Study and Design of Engine Cooling System with Distilled Water as a Coolant for FSAE Car

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Abstract - *Nowadays, the demand of automobile vehicles has increased. So, it is a great challenge for automotive industries to develop a powerful and efficient engine. Cooling system is one of the important systems of an automobile that affects the engine performance. Most internal combustion engine uses radiator as a heat exchanger to increase the heat transfer rate. Radiator regulates the engine temperature and thus increases engine efficiency. This paper covers a study about research & design parameters of radiator for a FSAE race car. The focus will be placed on increasing the engine efficiency and reducing the overall size of the radiator.*

Key Words: Automotive Radiator, Cooling System, Distilled Water, Parametric Studies, Design, FSAE

1. INTRODUCTION

In an automobile where usually internal combustion engine is used the power is generated by igniting air and fuel in a combustion chamber. This energy is not utilized completely it is wasted in the form of heat and exhaust gases, if this excess heat is not removed from the engine it results in the overheating of the engine which affects a lot on the engine performance as well as on the engine life. Usually small capacity engine uses air to cool the engine in this case fins are provided on the engine. But in case of high performance engine, air is not enough for cooling, so a liquid cooling system has to be used which uses a radiator, cooling fan, a pump and a thermostat. In this liquid cooling system, liquid is used for reducing the temperature of engine this liquid usually being (specialized coolants) but here we are designing a Liquid cooling system for a FSAE race car where we have to follow certain rules and regulation which includes compulsory use of distilled water as coolant, so we need to design our radiator accordingly also as we are talking about a race car the design of the radiator is of the main concern as it has to be compact, light in weight and as the engine is going to be used at its maximum capacity the cooling system should be very efficient.

These automotive radiators are mostly made up of thin aluminum fins and flattened aluminum tubes. The coolant flows from engine to inlet port of the radiator then it is circulated in radiator tube and undergoes heat transfer by conducting heat from fin to air flowing through radiator and then it goes back to engine through outlet port of the radiator.

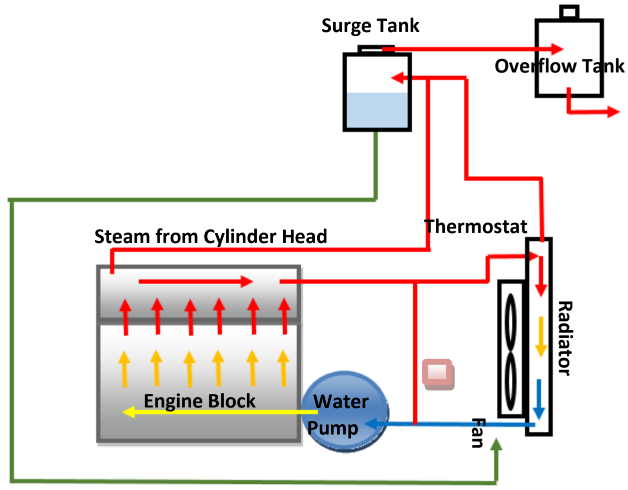

Figure 1: Parts of Engine Cooling System

2. AUTOMOTIVE RADIATOR

2.1 Working of Radiator

In the engine case, due to heating the coolant is circulated through the engine where it makes its way through passages in the engine block around the cylinder. Then the coolant flows towards radiator through the pipes. At the top of the radiator tank is present, which supplies the equal amount of coolant to radiator tubes. The fins attached to these tubes conduct the heat from tubes to surrounding air by convection. Then the coolant is goes back to the engine.

2.2 Various Components of Engine Cooling System

• **Reservoir:** It supplies the coolant to the radiator. It serves the extra amount of coolant in it and give it to radiator in the case of coolant level in radiator goes down.

• **Fan:** It is attached behind the radiator to increase cooling capacity. It drew fresh air through the radiator. It increases the mass flow rate of air which increases the effectiveness of the system.

• **Radiator:** The radiator is a type of heat exchanger in which the coolant transfers its heat to surrounding air by convection and conduction phenomenon. It consist of a fins attached to the no. of tubes which increases area exposed to surrounding.

• **Thermostat:** It controls the temperature by varying the amount of coolant going to radiator.

• **Hose Pipes:** It transfers the coolant from engine to radiator and again from radiator to engine.

3. OBJECTIVES

1. To minimize Size of the radiator
2. Optimization of hose pipes and volume
3. To reduce weight of the radiator and increase efficiency
4. Meet all of the design criterions while minimizing the system mass.
5. To improve engine performance
6. Maintain an optimal engine operating temperature over a wide range of ambient conditions.
7. Minimize electrical power requirements
8. Keep the system mass as central and as close to the ground as practical

4. MATERIAL SELECTION

As the material plays important role while working of a system. It is necessary to consider all parameters of a material which affects the performance of cooling system. The main goal of the car is to minimize its overall weight, so it becomes important to design a cooling system which has minimum weight. While selecting material we have to take care that the material should be less in weight and also has high heat transfer rate.

The material properties for the tube and fin are specified. The fin material is Copper alloy and the tube material is Red Brass.

Table 1: Composition and properties of the fin material

Composition 1. Copper : 99.5% Min. 2. Phosphorous : 0.026% Max.	
Thermal Conductivity	394 W/m K
Density	8.94 g/cm³
Specific heat capacity	394 J/Kg K

Table 2: Composition and properties of the tube material

Composition 1. Copper : 85.1% to 86% 2. Zinc : 15.15% 3. Lead : 0.029% 4. Iron : 0.001%	
Thermal Conductivity	159 W/m K
Density	8.75 g/cm³
Specific heat capacity	380 J/Kg K

5. DESIGN PARAMETERS

Information of the FSAE car on which the cooling system is to be installed:

1. The fuel is Gasoline (RON 95)
2. The coolant is 100% Distilled water
3. Engine: KTM Duke 390
4. The fan turns on when the temperature of the water entering the engine is greater than or equal to 95°C, and the fan turns off when the water entering the engine reaches 90°C.
5. The water pump is engine-driven

The mass flow rate of air is determined using the equation below:

$$\dot{m} = \rho v A \qquad \text{.......(i)}$$

Where,
$\dot{m}$ = mass flow rate of the air,
ρ = density of air = 0.985 Kg/m³,
V = average velocity of the air through the radiator
= 15 m/s considering vehicle speed of 60km/hr,
A = area of radiator = l x b, considering standard size of Radiator, l=0.38m, b=0.5m,
= 0.38 x 0.5 = 0.19m²
Therefore,

$\dot{m}$ = 2.807 Kg/sec ......(by eq.(i))

Engine Heat loses can be divided into:

$$\dot{Q}_{loss} = \dot{Q}_{coolant} + \dot{Q}_{oil} + \dot{Q}_{ambient} \qquad \text{.......(ii)}$$

General range of various heat losses is:

Type of loss	Range
Cooling	10 – 30 %
Oil	5 – 15%
Ambient	2 – 10%
Friction	10%

Regarding water temperature inside the radiator and its geometries:

Re =4847,
ρ_{water} = 964 kg / m³,
Cp = 4207(kJ / kgK),
μ = 309 x 10-6 (N s / m²),
h'_i = 765,
Ch = 1.28,
hi = 5571.7 W / m²K

Effectiveness of Radiator = Actual heat transfer / Maximum heat transfer

$$\varepsilon = \frac{q}{qmax} = 0.40 \qquad \text{.......(iii)}$$

Heat transferred from the wall surface to the air:

$$\dot{Q}_{conv-w} = \dot{Q}_{radnet} - \dot{Q}_{cond} \qquad \text{.......(iv)}$$

Convection heat transfer from the radiator to the air:

$$\dot{Q}_{conv-r} = \dot{Q}_{total} - \dot{Q}_{radnet} \qquad \text{.......(v)}$$

Total heat transfer to the air:

$$\dot{Q}_{air} = \dot{Q}_{conv-w} - \dot{Q}_{conv-r} \qquad \text{.......(vi)}$$

Therefore,

$$\dot{Q}_{air} = \dot{Q}_{tot} - \dot{Q}_{cond} \qquad \text{.......(vii)}$$

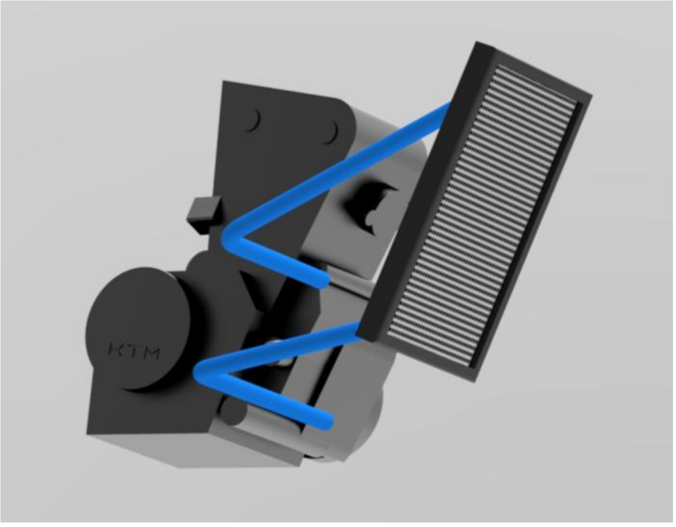

Figure 2: CAD Model of Radiator (without scale)

6. CONCLUSIONS

In this research paper, the study of automotive radiator is done. By considering the factors which affects the engine cooling system, the design parameters of radiator are studied. After that we came to the following result that the mass flow rate of air flowing through radiator i.e.

ṁ = 2.807 Kg/sec and effectiveness of the radiator, ε = 0.40

REFERENCES

[1] JP Yadav, Bharat Raj Singh, "Study on Performance Evaluation of Automotive Radiator", ISSN : 2229-7111, Vol. 2, Issue 2, 2011

[2] R. K. Barathraj, Dr. K. S. Amirthagadeswaran, M. Safraaj Salaamer, "Performance Analysis of a Copper Radiator Using CFD", IJMER, International Conference on Advances in Engineering and Management (ICAEM)

[3] Toure Ismael, Sheng Bu Yun, Fayzimatov Ulugbek, "Radiator heat dissipation Performance", Journal of electronics cooling and thermal control", 2016, 6,88-96

[4] Devendra Vashist, Sunny Bhatia, Ashish Kalra, "Some Studies on the Performance of Automotive Radiator at Higher Coolant Temperature", Journal of basic and applied engineering research, ISSN : 2350-0255; Vol. 1 no 3, Oct 2016

[5] Dr.Channankaiah, D. Arunpandiyan, "A Review of Automotive Radiator Performance"IJIRTS - International journal for innovative research in science & technology, volume-2 issue-10, March 2016

[6] Vishal Bhuria, Shashank Shekhar, Ramesh Soni, "Analysis of Automobile Radiator – A Review", International Journal of Engineering applied science and technology, 2017, vol.2, Issue 4

[7] Chavan D. K, Tasgaonkar G. S., "Study, Analysis and Design of Automobile Radiator (Heat Exchanger) Proposed With Cad Drawings and Geometrical Model of the Fan", International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN 2249-6890 Vol. 3, Issue 2, Jun 2013, 137-146

[8] D. Amrutha Vijay, P. Snehalatha, "Computer Aided Design and Analysis of a Heat Exchanger", International Journal of Science, Engineering and Technology Research (IJSETR) Volume 5, Issue 7, July 2016