Improving of Engine Cooling System

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Abstract -*In this paper, fundamental approach of engine cooling system is discussed and our final conclusion is; we made convenient radiator according to suitable material and production. This material selection and production method is gathered from literature review as we represented it already. Radiator is considered as the backbone of an engine cooling system. Coolant is the important factor which is used in radiator. The selection of coolant affects overall cooling system. In this paper we only used distilled water as a coolant to cool the engine. A radiator should take maximum amount of heat and cool the engine by using the minimum amount of water. Radiator's weight should be as minimum as possible; because it reduces overall weight of the car. This feature is most important and considered while designing the radiator.*

Key Words: **SOLIDWORKS, ANSYS, Engine, Cooling System, CFD**

1. INTRODUCTION

An engine provides mechanical energy from an air/fuel mixture with an efficiency between 20 and 45%. The rest flows in kinetic and heat energy in exhaust gases and in heat energy through metallic bodies due to the frictions. In this context, the cooling system must allow the engine to give its best performance, ensure the durability of this performance and ensure engine reliability by guaranteeing an acceptable level of thermo-mechanical stresses in any point of the engine. The goal of this paper is to develop an engine cooling system which will only use distilled water to cool the system without using any coolant particles. In Formula SAE competition centers they not only check the performance but also the design of the cooling system. The vehicle's performance will be entirely depending on cooling system. If the vehicle is running for longer period then cooling system of the vehicle will help to cool the engine of the car and oppose the engine getting overheated or in extreme cases it opposes the breakdown. This cooling has been achieved through numbers of iterations of design process to achieve optimum design.

2. LITERATURE SURVEY

Copper and brass were used in making radiator parts as they were good conductors of heat but were costly both as materials and for manufacturing. Ford Company in 1983 tried to find different alternative material which will be used in radiators. After several experiments aluminium was selected for making radiator parts. The reason behind it was that it was lighter in weight, lower in cost, reliable and durable to its copper and brass counter parts. It was selected where cooling requirements were moderate. It was used in making tubes, fins and header of the radiator. 3003 Al for tubes by extrusion process, hard 3003 Al for fins in flat plate design, 3005 Al for header of the radiator. Fin pitch was kept from 1.1mm to 2.2mm. The air side interface of this radiator joint was sealed with one part epoxy to prevent seepage and strengthen the header. The tank of the radiator was joint to the core by sandwiching a nitrile rubber gasket between header and tank. After the whole assembly, the radiator was tested and its calorimeter performance, durability, corrosion resistance and qualification with respect to vehicle was noted down. It was concluded from these experiments aluminium performed better in all the tests and was used in all automobiles manufactured by ford from that time. [1]

After several years to the foot fulfil the demand of a corrosion resistant radiator. For making in good corrosion resistant radiator tube the properties such as high corrosion resistant and high resistance to stress corrosion cracking due to solder flux should be satisfied. After testing different materials 'CACTUS CB203' was selected. Three main tests were performed on all the materials they were: - Salt Spray Test: -. According to ASTM-85 this test was conducted. In salt spray test mixture of salt and water is sprayed on the radiator tubes in order to examine the corrosion resistance on the radiator tubes. Under Microscope this test was conducted and researcher found out that maximum dezincification of brass CACTUS CB203 is about 1/10th of that Phosphorous and Comparable arsenic brass. Corrosion Test- Corrosion test was performed on the radiator tubes in which specimen were immersed in the solution and the results were obtained that 1/5th of brass and phosphorus stress. Corrosion Cracking Test: - Stress Corrosion is performed on CACTUS CB203 brass. In which slight corrosion was observed on the material in the form of graph. [2]

In year 1992 an experiment was performed to increase the thermal efficiency of radiator. It was done by using a converge shape at the starting of coolant flow which reduce the pressure of the tube in one size of tube made the coolant flow in smaller quantity from each tube. This helped the coolant to cool at faster rate increasing the thermal efficiency of tube. [3]

After a decade it was discovered that the airflow around the radiator had a huge part in cooling the system and the system was not optimize to use the air efficiently. Different tests were done on a vehicle with a radiator installed in it and all different measures that affects in cooling of the system were taken into account. Tests were done considering aerodynamic drag that acts on the vehicle and how it would influence the cooling airflow. Also, other test was done considering crosswind flowing through the vehicle when it's in yaw or lifted. Different thermal rejection methods were tested to achieve a radiator which was thermally balanced and was efficient throughout the test. [4]

The high thermal conductivity graphite was less in weight and has density between 0.2 to 0.6m/cm^3 & bulk thermal conductivity is 187w/m^2.k due to the bulk thermal conductivity of graphite it will increase the cooling which will result in reduction of tubes required for cooling the system. Using graphite in the radiator assembly will reduce the overall weight, cost & volume of the radiator thereby improving fuel efficiency of the vehicle. [5]

The radiators required a higher heat flux. The carbon foam has higher heat transfer efficiency & better heat dissipation. Using carbon foam, the material fins and tube had given great result in efficiency of cooling system. But the problem of carbon foam material was that it was not giving the required strength for the radiator and also there were bonding issue. To overcome this, carbon foam was coated with 2 different material made of Sic and metallization was done over it. This resulted increase in the strength and bonding of carbon foam material by 430% in which Sic coating gave increase 100% and metallization layer gave 330% improvement. [6]

The era of 2007 normal radiators were using parallel tubes which had aluminium fins attached to them. They were not giving the heat transfer coefficient to improve cooling. They designed some different fins which were made up of carbon foam which had porosity of 70% thickness of 0.762mm and heat transfer coefficient 1000 w/m^2 k. This resulted in better heat dissipation which increased the cooling efficiency of radiator. [7]

After several years an experiment was done which tested the radiator design with practical scenarios. The heat transfer rate of radiator was cross verified, internal flow of water through radiator tubes which was depended on area of tube, velocity of water flowing from the tubes, Reynold's number of water. Also, with these external flow of air over tubes and fins of the radiator, air Reynold's number, fin's dimension and its efficiency and effectiveness by NTU method. [8]

In the year 2009 using the side pod for improving the efficiency of radiator an Fsae team used aerodynamic consideration in which they used converging and diverging roles. The Design were tested on Ansys CFD Simulation. From the results they concluded that using an aerodynamically shape side pod was directing the air on face of the radiator which increased the cooling rate of the radiator and the issue of overheating was overcome. [9]

After a year a new material was discovered as carbon foam it was tested for material of fins. During research of the material it was discovered that it has extremely high thermal conductivity and had an open cell structure which will help to make a radiator efficient from a huge margin. The researcher also found out that they can improve the rate of heat dissipation through radiator by lowering the coolant inlet temperature and decreasing the air side resistance. After all the testing they observed that carbon foam's heat transfer coefficient was 40% greater than aluminium and it was 28% lighter in weight than aluminium. [10]

In year 2015 to reduce the size of radiator and also not come across overheating issues, the inlet port of radiator was provided with sensor attach to it. Same sensor was attach in the outlet port. Both sensor was connected to the ECU and were monitored continuously. Also, with these the coolant tank was brought closer to inlet port which made sure the flow of water was continuous without any lag; by doing this the overheating of engine was reduced by a huge margin. This resulted in reduction of the size of cooling system. The cooling system overall weight was reduced by 45% from its previous results. This not only reduce weight of the vehicle but also power loss done by radiator that was generated by the engine was reduced by huge margin. Also fuel efficiency was increased. [11]

An experiment was performed in 2016 using Nano-fluid materials in the coolant (silicon oxide, alumina, titanium). They achieved these by putting solid composite materials ranging from 1nm -100nm in size were mixed with the base fluid (used as coolants and include water, ethylene glycol, engine oil, etc.). During testing it was seen that the mixture of these resulted in giving better thermal properties than conventional fluids. Also due to this there was possibility in reduction of radiator size, reducing its weight and with that less fuel consumption was achieved. The mixture of fluid and solid particles can be done by two methods, first is one step method in which synthesis of Nano fluid was done, other method was called two step methods in which particles were directly mixed with base fluids. It was concluded that the density, viscosity and thermal conductivity of Nano fluid will increase with increase in volume concentration of particles in fluid. [12]

He also considers different ways and methods in different scenarios in which the first approach was by theoretical and numerical. From this calculation the size of tube and thickness of fin of radiator was determined. This calculation was then converted into a CAD model and it was simulated on 1-D simulation software. From the results he found out that overall radiator efficiency was improved.

[13] In year 2016 the different assembly of tubes in the radiator were tested on software and calculation basis different setups of tube were considered like parallel flow, cross flow, flat tube, helical tube structure, dual pass flow in which they found out that parallel flow setup was not providing better result in cooling the system but also the material required to build the assembly was less hence overall cost was reduced. [14]

3. CALCULATION

3.1Considered data

$T_{hot\ fluid\ in}$ = 115*C
T hot fluid out =55*C
T cold fluid in = 35*C
T cold fluid out = 68.89*C
Velocity of coolant = 20 LPM = 14.82m/s
Di =5.35mm
Mh = 0.165kg/sec
Mc= 1.498kw/m^{2}·c

3.2 Symbols tobe use

T (hot fluid in) =Inlet temperature of hot fluid
T (hot fluid out) = outlet temperature of hot fluid
T (cold fluid in) = inlet temperature of cold fluid
T (cold fluid out) = outlet temperature of cold fluid
Di = inner diameter of tube
Mh = Mass flow rate of hot fluid
Mc = Mass flow rate of cold fluid
Qw=heat absorbed by coolant
Qmax = maximum heat absorbed by coolant
F= Fouling Factor
U= Overall heat transfer coefficient
E_R= Efficiency of radiator
E_{fin}=Efficiency of fin

3.2 Calculation

T (hot fluid in) =115°c

T (hot fluid out) =55°c

T (cold fluid in) = 35°c

Mh (Cpc)*(ΔTh) =Mc (Cpc)*(ΔTc)

Where
Cph= specific heat capacity of hot fluid
Cpc= specific heat capacity of cold fluid
ΔTh=temperature difference of hot fluid
ΔTc=temperature difference of cold fluid

0.165×4.187× (115-55) =1.225×1×(Tco-34)
T (cold outlet) =68.83˚c
qw=0.165×4.187× (115-55)
qw=41.453w

LMTD= $\frac{\theta 1-\theta 2}{\ln(\frac{\theta 1}{\theta 2})}$

$=\frac{(115-68.83)-(55-35)}{ln\frac{(115-68.83)}{(55-35)}}$

θ_{lm}**=31.28˚c**

P= $\frac{Thot\ out-Thot\ in}{Tcold\ in-Thot\ in}$ **R=** $\frac{Tcold\ in-T\ cold\ out}{Thot\ out-Thot\ in}$

$=\frac{55-115}{35-115}$ $=\frac{35-68.83}{55-115}$

P=0.75 **R= 0.564**

F=0.824………………. (by correction factor chart)

Ch = Cph-mh

C= Cpc-mc

where
Ch=heat capacity of hot fluid
Ch= 0.165×4.187
Ch= 0.690 J/˚C
Cc=heat capacity of cold fluid
Cc=1.225×1
Cc=1.225 J/˚C
Area of radiator (A)

A= $\frac{q}{UF\theta LM}$

A=$\frac{41.45}{1.498\times0.82\times31.28}$

A=1.078m²

Total flow area (AF)

AF= $\frac{mh}{v\times\rho}$ **v=** $\frac{0.165}{0.741\times1000}$

A=1.078m²

AF = n×π/4×di²

2.2267×10⁻⁴= n×π/4× (5.35×10⁻³)²

n =50

NTU = $\frac{U.A}{Cmin}$

$=\frac{1.498\times1.078}{0.69}$

NTU= 2.25

$Q_{max}=C_{min}\ (T_{hotin}-T_{Coldin})$
$=0.69(115-35)$

$Q_{max}=55.2w$

$\epsilon_R = \frac{q}{qmax}$

ϵ_R= **Efficiency of Radiator**

$\epsilon_R = \frac{41.45}{55.2}$

$\epsilon_R = 0.75$

Reynold's No: -

$RE = \frac{\rho Di}{\mu}$

$= \frac{1000\times0.741\times(5.35\times10^{\wedge}-3}{8.90\times10^{\wedge}-4}$

RE=4454

Flow in turbulent

FIN Efficiency: -

$\eta_{fin} = \frac{\tanh(mLc)}{mLc}$

where

Lc = Characteristic length of fin

$=\frac{\tanh(mLc)}{mLc}$

$L=\frac{Volume\ of\ body}{Area\ of\ surface}$

$=\frac{l\times b\times h}{2(l\times b+b\times h+l\times h)}$

$=\frac{0.35\times0.028\times0.0001}{2(0.35\times0.028)+(0.028\times0.0001)+(0.35\times0.0001)}$

$L =4.98\times10^{-5}m$

$\in=\frac{\tanh(mLc)}{mLc}$

$=\frac{\tanh(1.1225\times4.98\times10^{\wedge}-5}{1.225\times4.98\times10^{\wedge}-5}$

4. DESIGN

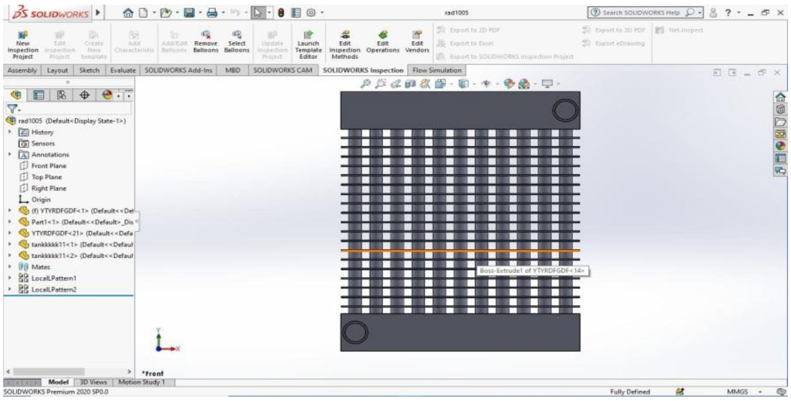

Fig -1: **Radiator design**

Thinner copper-brass metal leads to lower air side pressure drop that in comparable aluminium radiators. This translates to more efficient radiators, lower cooling module costs, less parasitic engine losses and greater fuel economy. This radiator is 30-40% lower in weight compared to traditional and correspondingly lower in class. The brazed copper-brass radiators also provide 30% or more percentage lower air side pressure drop than aluminium radiators because their copper and brass components are much thinner than the components in their aluminium counterparts.

5. ANALYSIS

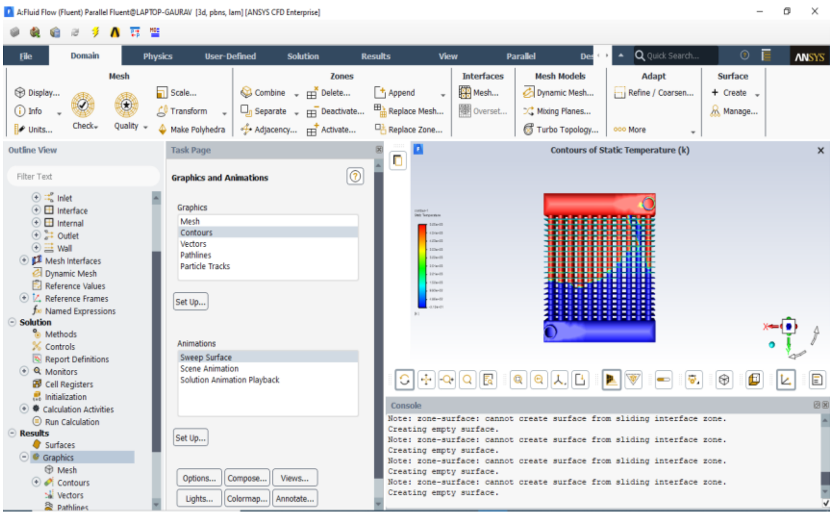

Fig -2: **After analysis**

After the solid modelling in solid works we need to do radiator analysis. And this radiator analysis is done using Ansys software. Ansys software is used for analysis. In this software we can do different types analysis like Structural, Modal, Harmonic analysis, Computational Fluid Dynamics (CFD). In CFD analysis different types of steps are involved. Following are the steps of CFD analysis: -

1) After completing modelling, we have to save that file in. STEP or. IGS

2) After that we open the Ansys Software. This software may take few minutes to open.

3) Once the workbench opens; choose the CFD (fluent) option which is located at left side of the window. This window shows different types of options.

- Geometry
- Mesh
- Step
- Result

4) Click on the Geometry option & import the solid work's file which we have saved before; And after that open Ansys Workbench.

5) After opening the model in workbench check out the components are connected or not; because the Ansys is CAE software (computer aided engineering) and solid works is CAD (computer aided design) Software. When we import the certain CAD file to CAE file there are some chances to lose the components.

6) After inspecting the model in workbench; click on mesh option. In that click on the Generate mesh option. After choosing generate mesh it will create mesh on the component. That means component will divided into small number of parts. Mesh performs a very important role in Analysis or in CAE.

6. RESULT

Many material and type are check to have a successful radiator with all needs. We select the copper and brass material and triple row tube and straight fin due to this we can reduce the size of radiator. In this analysis type we get the temperature of water at different intervals of time and from results it seems that the temperature of water decreases through simulation.

7. CONCLUSIONS

Thus,

- This work has made a study and analysis of the thermal behaviour of the automobile radiators using the LMTD and ε–NTU methods of designing radiators for various parameters of mass flow rates of coolant and air with its specific geometrical parameters.
- The performance enhancement of automobile radiators is found to be accomplished mainly by altering the convective heat transfer coefficient.
- The presence of case studies and comparing their results with the software generated results has proved an easier way of designing radiators which saves the time of the designer.
- In addition, the case studies reveal that ε–NTU method is the most reliable method of designing radiators which are of cross flow type heat exchangers.

We did a lot of research to get best results of cooling of an engine with improved efficiency. And our performance got improved each time as we did our experiments on cooling system.

REFERENCES

- Elankathiravan Mathivanan and Liping Liu. May 4, 2016. Impact of Nanofluids on Heat Transfer Performance of a Motorcycle Radiator.
- Vishal v. Kulkarni, Abhijeet S. Dhakane. 07 July, 2016. Design and Development Cases of Tubes Structure for Automobile Radiator Performance and Compactness. (2278-0181)
- Gabriel Kuntzer, Mario Edurado Santos Martins, Paulo AusgustoSoliman, Fernando Mariano Bayer, Marcello Sangaletti. 22 September- 24 September 2015. Development of a Fsae racecar cooling system.
- Dhananjay Kale. January 12, 2013. Improve Heat Dissipation Rate of the Vehicle Radiator by Using Carbon Foam Material for the Fin.
- Matthew Carl, Dana Guy, Brett Leyendecker, Austin Miller, and Xuejun Fan. April 4, 2012. THE THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THEHEAT TRANSFER PROCESS OF AN AUTOMOBILE RADIATOR.
- Lasse Christoffersen, David Soderblom, Lennart Lofdahl. 6 July- 7 July 2009. Optimizing the cooling Air flow of a formula Car using CFD.
- James klett, ronott&aprilmcmillan. June 19, 2000. Heat exchanger for heavy vehicles utilizing high thermal conductivity graphite foam.
- Tim (Zhigang) Lin and Rick J. Yoon, X. A. Zhu and C. T. Tsai, Jeffrey Kozierowski and WsewolodHnatczuk. April 11 2005. A Strength-enhanced, High Efficiency Carbon Foam Radiator.
- P.S. Amrutkar, S.R. Patil. 01 January, 2005. Automotive Radiator Sizing and Rating. (2320-334X)
- Brandon Fell – Recorder Scott Janowiak – Team Leader Alexander Kazanis – Sponsor Contact Jeffrey Martinez – Treasurer. 2007. High Efficiency Radiator Design for Advanced Coolant.
- Rick Ruijsink, John Hoorneman, and Coen Mulders, March 29-Apri l 1, 1993. The Measurement of the Distribution of the Airflow Through a Radiator, Vehicle Thermal Management Systems Conference Columbus, Ohio.

- Ralph L. Webb. 24 February, 1992. The Tubes Touching Multi-row Radiator Design. (920548)
- Junji Miyake, Masahiro Tsuji, Susumu Kawauchi. 1986. Corrosion Prevention for Automobile Radiator Tubes.
- Thomas R. Veling, Nancy E. Marsh, Gene D. Dickirson, Joseph R. Glasser. February 28, 1983. Ford Mechanically Assembled Aluminum Radiator, 400 COMMONWEALTH DRIVE WARRENDALE, PA 15096.
- Chavan D. K. June, 2013. Study, analysis and design of automobile radiator proposed with cad drawings and geometrical model of fan.
- Prof. V. C. Pathade, Sagar R. Satpute, Mayur G. Lajurkar, Gopal R. Pancheshwar, Tushar K. Karluke, Niranjan H. Singitvar. 2017. Design and analysis of car radiator by FEA.
- Sandeep Patel, Dr. S. P. Deshmukh. November, 2017. Analytical design and verification of automotive radiator using 1-D simulation.
- Kishor Udawant, Vikram Tandon and Ashok Joshi. 16 April, 2012. Design and development of radiator fan for automotive application.
- Supra SAEINDIA Student Formula Rule Book 2020.