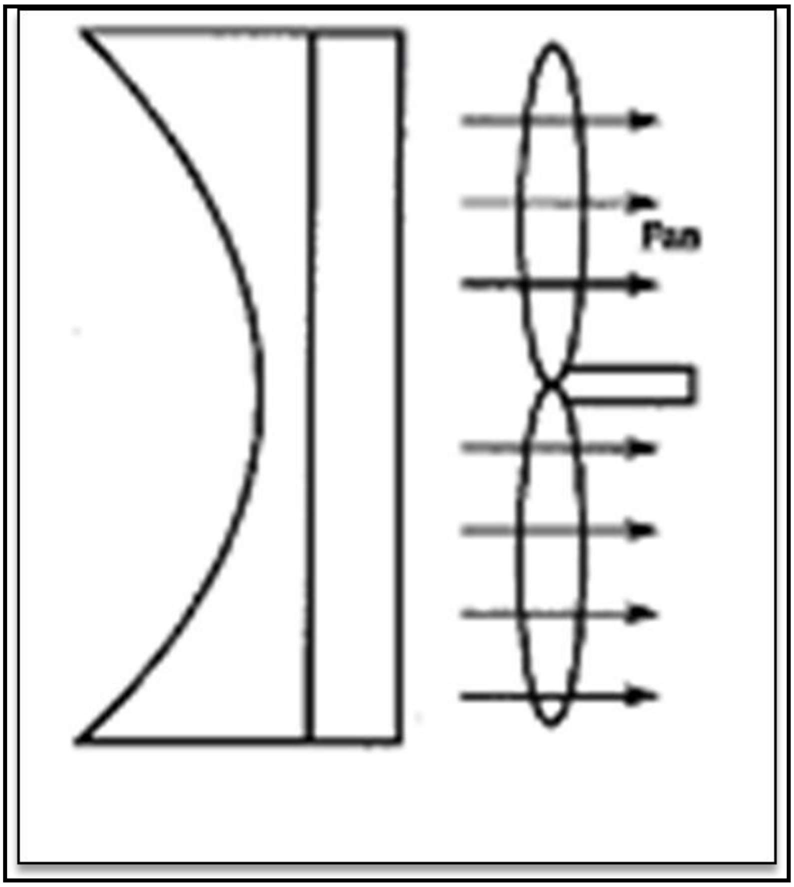

Figure 2.2: Velocity profile of an air-cooled heat exchanger using a fan.

Khovakh et al, (1977) state, the cooling system is one of the major motor vehicle engine systems that helps ensure the temperature of the engine is kept within the limits imposed for safety and efficiency. The cooling agent customarily employed is air or liquid thus they are air or liquid (water) cooling systems. For effective control of heat in a water cooling system, a "Heat Exchanger" is employed.

Alamu et al, (2003); Banga and Singh, (1987); and Rogers and Mayhew, (1992) state that a device that transfers heat from a region of higher temperature to lower temperature through fluid separated by a solid It is labeled various names depending on the particular purpose it serves, thus the name boiler, evaporator, condenser, or radiator are often employed. Among the factors that determine the efficiency of water-cooling system is the fan blade diameter and depth of the radiator.

Bent and Stephens, (1974) and Dolan, (1996) describe the existing literature that the fan contains shrouds and blades, which drawn in air through the radiator thereby reducing the temperature of the water.

Lateef et al, (2004) state the fan increases air flow allowing the use of a smaller radiator, which can dissipate the required amount of heat. The radiator on the other hand, is a vessel that receives and stores heated water from the engine and exposes it to the fan. The matrix of the radiator may be either tube-and-fin type (Figure 1) or film (cellular) type.

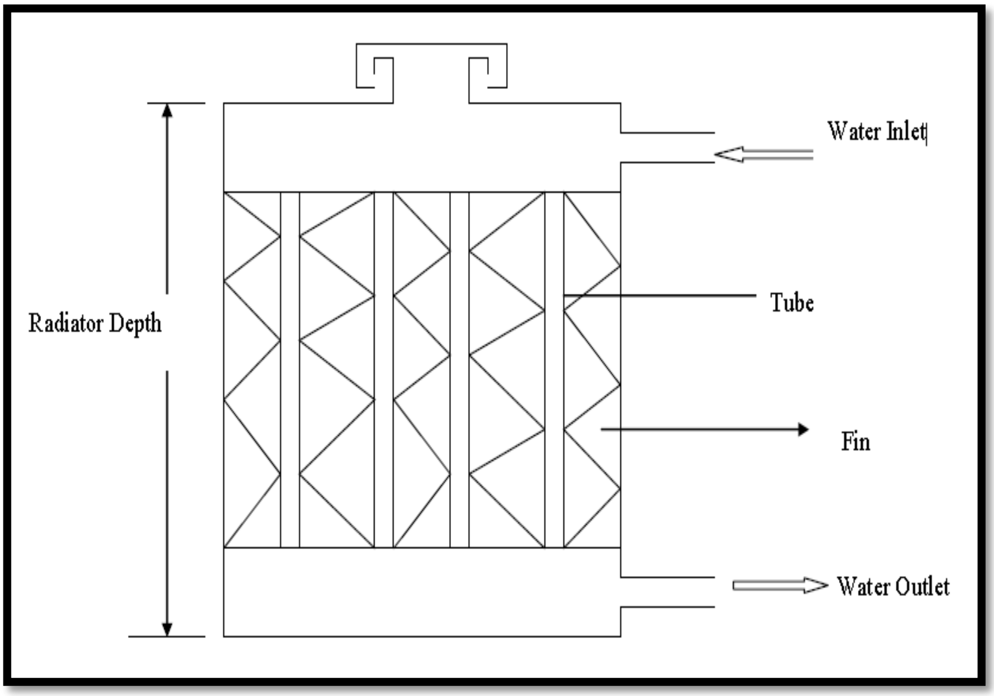

Figure 2.3: Tube and fin radiator.

A. Witry et al state that for the internal flow, heat transfer augmentation caused by the repetitive impingement against the dimple obstructions renders such as geometries equal to those of aerospace industry pin-fin whilst lowering pressure drops due to the wider cross-sectional areas. For the internal flow, the wider and wavy nature of the surface area increase heat transfer leaving the addition of extra surface roughness add-ons as option.

2.1 Engine Cooling System

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 1000°F. In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. It has been stated that a typical average-sized vehicle can generate enough heat to keep a 5-room house comfortably warm during zero degree weather (and not talking about using the exhaust pipe).

Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3 must be removed from the engine by the cooling system. Modern automotive engines have basically dumped the Air Cooled System for the more effective Liquid Cooled System to handle the job. In a liquid cooled system, heat is carried away by the use of a heat absorbing coolant that circulates through the engine, especially around the combustion chamber in the cylinder head area of the engine block.

The coolant is pumped through the engine, then after absorbing the heat of combustion is circulated to the radiator where the heat is transferred to the atmosphere. The cooled liquid is then transferred back into the engine to repeat the process. Excessive cooling system capacity can also be harmful, and may affect engine life and performance. Therefore, must to understand that coolant temperatures also affect oil temperatures and more engine wear occurs when the engine oil is below 190°F. An effective cooling system controls the engine temperature within a specific range so that the engine stays within peak performance.

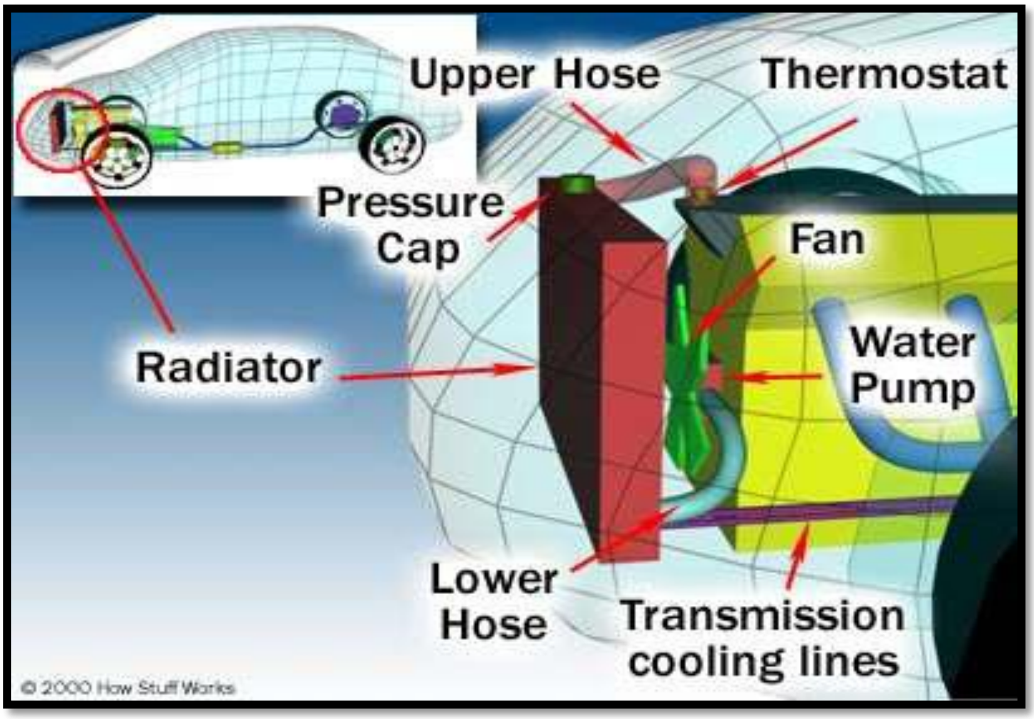

Figure 2.4: Engine cooling system.

This engine is cooled by a pressurized water forced circulation cooling system equipped with a thermostatically controlled by pass valve mounted on the inlet side. This engine is cooled by a pressurized water forced circulation cooling system equipped with a thermostatically controlled by pass valve mounted on the inlet side. The operation of cooling system is composed of the water jacket (inside the cylinder block and cylinder head), radiator, water pump, and thermostat, cooling fan, fluid coupling, hoses and other components.

Engine coolant, which has been heated in the water jacket, is drawn into the radiator by the water pump. The radiator is cooled by air drawn in by the cooling fan and by the air flow from the vehicle's forward motion. This in turn cools the coolant in the radiator. The coolant is then drawn into the water pump and then discharged back to the cylinder block. The water jacket is a network of channels in the outer area of the cylinder block and cylinder head. It is designed so that the engine coolant flowing through it can provide adequate cooling to the areas subjected to the highest thermal stresses, in particular, the cylinders and combustion chambers, during engine operation.

The radiator, mounted at the front of vehicle, consists of an upper and lower tank and a core connecting the two tanks. The core contains many tubes through which engine coolant flows from the upper tank to the lower tank. Air passing over the radiator fins cools the heated engine coolant flowing through the radiator. The upper tank has an inlet for engine coolant from the water jacket and it has a filler inlet. It also has a hose attached through which excess engine coolant or steam can flow. The lower tank has an outlet for the engine coolant and a drain cock. Automatic transmission models include an automatic transmission fluid cooler.

The radiator cap is a pressure type cap which seals the radiator, resulting in pressurization of the radiator as the coolant expands. The pressurization prevents the engine coolant from boiling even when the engine coolant temperature exceeds 100°C (212°F). A relief valve (pressurization valve) and a vacuum valve (negative pressure valve) are built into the radiator cap. The relief valve opens and lets steam escape out of the overflow pipe when the pressure generated in the cooling system exceeds the limit (engine coolant temperature: 110 –120°C (230 – 248°F), pressure: 58.8 – 103.0 kPa, 0.6 – 1.05 kgf/cm^2, 8.5 – 14.9 psi). The vacuum valve opens to allow engine coolant to enter in order to alleviate the vacuum which develops in the engine coolant system after the engine has stopped and the engine coolant temperature drops.

The reservoir tank is used to catch engine coolant which–overflows the cooling system as a result of volumetric expansion when the engine coolant is heated. When the engine coolant temperature drops, engine coolant in the reservoir tank returns to the radiator, thus keeping the radiator full at all times and avoiding needless engine coolant loss. To find out if the engine coolant needs to be replenished, check the reservoir tank level.

The water pump is used for forced circulation of engine coolant through the cooling system. It is mounted on the front of the engine block and driven by the timing belt.

The thermostat has a wax type by–pass valve and is mounted in the water inlet housing. The thermostat includes a type of automatic valve operated by fluctuations in the engine coolant temperature. When the engine coolant temperature is low, the valve closes to prevent the engine coolant flowing to the radiator, thus permitting the engine to warm up rapidly. When the bypass valve opens the by–pass circuit, the engine coolant continues to circulate inside the engine, quickly and uniformly warming up to the operating temperature. When the engine coolant temperature is high, the valve opens and the engine coolant flows to the radiator where it is cooled. When the wax inside the thermostat is heated, it expands and thus creates pressure which overpowers the force of the spring which keeps the valve closed. When the wax cools, its contraction allows the force of the spring to take effect once more, closing the valve. The thermostat in this engine operates at a temperature of 82°C (180°F).

2.2 Cooling System Function

Randy Rundle, (1999) state that temperatures in the combustion chamber of the engine can reach 4,500°F (2,500°C), so cooling the area around the cylinders is critical. Areas around the exhaust valves are especially crucial, and almost all of the space inside the cylinder head around the valves that is not needed for structure is filled with coolant. If the engine goes without cooling, the metal got hot enough for the piston to weld itself to the cylinder. This usually means the complete destruction of the engine. The cooling system removes enough heat to keep the engine at a safe temperature for best performance. A secondary function of the cooling system is to provide interior cabin heat during cold winter.

2.3 Type of Cooling System

2.3.1 Air Cooling

Some older cars, motorcycle and very few modern cars are air-cooled. Instead of circulating fluid through the engine, the engine block is covered in aluminum fins that conduct the heat away from the cylinder. A powerful fan forces air over these fins, which cools the engine by transferring the heat to the air. Since most cars are liquid-cooled, we will focus on that system in this project.

2.3.2 Liquid Cooling System

Figure 3 illustrates the cooling system components, and in these sections we'll talk about each part of the system in more detail. Figure 4 illustrates the liquid cycle in the system.

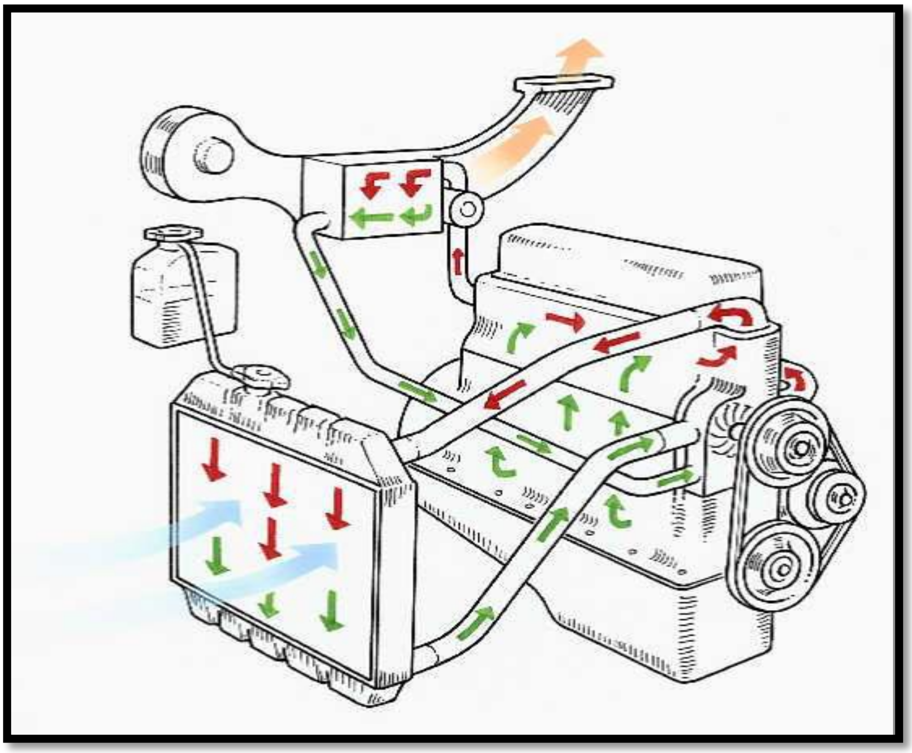

Figure 2.5: Liquid cycle in cooling system.

2.4 Working of Radiator

Tenkel F. G. describes about the pump sends the fluid into the engine block, where it makes its way through passages in the engine around the cylinders. Then it returns through the cylinder head of the engine. The thermostat is located where the fluid leaves the engine. The plumbing around the thermostat sends the fluid back to the pump directly if the thermostat is closed. If it is open, the fluid goes through the radiator first and then back to the pump.

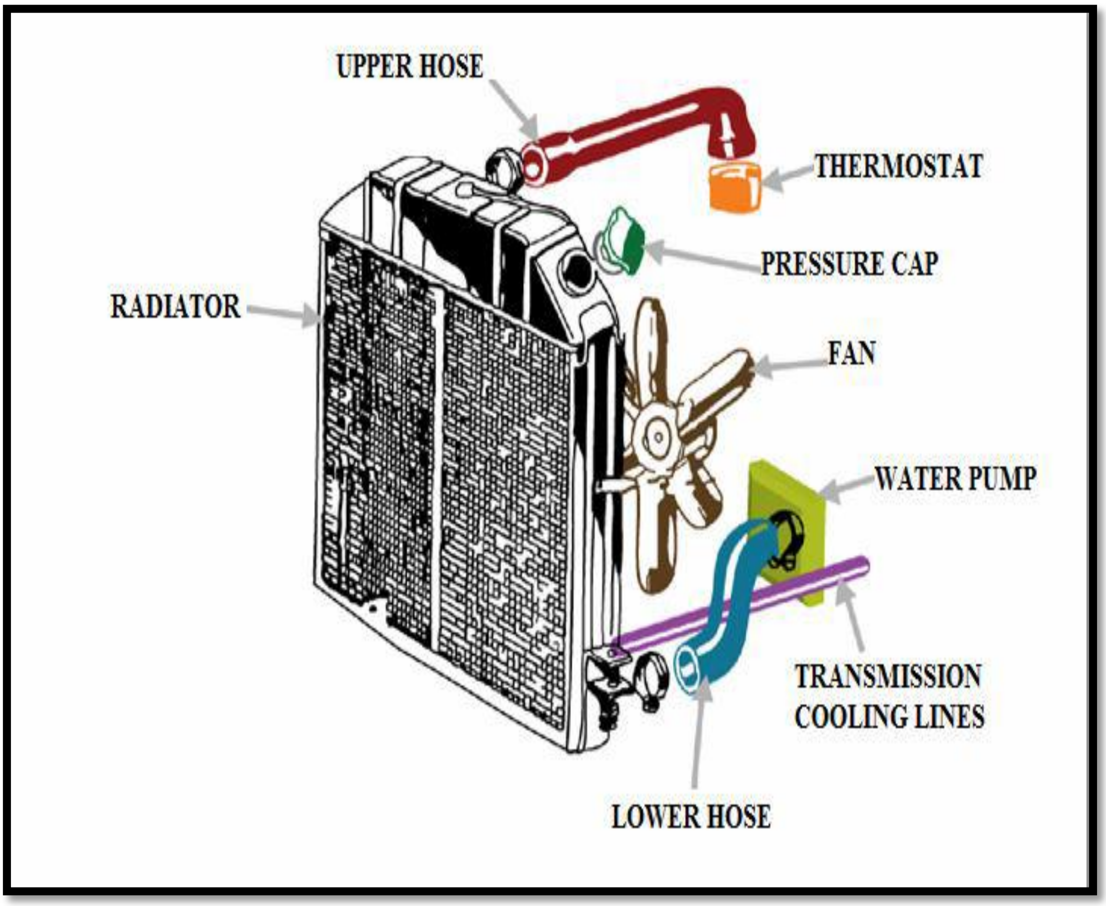

Figure 2.6: Parts of cooling system.

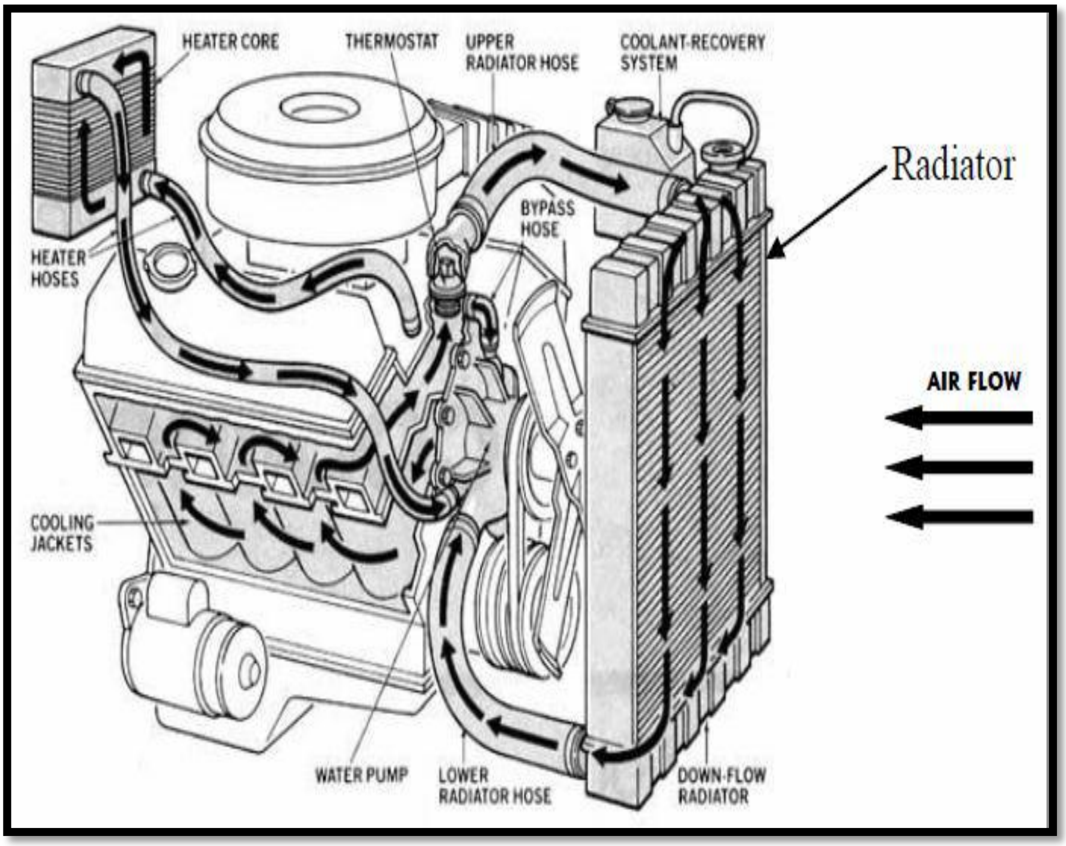

Figure 2.7: Working of radiator.

There is also a separate circuit for the heating system. This circuit takes fluid from the cylinder head and passes it through a heater core and then back to the pump. On cars with automatic transmissions, there is normally also a separate circuit for cooling the transmission fluid built into the radiator. The oil from the transmission is pumped by the transmission through a second heat exchanger inside the radiator.

2.5 Theory of Radiator

A radiator is a type of heat exchanger. It is designed to transfer heat from the hot flows through it to the air blown through it by the fan. Most modern cars use aluminum radiators. These radiators are made by brazing thin aluminum fins to flattened aluminum tubes. The coolant flows from the inlet to the outlet through many tubes mount in a parallel arrangement. The fins conduct the heat from the tubes