DESIGN AND ANALYSIS OF CAR RADIATOR BY FINITE ELEMENT METHOD

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ABSTRACT

An automobile radiator is a heart of an automotive cooling system which plays a major role in transferring the heat from the engine parts to the environment through its complex system and working. It is nothing but a type of heat exchanger which is designed to transfer the heat from the hot coolant coming from the engine to the air blown through it by the fan. The heat transfer processes takes place from the coolant to the tubes then from the tubes to the air through the fins. Radiators are used for cooling internal combustion engines, mainly in automobiles & also in piston-engine aircraft, railway locomotives, power generating plant or any similar use of such an application. This project on "Design and Analysis of Car Radiator by Finite Element Method" mainly focuses on the thermal design and analysis of radiator as heat exchanger only. We have developed this work as our semester project with a view to get familiar with the technologies as well as application of theories into practical work done by industries. This project contains the design and analysis of the radiator for different type of car also. For better efficiency, improvement of heat transfer rate is important phenomenon. So we try to improve this by using Maruti Wagon-R car engine specifications.

Keyword: - *Radiator, Finite Element Method, Heat Exchanger, ANSYS.*

1. Introduction

Modern automotive internal combustion engines generate a huge amount of heat. This heat is generated when the fuel and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine and creates power. Metal temperatures around the combustion chamber can exceed 1000° F. Out of this generated heat approximately 30-35% of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 35-40% of the heat is carried off into the atmosphere through the exhaust system. The remaining 30-35% must be removed from the engine by the cooling system 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 this heat. But sometimes this heat cannot be effectively removed due to inefficient design of radiator. This problem has been taken into consideration for our project work. Also excessive cooling system capacity can also be harmful, and may affect engine life and performance. So our ultimate aim is to design an effective cooling system which controls the engine temperature within a specific range so that engine stays within peak performance.

1.1 Cooling System

The cooling system is made up of the passages inside the engine block and heads, a water pump to circulate the coolant, a thermostat to control the temperature of the coolant, a radiator to cool the coolant, a radiator cap to control the pressure inside the system, and some plumbing for 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.

Basically, there are two types of cooling systems which are as follows:

1. Air cooling system 2. Liquid or Water cooling system

Liquid or Water cooling system is most widely used in cars due to high cooling rate. The cooling system consists of various parts as shown in following fig.1.1.

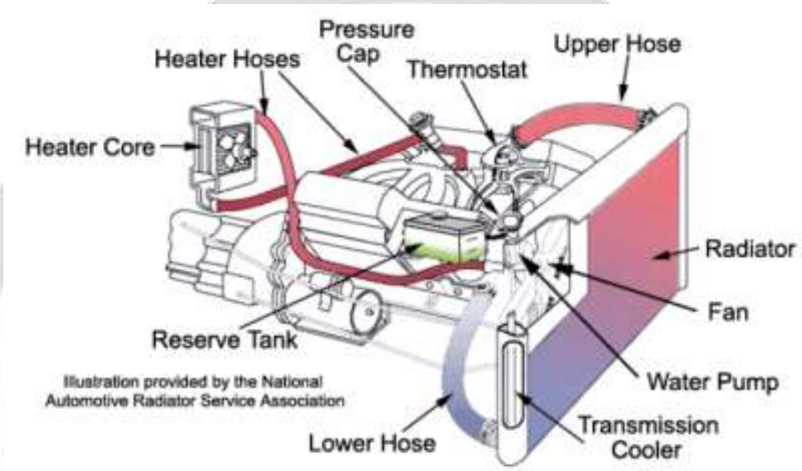

Fig. 1.1 Schematic of cooling system

1.2 Radiator

The radiator is a main component of cooling system. It is a device designed to dissipate the heat which the coolant has absorbed from the engine during its circulation. It is constructed to hold a large amount of water in tubes which provide a large area in contact with the atmosphere. It usually consists of a radiator core, with its water-carrying tubes and large cooling area, which are connected to a receiving tank (end cap) at the top and to a dispensing tank at the bottom. Side flow radiators have their "end caps" on the sides, which allow a lower hood line. In operation, water is pumped from the engine to the top (receiving) tank, where it spreads over the tops of the tubes. As the water passes down through the tubes, it loses its heat to the airstream which passes around the outside of the tubes when vehicle is moving on a road.

The radiator core is usually made of aluminum tubes with aluminum strips that zigzag between the tubes called fins. These fins transfer the heat in the tubes into the air stream to be carried away from the vehicle. On most modern radiators, the tubes run horizontally with the plastic tank on either side. On other cars, the tubes run vertically with the tank on the top and bottom. On older vehicles, the core was made of copper and the tanks were brass. The new aluminum-plastic system is much more efficient and economical to manufacture. On radiators with plastic end caps, there are gaskets between the aluminum core and the plastic tanks to seal the system and keep the fluid from leaking out.

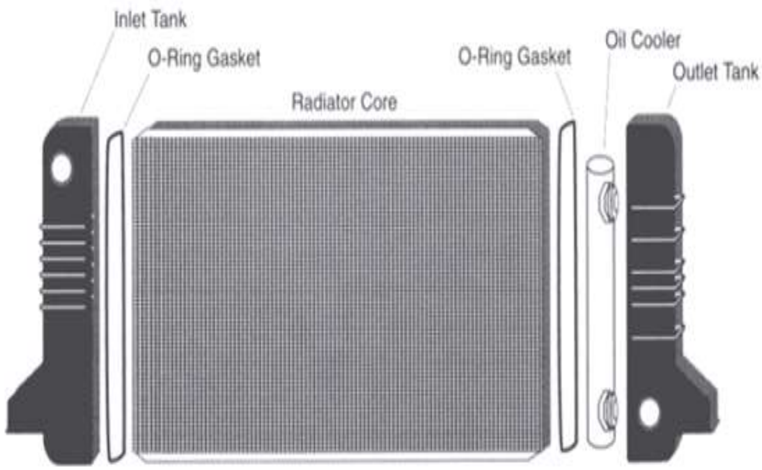

Fig.1.2.1 Radiator

Radiators can be constructed with the tanks at the top and bottom of the core or on the sides. On the basis of these, radiators are classified as:

Down flow Radiator: - If the tanks are at the top and bottom, it is the Down flow radiator. In this radiator, the tubes are arranged vertically and the coolant flows from top to bottom.

Cross flow Radiator: - If the tanks are at the sides, then it is the Cross flow radiator. In this radiator, the tubes are arranged horizontally and the coolant flows across the radiator from one tank to other.

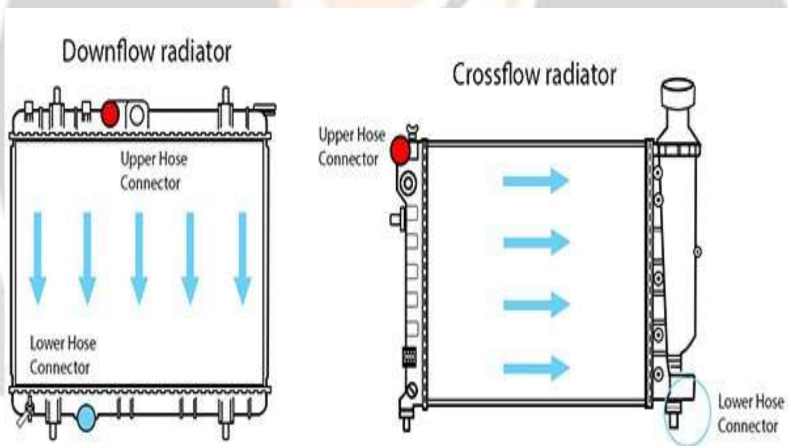

Fig.1.2.2 Type of radiator

2. Proposed Design

The proposed design of radiator is done as per the standard designing procedure for our project work. It includes the design of radiator model on 3D modeling mechanical software (CREO and CATIA), its manual calculations, CFD analysis on ANSYS software and its results.

2.1 CAD Model

The designed model of radiator is made with the help of CREO software as per dimensions and calculations carried out for our project work. Figure 2.1.1 shows the 3D model of radiator.

Fig.2.1.1 3D Model of Radiator using CREO

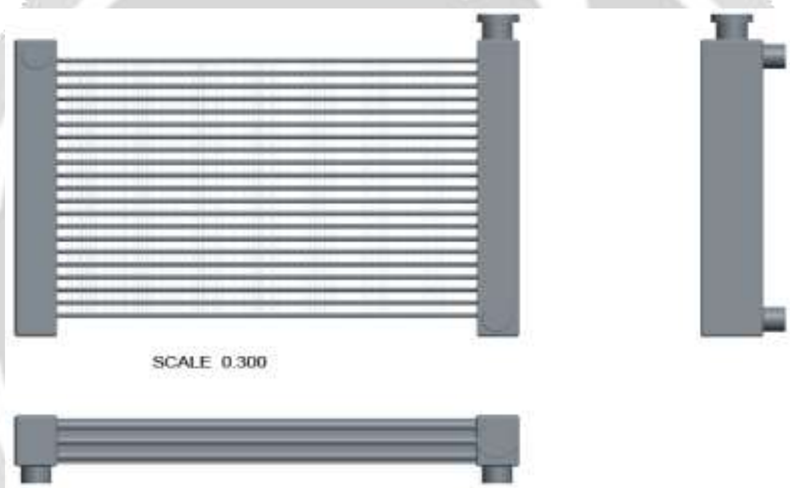

Fig.2.1.2 Front view, Top view & Side view of model

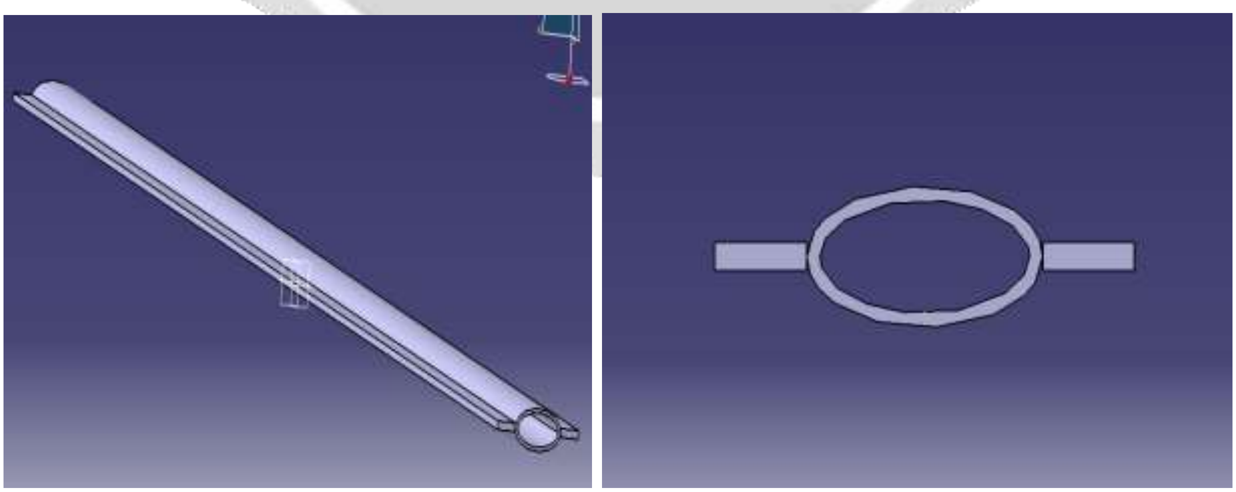

Fig.2.1.3 3D and Cross-sectional views of radiator Tube

2.2 Design Calculations

We have following data of Maruti Wagon-R car

Engine	: -	K10B
Displacement	: -	998cc
Fuel Type	: -	Petrol (Gasoline)
Max. Power (P)	: -	67.04 BHP @ 6200 RPM

Amount of heat lost by radiator

$$\text{Brake Power, BP} = \frac{2\times\Pi\times N_{max}\times T_{max}}{60} = \frac{2\times3.142\times6200\times90}{60}$$

BP = 58.43 KW

Let, Mechanical efficiency, η_{mech} = 85% = 0.85

Indicated Power, IP = BP / η_{mech} = 58.43 / 0.85 = 68.74 KW

Now, Let Indicated thermal efficiency, η_{ith} = 30% = 0.3

Therefore, Total Heat Produced, Q = IP / η_{ith} = 68.74 / 0.3

Q = 230 KW

Now, out of this total heat,

Heat Exhausted & Unaccounted, = 40% = 92 KW

Heat used for Power Generation, = 30 - 35% = 69 - 80.5 KW

Heat loss in Design for Radiator, = 30 - 35% = 69 - 80.5 KW

So we have to remove minimum 69 KW and maximum 80.5 KW of heat through the cooling system. We have done calculations to remove this amount of heat through from designed radiator.

Available data:

Sr. No.	Parameters	Specifications
1.	Inlet Temperature of Water (Th1)	85ºC
2.	Inlet Temperature of Air (Tc1)	35ºC
3.	Dimensions of inlet & outlet tanks (mm)	50 × 60 × 354
4.	Shape of Tube	Elliptical
5.	Major & minor axis of tube respectively	8 mm & 4 mm
6.	Length of tube	400 mm
7.	Number of tubes	32
8	Distance between two tubes	30 mm
9.	Length of the fin on tube	5 mm
10.	Thickness of fin on tube	1 mm
11.	Length of fin between two tubes	30 mm
12.	Thickness of fin	0.5 mm
13.	Distance between two fins	2.85 mm

Calculated data:

Sr. No.	Parameters	Specifications
1.	Outlet temperature of water (Th2)	62.90ºC
2.	Outlet temperature of air (Tc2)	65.25ºC
3.	Mass flow rate of water (m_w)	0.746 Kg/sec
4.	Mass flow rate of air (m_a)	2.27 Kg/sec
5.	Total heat transfer coefficient (U)	27.216 W/m^2K
6.	Total Heat transfer (Q)	73.072 KW
7.	Effectiveness (ε)	90.77 %

3. Analysis of proposed radiator

Step 1: Importing Radiator model

The first step involves importing of radiator model in ANSYS software. File format for importing radiator model is iges. After importing the radiator model in to ANSYS surrounding it look like as shown in following figure 3.1.

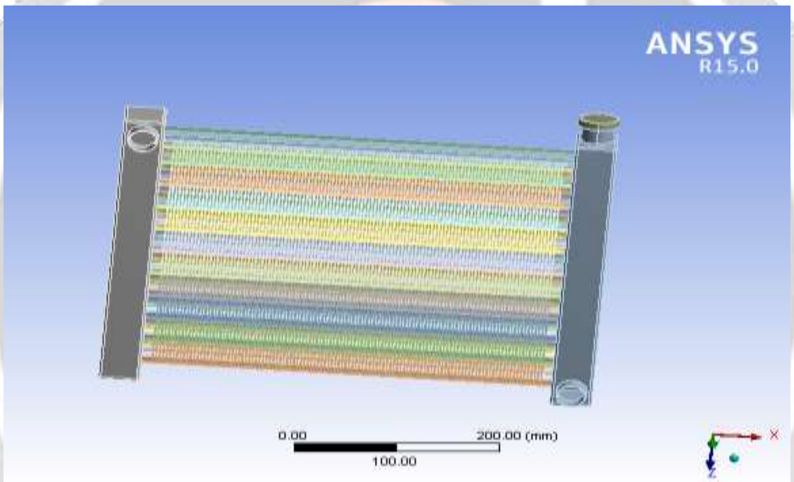

Fig3.1 Imported model

Step 2: Meshing of Radiator model

It involves meshing of radiator model. Meshing is nothing but dividing the model into large number of elements having a number of nodes. This method of dividing the component into large number of elements is called as discretisation. Greater is the number of elements, greater is the accuracy

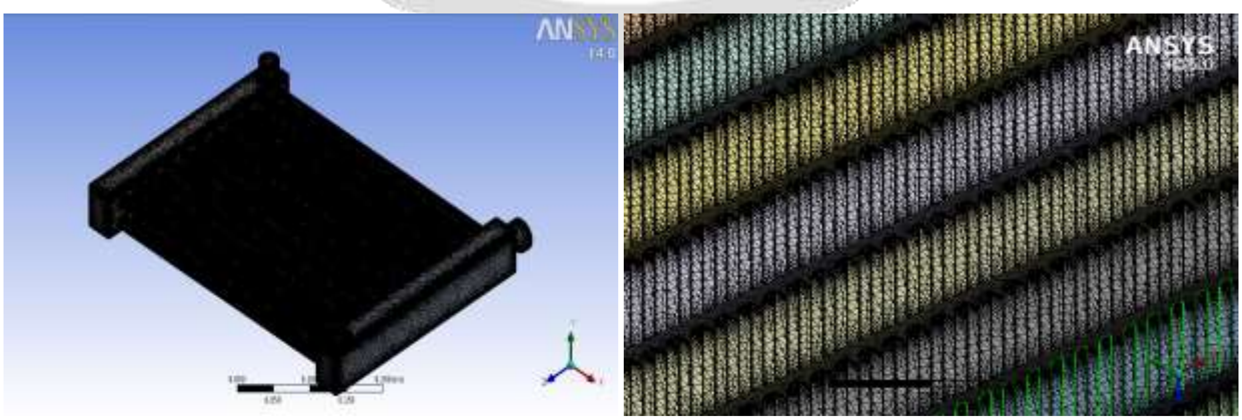

Fig.3.2 Meshing model of radiator

Step 3: Problem Setup for Radiator model

In this step we have apply various conditions to our radiator model and final setup is form. The following figure 3.3 shows a setup figure after meshing.

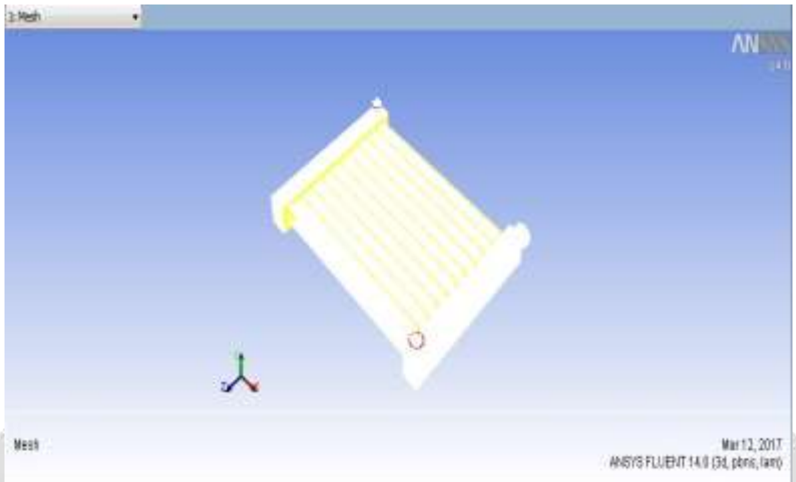

Fig.3.3 Problem setup for model

Step 4: Calculation of problem for radiator model

In this step calculation is carried out for problem setup in previous step. It is important step in forming the solution for problem setup.

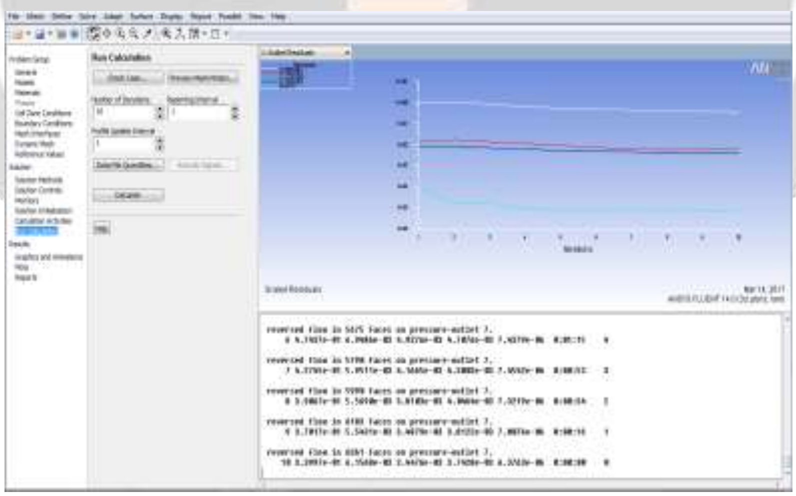

Fig.3.4 Graph produced at calculation

Step 5: Solution of Radiator model

The generated solution after calculation of setup problem is shown in following figure 3.5.

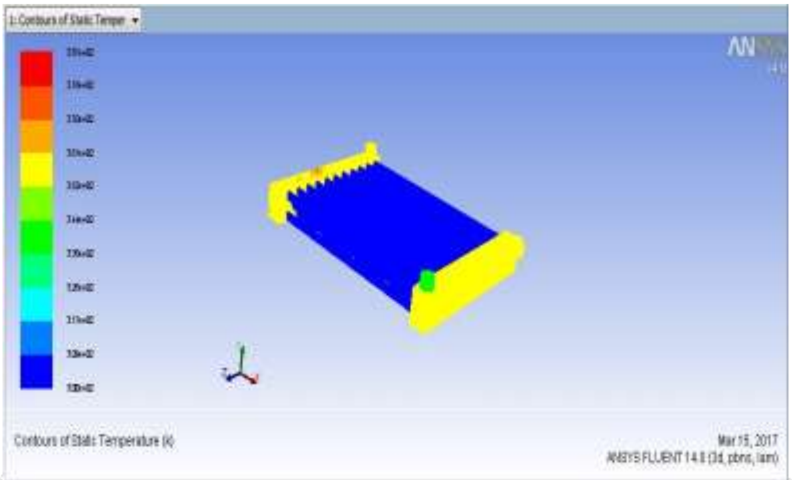

Fig.3.5 Final solution figure

3.1 Ansys Result

From the solution of radiator model (Step 5), we found that the CFD analysis only gives the temperature distribution as a result. From this we get the outlet temperature of fluid (water) and calculate the Total heat transfer rate & Effectiveness of the Radiator.

Inlet Temperature of Water (T_{h1}) = 358 K = 85 ºC

Inlet Temperature of Air (T_{c1}) = 307 K = 34 ºC ------------ (Given)

Outlet Temperature of Water (T_{h2}) = 335 K to 334 K = 62ºC to 71ºC ------------ (From fig)

Outlet Temperature of Air (T_{c2}) = 339.23 K ---------- (Calculated)

Heat transfer rate, $Q = U \times A \times \Theta m \times F$

Where, $U = 7.43$ KW/m² ºC = 27.216 W/m² K

$A = 0.51$ m²

$\Theta m = 23.07$ ºC --------- (Calculated)

$F = 0.87$ --------- (From graph)

Therefore, **<u>Q = 76 KW</u>**

Effectiveness, $\varepsilon = Q / Q_{max} = 76 / 80.5 = 0.95$

<u>ε = 95 %</u>

Comparison:

Sr. No.	Parameters	Proposed Model	
		Theoretically	**ANSYS**
1.	Geometry of Tubes	Elliptical	Elliptical
2.	Number of Tubes	32	32
3.	Heat Transfer Rate	73.072 KW	76 KW
4.	Effectiveness	90.77 %	95 %

4. Conclusions

1. The Heat transfer rate through this Radiator is 73.072 KW (Theoretically) & 76 KW through (ANSYS).
2. The Effectiveness of the Radiator is 90.77 % (Theoretically) & 95 % through (ANSYS).

In this way we have studied the design process of radiator and design a model successfully. Also we conclude that the proposed radiator model is more effective.

5. Acknowledgement

We would like to thank our project guide Prof. V. C. Pathade under whose necessary guidance we have completed our project successfully. Without his unending help, constant encouragement and motivation this would not have been possible.

Dedication and preservance when supported by inspiration and guidance leads to success. For us inspiration and guidance was given by our guide who was accessible for us to obviate the darkness our problem with light of his knowledge of the relevant subject enriched by his hands on experienced in the field of technology. We truly sense it was privilege for us, to have them as our guide. We fill highly honored working under his hands.

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