International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 03 | Mar 2020 www.irjet.net p-ISSN: 2395-0072

REVIEW PAPER OF ENGINE COOLING SYSTEM

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ABSTRACT-

In this paper we will see how an automobile radiator was designed, developed and how it was made efficient for automobile in all condition. The first research was done 1983 by Ford Company who used first radiator which was using aluminium in most of its portion. It was better in transferring heat away from the engine keeping it cool. Many companies adopted this and used in their automobiles. Many discoveries were made in the engine cooling system one was done in 1993 regarding airflow through radiator which made sure that the radiator work efficiently and will not heat up in long rides. They considered aerodynamic drag, crosswind, heat rejection and thermal balancing was done on it. In 2012 theoretical and experimental investigation on heat transfer of an automobile radiator was done to make sure that the radiator will work safely on paper as well as in practical usage. From year 2000 to 2013 researches were done using new material carbon foam which was used for making the fins of the radiator. It was compared with other materials (Aluminium) which were used in making fins and found to be better in most of the scenarios. In 2016 nano-fluids were used in the coolant and were tested in different conditions and was found to be giving excellent results in transferring heat away from the engine.

INTRODUCTION-

Before 1983 automobile's radiator were made of using copper and brass. In 1983 ford company discovered that aluminium was a better material for transferring heat away from the engine and was lighter than copper and brass and was lower in cost, reliable than copper and brass. 3003 Al was used for making walls (tubes), fins with hard 3003 Al, header with 3005 Al. different testings like calorimeter, extreme durability, corrosion, qualification for vehicles. In 1986 researches were done in which they found out that corrosion resistant material was better for automobile radiator tubes and it is beneficial for effective cooling. From various materials brass was fulfilling the requirement. In the year 1992 author Ralph L. Offer mechanical and thermal design advantages for copper-brass radiators. This core design provides good heat conduction in full fin depth. This was done by changing shape of tube and also introduced two in size of one tube. In 1993 tests were done on airflow passing around the radiator which makes sure that the radiator runs at its optimum condition. An automobile with a radiator installed in it was tested in a lab on practical and software basis. All the scenarios which the radiator will come across were tested (aerodynamic drag, crosswind flowing from the radiator, etc.). How air was acting around the radiator and helping the radiator to cool down the engine and all things were noted. In this paper the author used different method for optimizing radiator size from calculation they used e-NTU method to achieve the desired radiator specification. In year 2009 am SAE team from Sweden Made a FSAE car in which they were radiators cooling was improved by having overheating issue. To overcome these issue; they implemented the side pods which were improving the radiators assembly by using aerodynamic of the car. In 2012 a detailed testing was done on the radiator and was cross-verified with theoretical calculations which were used to design them. The formulae derived for making the radiator were checked in practical life. In 2013 radiator were tested on their heat dissipating factor by using different materials for fin. Materials like brass, copper, aluminium and a new material carbon foam. They were tested in different scenarios and in those experiments, it was found that carbon foam was performing better in most of the experiments and was 40% better than aluminum and was giving better heat dissipation from the radiator. Up to year 2015 the radiator that were manufactured were bigger in size due to which carrying them with the vehicle had huge load on the engine. To overcome this and reduce the size of the radiator different ways were taken into consideration and size both radiators was achieved. In 2016 nano-fluids were discovered and a test was performed using them as a substitute in the coolant used in automobiles. It was found that by using them in the coolant, better thermal properties were achieved then the conventional fluids used in those days. Also, in the year 2016 an experiment was done in which they used different types, shapes and flow of the tube in the tube in the assembly of radiator. They found different result in each case. The result was compared and a better tube assembly was selected.

LITERATURE REVIEW-

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 fulfill 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 $1/10^{th}$ 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 $1/5^{th}$ 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 its 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 whichwas 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 helpto 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 testings they observed that carbon foam's heat transfer coefficient was 40% greater than aluminium and it was 28% lighter in weight than aluminum. [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 were 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 nanofluid 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 nanofluid 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]

CONCLUSION-

- In 1983 it was concluded that using aluminium for making radiator was providing better reliability and durability to the radiator also made the radiator light and was also lower in cost to its copper and bronze counter parts.
- In 1993 it was concluded that the air flowing around the radiator played a major role in cooling of the fluid which decided the heat transfer from the radiator.Different air flow was considered while considering drag, thermal balancing, crosswind Sensitivity influenced by yawing and lift of vehicle.
- In 2000, carbon foam was introduced which resulted in the increase of thermal conductivity of the radiator.
- In 2005, to improve the carbon foam strength and bonding with each other SiC coating and metallization layer was added
- In 2007 the porosity and heat transfer coefficient of carbon foam was increased
- In 2012 it was concluded that the theoretical approach and practical approach were similar in most tests.
- In 2013 it was concluded that using carbon foam material for making fins of the radiator provided excellent heat dissipation, better thermal conductivity.
- In 2016 it was concluded that using nanofluid in the coolant resulted in better heat transfer rate,

also helped in reducing the weight and size of radiator, also it was seen that the consumption of fuel was reduced.

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