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Analysis of Heat Dissipation in Radiator of SI Engine

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Abstract - *In an automobile, fuel and air produce power within the engine through combustion. Only a portion of the total generated power actually supplies the automobile with power the rest is wasted in the form of exhaust and heat. If this waste heat is not removed , the engine will become more hot, that results in overheating and viscosity breakdown of the lubricating oil, metal weakening of the overheated engine parts, and stress between engine parts resulting in quick wear of piston rings, connecting rod etc.*

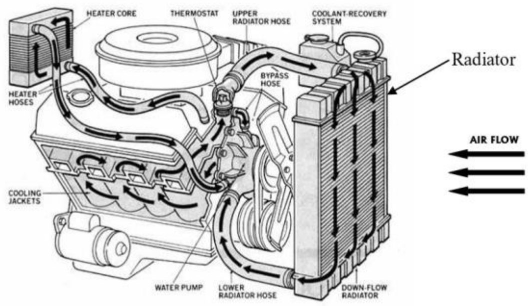
In the present work quick evaluation approach to internal combustion engine's radiator cooling system analysis is presented. Calculation and analysis of engine cooling parameters such as fluid flow rate, effective cooling surface area, coolant passage tubes and rate of heat dissipation when the density and specific heat at constant pressure vary due to changing temperature. The performance and efficiency of water cooling machine applied in automobiles relies on effective heat exchange between surrounding medium. Efficiency of radiator is increased by varying the geometrical parameters like diameter of tubes, by varying coolants, by comparing the materials. We are going to design a radiator and perform CFD analysis, compare CFD analysis and experimental analysis

***Key Words*: Cooling system, Engine Cooling, Heat lost in Radiator, water properties.**

I. INTRODUCTION

Radiators also called as heat exchangers designed to cool the engine with the help of a coolant. The majority of radiators are made for engine cooling in automobiles. In radiator there are two types of process happening one is natural and the other is forced convection .Convection means having a contact between solid and the medium flowing. Depending on application we choose our radiator process. Radiators are used to transfer thermal energy from one medium to another for the purpose of cooling engine. Despite the name, most radiators transfer the bulk of their heat via convection instead of thermal radiation.

In automobile due to combustion process power is developed, only some amount of power is used for moving a vehicle but remaining power is wasted for the process of removal of exhaust gases and for the pumping etc. due to the combustion process maximum amount of temperature is developed, if the excess heat is developed there will be damage to engine components. For the proper lubrication of the engine parts oil should flow freely at the right viscosity and temperature. These high temperatures produced in the cylinders are transferred through the cylinder wall liners, cylinder heads, pistons and valves to the coolant by convection, in discussing such high temperatures exposing engine metal parts to such high temperatures will cause them to expand considerably, weaken them, result in high thermal stresses with reduced strength, safety concerns in overheated cylinders attaining flash temperature of the fuel thereby likely leading to resignation, cause lubricating oils to evaporate rapidly leading to sticking pistons, piston rings, cylinders and eventual seizure and damage. So we need to have a radiator in order to remove excess heating. Mostly for cooling of engine component involved are radiator, thermostat, electric cooling fan, water pump, pressure cap, jackets, and hoses for connection radiator to engine. Function of pressure cap is to whenever there is a more amount of pressure difference water will not go down, in order to prevent this pressure cap is used, electric fan for taking of air, water pump for circulation of water, thermostat for detection of temperature of coolant and give passage, radiator is for cooling of coolant coming from engine and the engine temperature is taken by coolant.



Most commonly made out of aluminum, automobile radiators utilize a cross-flow heat exchanger design. The

two working fluids are generally air and coolant (50-50 mix of water and ethylene glycol). As the air flows through the radiator, the heat is transferred from the coolant to the air. The purpose of the air is to remove heat from the coolant, which causes the coolant to exit the radiator at a lower temperature than it entered at the engine.
Considering the various types of radiator present, out of that we are representing cross flow heat exchanger because of considering it in race car.

1. Heat exchanger:-

Heat exchanger is a device for transfer of heat from one fluid to another fluid without mixing them. The exchange of heat may be gas to gas or liquid to liquid etc. e.g. in a car radiator heat exchange takes place between air and water flowing through radiator tube in a steam condenser heat exchanger takes place between steam and water. In diesel engine oil cooler the exchange of heat is between lubricating oil and water in an air free heater used in steam power plant, heat exchange is between hot flue gases and cool air .in all these devices the purpose is to either effectively recover the heat energy in the hot fluids as in the air free heater or cooling it to desired extent as in the car radiator .this can be achieved by providing effective heat between two fluids.

2.1 Classification of heat exchangers:

The heat exchangers are classified based on the types of fluid, the number of fluids and the heat transfer rate. Some of the major types of heat exchangers and their construction features are explained briefly.

2.1.1 Tubular heat exchanger:

A shell and tube heat exchanger consists of a number of circular tubes parallel to that of a shell. The important features of a shell and tube heat exchanger, in this, the tube fluid passes only once and shell fluid passes through the shell. One shell tube pass in which the tube fluid passes twice through the smell.in some cases tubes are kept one in another concentrically such that one fluid passes through the inner tube and the other fluid passes through the annular space between the tubes. This is known as parallel flow and if the fluids pass opposite to one another bit is known as counter flow

2.1.2 Plate Type Heat Exchanger:

In plate type heat exchanger as the name implies it is made up of two plates and the hot and cold fluids pass through either side of a plate exchanging heat through it. In some cases the plates are made in the form of corrugated sheets through which the fluid passes. Parallel flow, counter flow and cross flow arrangements are possible. In some other types the plates are fixed with number of fins to enhance the rate of heat transfer.

2.1.3 Tube Type Heat Exchanger:

For heat exchange between a gas and other fluid these kinds of tube heat exchangers are most useful. Like in car radiators, evaporators and condensers of small refrigeration systems etc. either round tubes or tubes with fins on their surface are used. These kinds of heat exchangers are known as cross flow radiators. The flow of fluid through the tubes is unmixed whereas the flow of fluid over the tube is considered as mixed one. The flow of two fluids acts in two perpendicular planes.

2.1.4 Regenerative Type Heat Exchanger:

A porous medium generally of metal balls, pebbles, powder etc. called bed or matrix through which hot and cold fluids are passed alternatively. Thus during the flow of hot fluid bed absorbs heat and when cold fluid is passed the heat is transferred from the bed to fluid. During rotation the bed periodically passes through hot stream and then through the cold stream. However, this kind of rotary regenerators are useful for gas-to-gas exchange and not useful for liquid since the heat capacity of the bed is less for liquids. However, most of the heat exchangers can be brought under a common classification i.e., parallel flow, counter flow and cross flow heat exchangers.

2.1.5 Compact Heat Exchanger:

When the surface area to volume ratio of a heat exchanger is greater than 750m^2/m^3 then the exchanger is known as compact heat exchanger. Generally, when one of the fluids is gas and having small heat transfer coefficient it requires large surface area and a compact heat exchanger is best suitable. In the case of compact heat exchangers the pressure drop of fluid is high and is of important consideration. In many cases the heat transfer characteristics and friction factor of such configurations are found experimentally. Several Researchers have done extensive work on compact heat exchangers and developed charts to obtain heat transfer and friction factors, for a specified matrix and Reynolds number. Thus the value of U for a compact heat exchanger can be obtained from these charts and applying either LMTD or NTU method we can estimate the rate of heat transfer and its size requirements etc.

Depending on the engine cooling systems are classified into various types.

2. ***Types of Cooling System***

- *Air Cooling or direct cooling system*
  - *Aviation engines, motor cycles engines*
- *Liquid Cooling or indirect cooling*
  - *Automobile engines*

3.1 Air Cooling system:

- *Air cooled engines depend on airflow across their external surfaces of the engine cylinders to remove the necessary heat.*

The amount of heat dissipation depends up on:

- *The area of cooling surface in contact with the air*
- *Mass flow rate of air*
- *Temperature difference between the cylinder and air.*
- *Conductivity of metal*

3.1.1 Cooling fins in air cooled system:

- *Area of the cooling surface is increased by forming fins, either integrally by machining them on the outer walls of the engine cylinder and cylinder head or by attaching separate fins to them*

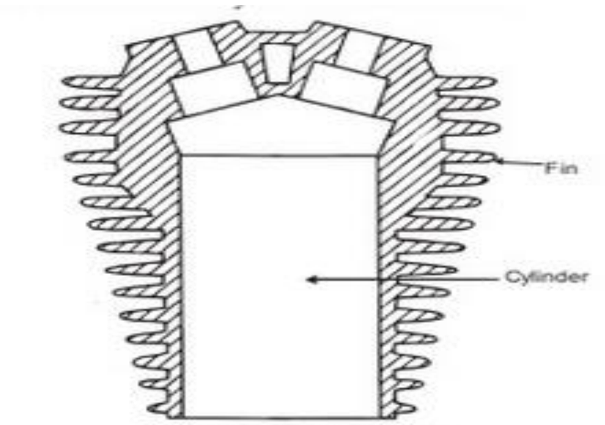


Figure 5.1 : Cylinder with Fins

Advantages of Air cooling system:

- *Absence of radiator, cooling jackets and pumps make engine lighter.*
- *The engine can be operated in cold climate where liquid may freeze.*
- *In places where water is scarce, air cooled engine is an advantage.*
- *Handling of liquid and pumping auxiliaries are eliminated.*
- *Air cooled engines have no coolant leakage or freezing problems.*

Disadvantages of Air Cooling:

- *Engines give low power output.*
- *Cooling fins under certain contain may vibrate and amplify the noise level.*
- *Cooling is not uniform.*
- *Engines are subjected to high working temperature.*

3.2 Water Cooling System:

- *The cooling system is made up of the passages inside the engine block and heads.*
- *Water pump to circulate the coolant.*
- *Thermostat to control the temperature of the coolant.*
- *Radiator to cool the coolant.*
- *Radiator cap to control the pressure in the system.*
- *Some plumbing consisting of interconnecting hoses to transfer the coolant from the engine to radiator and also to the car's heater system where hot coolant is used to warm up the vehicle's interior on a cold day.*
- *A cooling system works by sending a liquid coolant through passages in the engine block and heads.*
- *As the coolant flows through these passages, it picks up heat from the engine.*
- *The heated fluid then makes its way through a rubber hose to the radiator in the front of the car.*
- *As it flows through the thin tubes in the radiator, the hot liquid is cooled by the air stream entering the engine compartment from the grill in front of the car.*
- *Once the fluid is cooled, it returns to the engine to absorb more heat.*
- *The water pump has the job of keeping the fluid moving through this system of plumbing and hidden passages.*
- *A thermostat is placed between the engine and the radiator to make sure that the coolant stays above a certain preset temperature.*
- *If the coolant temperature falls below this temperature, the thermostat blocks the coolant flow to the radiator, forcing the fluid instead through a bypass directly back to the engine.*
- *The coolant will continue to circulate like this until it reaches the design temperature, at which point, the thermostat will open a valve and allow the coolant back through the radiator.*

Types of Water Cooling Systems:

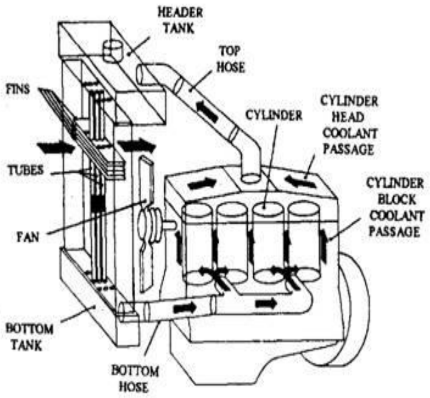
There are two systems of water cooling

- *Thermo-syphon cooling system*

- *Pump circulation system*

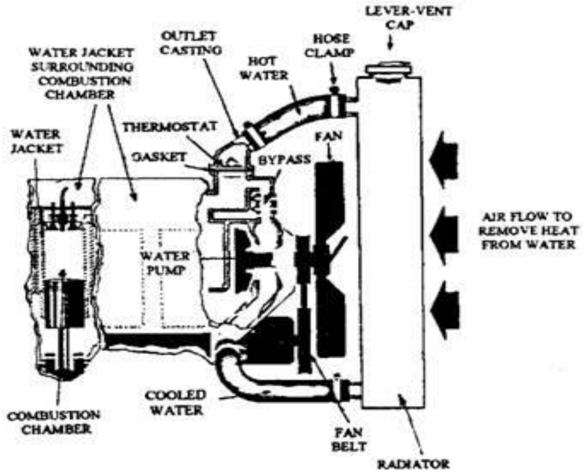
3.2.1 Thermo-syphon System:

- *In this type of cooling system, the circulation of water is obtained due to the differences in densities of hot and cold regions of the cooling water.*
- *This variations in density sets up convection currents so that circulation of water.*
- *There is no need of pump to circulate the water.*
- *The hot water from the engine jacket being lighter rises up in the horse pipe and goes in the radiator from the top side.*
- *It is cooled there and hence goes down at the bottom side of the radiator, from where it goes again in the engine jackets.*
- *The system is quite simple and cheap, but cooling is rather slow.*
- *To maintain the continuity of the water flow the water must be maintained up to a certain level.*
- *If the water level falls down, the circulation will discontinue and the cooling system fails.*



3.2.2 Pump Circulation System:

- *In this system of cooling the circulation of water is obtained by the pump.*
- *The pump is driven by the means of a belt from the pulley on the engine crankshaft.*
- *This system is more effective.*
- *The circulation of water becomes faster as the engine speed increases.*
- *There is no necessity of maintaining the water up to a correct level.*



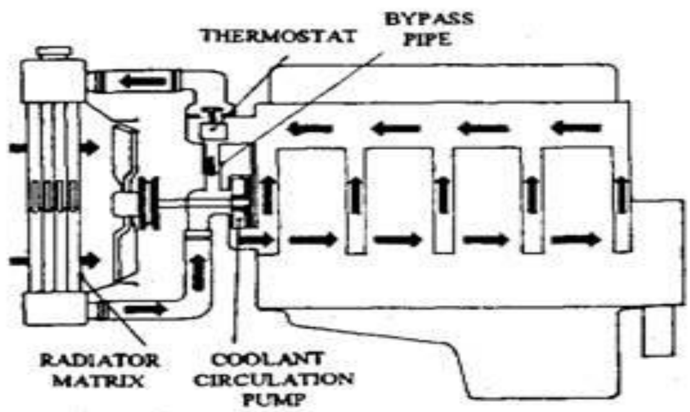
Advantages of Water Cooling System:

- *Uniform cooling of cylinder, cylinder head and valves.*
- *If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.*
- *Engine is less noisy as compared with air cooled engines, as it has water for damping noise.*

Disadvantages of Water Cooling System:

- *It depends upon the supply of water.*
- *The water pump which circulates water absorbs considerable power.*
- *If the water cooling system fails then it will result in severe damage of engine.*
- *The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.*

By pass System:



II. PROBLEM IDENTIFICATION

If we consider bike engine which is air cooled, for this there is no need of radiator directly air comes into *contact with cylinder head. But for small formula style racing competitions, cars are fabricated by undergraduates and graduates based on rules, specifications of competition. Considering this if a car is fabricated with a bike engine, then due to more amount of load, heat coming out of engine is more and if air cooling method is used for heat dissipation, it may not be sufficient to remove required heat energy. Due to this there will be a knocking, vibrations, damage to engine components.so considering this problem using bike engine fabricate a car we need to have radiator which is for cooling of the engine.so we are going to design a radiator for bike engine whose heat transfer rate is more than or equal to car radiator.*

Effects of Overcooling:

- *The thermal efficiency is decreased due to more loss of heat carried away by the coolant.*
- *The vaporization of the fuel is less resulting in lower combustion efficiency.*
- *At low temperature the starting of the engine will become difficult.*
- *Inadequate lubrication of the engine, due to oil not being warm enough to flow freely, results in greater frictional losses.*

So, in order to avoid this engine from getting not too hot and at the same time not to keep it too cool either! Proper cooling should be maintained

III. EQUATIONS

1. $Q_{(radiator)} = Q_{(engine)}$
2. $Q_{(engine)} = mc_p\ (\Delta t)$
3. Heat lost by hot water = heat gained by cold air
4. $Mc_p\ (T_{hi}-T_{ho}) = Mc_p\ (T_{ao}-T_{ai})$
5. Thermostat temperature range 100^oc
6. Mass flow rate (m) = $\rho * a * v$
7. Area= (pi/4) d^2
8. Where T_{hi} = hot water inlet temperature
9. T_{ho} = hot water outlet temperature
10. T_{ao} = air outlet temperature
11. T_{ai} = air inlet temperature
12. d = diameter of pipes(mm)
13. m_w = mass flow rate of water(kg/s)
14. m_a = mass flow rate of air(kg/s)
15. ρ_w = density of water(kg/m^3)
16. ρ_a = density of air(kg/m^3)
17. v_w = velocity of water(m/s)
18. v_a= velocity of air(m/s)
19. c_{pw} = specific heat of water at constant pressure (kj/kgk)
20. c_{pa} = specific heat of air at constant pressure (kj/kgk)

IV. SPECIFICATIONS

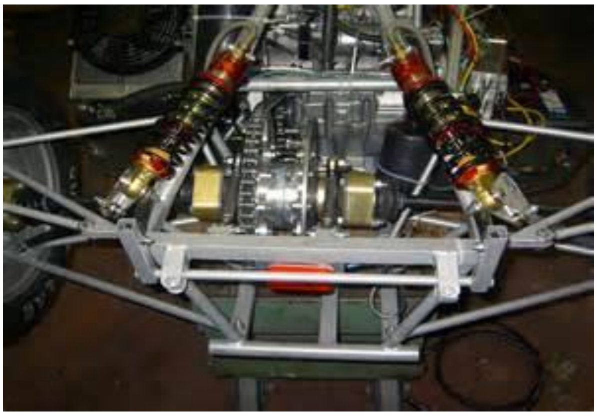
(A) Engine specifications:

Maximum power: 43BHP @ 9500RPM
Maximum torque: 35 N-m
Engine oil: 1.6 litres (SAE 15W/50)
Engine design: 1 cylinder 4 stroke engine
Coolant: water
Displacement: 375cc
Stroke: 60mm
Bore: 89mm
Compression ratio: 12.8:1
Inlet wall diameter: 36mm
Exhaust wall diameter: 29mm

(B) Radiator specifications:

Material of tube: copper
Height of the fin: 30mm
Depth of the fin: 50mm
*Length breadth width of radiator: 500*400*60mm*
Temperature of hot water inlet=373K
Temperature of hot water outlet=303K
Temperature of air inlet =307k
Material surface =aluminium
Diameter of tube = 5.5 mm

V. EXPERIMENTAL APPROACH



(A)RESULTS

TABLE-1:

Air flow (M/Sec)	*Coolant flow (L/Min)*	*Heat Rejection (KW)*	*Coolant*	*C_p Value of water (kj/kgk)*
2	*3*	9.3	*Ethylene glycol*	*2.518*
4	*8*	*19.62*	*Ethylene glycol*	*2.518*
6	*12*	*28.91*	*Ethylene glycol*	*2.518*

TABLE-2:

Air flow (M/Sec)	*Coolant flow (L/Min)*	*Heat Rejection (KW)*	*Coolant*	*C_p Value of water (kj/kgk)*
2	*4*	*20.3*	*Water*	*4.1805*
4	*8*	*40.6*	*Water*	*4.1805*
6	*12*	*61.02*	*Water*	*4.1805*

(B) CALCULATIONS

For water:-

Q=heat rejection (kW) = m $c_p \Delta t$

Where m=ρ a* v*

A = area of cross section of water jacket

V = velocity of water flowing

Diameter of water jacket = 20mm

Mw = 1250.00kg/hr

⇨ *(1250/3600=0.3472kg/s)*

Hot water temperature (inlet) = 373.00k

Hot water temperature (outlet) = 316k

Ts = 310.00k

T_{air} = 298k

Tube diameter = 5.50m

$Q_{engine} = Q_{radiator}$

Q = $Mc_p (T_{hin}-T_{hout})$

*= 1250/3600*4.1805(373-316)*

Q = 84kw

For ethylene glycol:-

Mw =1250kg/hr

=0.3472kg/s

Hot water inlet temperature =373.00k

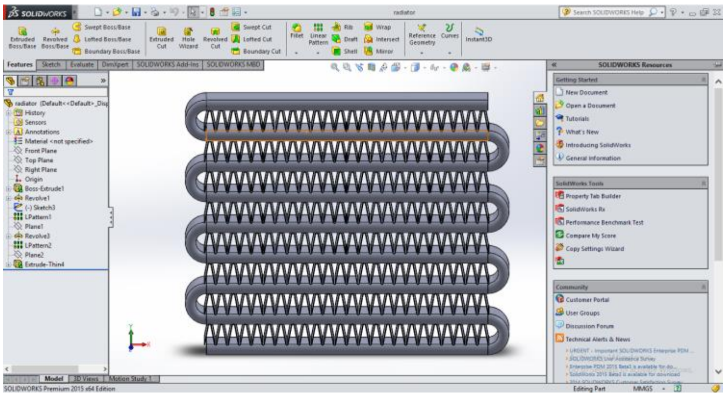
Hot water outlet temperature =316k

Q =$Mc_p (T_{hin}-T_{hout})$

*=0.3472*2.518(57)*

Q =49.832kw

VI. DESIGN OF RADIATOR IN SOLID WORKS



VII. CONCLUSION

Experiment approach was conducted on cross flow heat exchanger that is radiator for cooling of petrol engine which is SI engine by varying velocity of air, and the velocity of water, the effect of this parameters is as velocity of water increases heat transfer rate increases (Q), and temperature of air outlet also increases, by comparing with other journals values of heat rejection values with our values we got more than that heat rejection which increases the performance of the engine, so our design of radiator is suitable for petrol engine with optimum size and more efficient.

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