BE Project Report

Project Title:

Design and Manufacturing of a Cooling System of a Vehicle

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Certificate

This is to certify that the Dissertation entitled "Design and Manufacturing of cooling system of a vehicle" is bona fide record of the dissertation work done by

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In the year 2016-17 under the guidance of Prof. Vijay Shinde of Department of Mechanical Engineering in partial fulfilment of requirement for the Bachelor's Degree in Mechanical Engineering of University of Mumbai.

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Guide/ Co-Guide Head of the Department

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Principal

Date:

Place: Mumbai-77

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Certificate of Approval of Examiners

We certify that this project report entitled “Design and Manufacturing of cooling system of a vehicle” is bona fide record of project work done by

1. Apoorva Kini
2. Karan Parikh

This project is approved for the award of Bachelor’s Degree in Mechanical Engineering of University of Mumbai.

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External Examiner Internal Examiner

Date:

Place: Mumbai-77

Introduction:

Main aim of an engine cooling system is to reject excess heat of engine efficiently, i.e. keeping engine at its optimum working temperature for smooth running of a vehicle. This should be achieved taking weight and compactness into consideration. If the system is too bulky it might hinder with the other systems which is undesirable. Implementing the theory of heat transfer to design and manufacture a reliable and effective system is our goal. The sole purpose for this is to safeguard the engine from wear and tear and prevent the scuffing of pistons rings. The material used will be based on a number of factors and parameters. The design will then optimised by iterating different types of heat exchangers in calculation and one final design will be selected. The manufacturing of the design begins and then the radiator will be placed according to the placement of other components of the vehicle. The placement will be considered to be near the engine for easier and effective routing. After the radiator placement the routing is to be made based on the space constraints. Routing material will be selected considering an approximate temperature of radiator outlet which can be calculated and again weight is to be considered. Care should be taken that routing should not be complex as complex routing might not be feasible for manufacturing. Other components include the header tank, catch can and pressure cap. Then whole system is to be integrated and this establishes the efficient cooling system of a vehicle. The practical testing of this can be done by sensors logging the data in running conditions and the system is finally validated. Any mishaps or problem encountered will be looked after and worked accordingly. Thus this will validate the reliability and efficient working of the cooling system as a whole.

Literature Review:

Failures of the cooling systems were, by far, the leading cause of engine failures. It is generally a limitation of most cooling systems that the cooling fluid is not allowed to boil, as the need to handle gas in the flow greatly complicates design. For water cooled system, this means that the maximum amount of heat transfer is limited by the specific heat capacity of water and the difference in temperature between ambient and 100°C. This provides more effective cooling in the winter or at higher altitudes where the temperatures are low but system might over heat or cause dry running at tropical temperature. The most obvious, and common, solution to this problem was to run the entire cooling system under pressure. This maintained the specific heat capacity at a constant value, while the outside air temperature continued to vary.

- Parts Used:
  - Radiator:

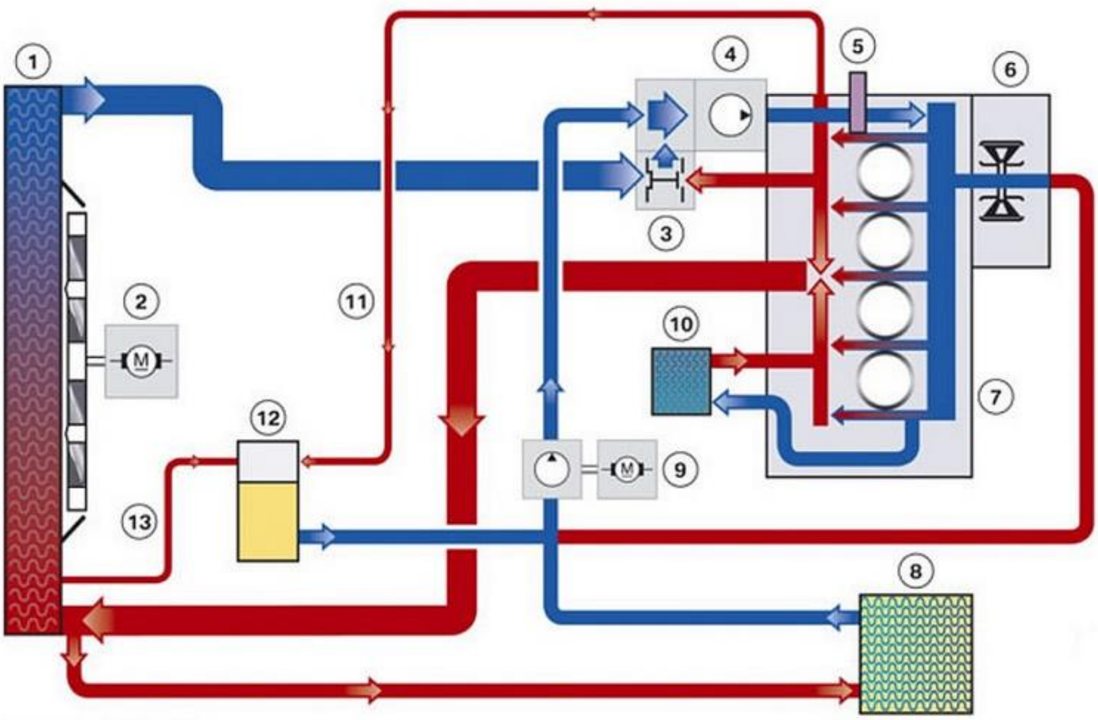
    Radiator is main part of cooling system. The radiator is connected to the engine with channels through which a liquid is pumped. This liquid can be water or another coolant, such as antifreeze. By taking the liquid through the engine, it heats up the liquid and takes it outside of the engine to let it cool down. It is usually located in front of the vehicle's grill in order to benefit from the airflow as the vehicle moves.

- Header Tank & Catch can:

Header tank and catch can is the storing units of extra coolant in a cooling system. In case of loss of coolant in running system due to leakage, vaporization or any other losses, coolant from header tank will take its place. Catch can is used to cool and condense the vaporised coolant and bring it back to the system when needed.

- Routing:

Routing is the pipe that carries coolant from engine to radiator and back. The main consideration of routing pipes is that it should not melt or chemically react to form other material when hot coolant passes through it. Routing should also be able to sustain the pressure of the pressurised system. Positioning should be such that it should not come in contact with any human as well as electronics system.



- Pressure Cap:

  Pressure cap is an important part in running this pressurised system. It checks for the system pressure. If the system pressure exceeds the Rated Pressure spring will compress and vapours will be released which goes into the catch-can and condenses. When the cooling system pressure drops the pressure cap pulls condensed water from catch-can thus serves the purpose of maintaining the pressure in the pressurised system.

- Fan:

  Fan is used for forced convection. When the temperature of the system exceeds a certain value due to insufficient air flow rate (i.e. at stationary conditions or at a lower speed of a vehicle) fan is switched on either mechanically or automatically (using MoTec).

- Duct:

  Duct is used to concentrate the flow of air through the radiator. Using Bernoulli's principle and continuity equation duct is designed.

Methodology:

First the flow rate of engine mechanical pump is calculated using flow meter test. The engine is mounted on a test rig and the flow rate at different RPM is calculated using flow meter. These values are required to calculate the heat load to be rejected by the system.

Material is to be selected based on various parameters like:-

1. Coefficient of Conductivity (k)
2. Density of the material
3. Manufacturing Feasibility
4. Availability of material
5. Cost

The most probable material are:-

1. Copper
2. Aluminium
3. Aluminium with copper brazing

The type of cross flow radiator used is based on size and compactness of the heat exchanger based on the calculations of heat load to be rejected and material selected. The two types of heat exchangers considered are:-

1. Single Core
2. Dual Core

Increasing the radiator fin count, or number of fins per inch, provides more surface area for the transfer of heat to the cooling air. However, increasing the fin count increases the restriction of the radiator to cooling airflow. Lower cooling airflows result in lower heat transfer. In every installation there is an optimum combination of fin performance and core restriction that will produce maximum heat transfer. Increasing the core restriction from this optimum point by increasing fin count will reduce the heat transfer performance of the radiator. On the other hand, if the original radiator has a very low fin count, increasing will improve heat transfer. In general, for high performance applications, fin counts from 12 fins per inch to 16 fins per inch are optimum.

Increasing the fin count above 16 fins per inch will almost always result in reduced heat transfer performance. Since, as we have seen, in a given installation under "steady-state" conditions the radiator must transfer the given heat load no matter what, the reduced heat transfer performance resulting from an excessively restrictive high fin count must be compensated for by increased coolant temperature, possibly to the point of overheating.

Types of Fins

1. Serpentine
   a. Louvered
   b. Non-louvered
2. Pin fin
3. Annular fin
4. Variable area fin
5. Constant area fin

Dual Core Vs Single Core

In a dual core system the weight increases significantly as the flow rate is reduced while passing through the second core where as a single core required to reject same amount of heat will be less in weight and much more effective. The compactness of the radiator in a dual core is more than a single core.

The fins used are louvered fins. The fins are corrugated to induce transition state in cross flow to increase heat transfer process. Various other parameters such as fin pitch, fin density and fin angle is fixed according to the manufacturing constraints given by the manufacturer. The radiator dimensions are calculated using Number of Transferred Units (NTU) method of heat load rejection.

The radiator placement is dependent on the size of the radiator and placement of the other components of the system. The placement is considered based on the air flow into the radiator, closeness to the engine for effective flow of the coolant.

The routing is made based on the placement of the radiator in the component. The routing hoses are made up of silicone and vulcanised rubber. Coolant used is water as this is the restriction given by the competition. After the manufacturing the testing is done by practically mounting the radiator in the desired position and running it at different conditions. The data is logged using various sensors and validated.

The pressure drop across the radiator is calculated using pitot tube apparatus by constructing a wind tunnel for the same.

RADIATOR CALCULATIONS:

Cooling calculations using NTU method:-

Radiator- 330*250*30 (mm)

Length- 250mm

No. of tubes- 24 (2mm tube 24mm wide tubes)

Fins per inch = 16

Height = (24*2) + (25*8) = 248mm

Fin pitch = 1.67mm

Total no. of fins = .63*250*25 = 3937

Fin thickness = 0.1mm

Louver angle = 32^0

Louver pitch = 1mm

Pump flow rate = 85 litres/min

For calculations taking pump flow rate 80LPM accounting losses

Air velocity =7.5 m/s (assuming)

Water inlet temperature = 90 ^{0}C

Air inlet temperature = 30 ^{0}C

80 Litres/min = 0.08 m^3 /s = 1.33×10^{-3} m^3 /s

Flow in one tube = 5.54×10^{-5} m^3 /s

Velocity in one tube = 1.85 m/s

$$Re = \frac{\rho V\ D}{\mu}$$

$$Dh = \frac{4 \times Acr}{L \times \rho \times C}$$

$$= \frac{4 \times 1 \times 30 \times 10^{-6}}{\left(\frac{2}{100}\right) + \left(\frac{2 \times 30}{1000}\right)}$$

$$= 1.935 \times 10^{-3}\ m$$

$$R_{CD} = \frac{\rho V\ D}{\mu}$$

$$= \frac{965 \times 1.85 \times 1.935 \times 10^{-3}}{0.000315}$$

$$= 10953$$

$$f = (0.79 \ln Rcd - 1.64)^{-2} = 0.3$$

$$N_u = \frac{\left(\frac{f}{8}\right)(Rcd - 1000)Pr}{1 + 12.7\left(\frac{f}{8}\right)^{0.5}\left(Pr^{\frac{2}{3}} - 1\right)}$$

$$= \frac{\left(\frac{0.03}{8}\right)(10953 - 1000)(1.96)}{1 + 12.7\left(\frac{0.03}{8}\right)^{0.5}\left(1.96^{\frac{2}{3}} - 1\right)}$$

$$= \frac{(3.75 \times 10^{-3})(9953)(1.96)}{1 + 12.7(0.0612)(0.566)}$$

$$= 50.791$$

$$55.69 = \frac{h_c R_{cd}}{k_c}$$

$$hc = 16823.02\ W/m^2K$$

<u>Air</u> <u>Side</u> :

$$R = \frac{\rho V\ D}{\mu}$$

$$= \frac{1.33 \times 7.5 \times 2.763 \times 10^{-3}}{1.8 \times 10^{-5}}$$

$$= 1289.89$$

$$D_{h,air} = \frac{4 \times 8 \times 1.67}{(8 + 1.67) \times 2} = 2.763\ mm$$

Colburn Factor (j) :

$j = (R_{epl})^{-0.49}(\frac{\theta}{90})^{0.27}(\frac{Pf}{Pl})^{-0.14}(\frac{Lf}{Pl})^{0.29}(\frac{Dt}{Pl})^{-0.23}(\frac{L}{Pl})^{0.68}(\frac{Pt}{Pl})^{-0.28}(\frac{tf}{Pl})^{-0.05}$

$= (1289.89_{l})^{-0.49}(\frac{30}{90})^{0.27}(\frac{1.67}{1})^{-0.14}(\frac{8}{1})^{0.29}(\frac{25}{1})^{-0.23}(\frac{6}{1})^{0.68}(\frac{10}{1})^{-0.28}(\frac{0.1}{1})^{-0.05}$

$= 0.049\times0.74\times1.144\times0.047\times3.382\times0.5248\times1.122$

$= 0.0344$

$j = \frac{h_a\times Pr^{2/3}}{\rho a\times \mathrm{Va}\times \mathrm{Cpa}}$

$0.0344 = \frac{\mathrm{ha}\times(0.712)^{2/3}}{1.164\times7.5\times1.005\times10^3}$

ha = 378.52 W/m^{2}K

$m = \sqrt{\frac{\mathrm{ha}\times\mathrm{Pf}}{\mathrm{Kf}\times\mathrm{Acr}}}$

$P_f = 30\times2+0.1\times2 = 60.2$mm

$A_{cr} = 30\times0.1 = 3\times10^{-6}$ m^2

$m = \sqrt{\frac{176.78\times60.2\times10^{-3}}{250\times3\times10^{-6}}}$

$= 174.305$

$n_f = \frac{\tanh\left[m\left(\frac{Lf+m}{2}\right)\right]}{m\left(\frac{Lf}{2}\right)} = 0.8642$

$A_f = (3937\times8\times30\times2)$ mm^2 = 1.89 m^2

A_{ps} = (250*30+30*250+250*250) mm^2 = 0.192 m^2

$A_{total} = A_f + A_{ps} = 2.08176$m^2

$\eta_{total} = 1 - \frac{\mathrm{Af}}{Atotal}(1-\eta\mathrm{f}) = 0.877 = 87.7\ \%$

$U = (\frac{1}{hw} + \frac{tt}{kt} + \frac{Ao}{Atotal\times\eta\mathrm{total}\times\mathrm{ha}} + Rf)^{-1}$

$= (\frac{1}{15263.53} + \frac{0.5\times10^{-3}}{250} + \frac{0.192}{2.08176\times.877\times174.305} + 0.0003)^{-1} = 1545.859$

$U = 1545.859\ W/m^2K$

$M_h\ C_{ph} = C_h \rightarrow$ hot fluid capacity rate

$M_c\ C_{pc} = Cc \rightarrow$ cold fluid capacity rate

$M_h = 1.33\times10^{-3}\ m^3/s = 1.33$ kg/sec

$C_{ph} = 4.208\ KJ/kg^0K$

$C_h = 1.33\times4.208 = 5.6$ KW/K

Air velocity $\rightarrow$ 7.5m/s

Blocked Area = $(2\times250\times30)+(3937\times0.1\times8) = 15053.6\ mm^2$

Total Area $\rightarrow 248\times250 = 62000\ mm^2$

Air Flow Area = $46946.4\ mm^2 = .046946\ m^2$

Air velocity flow area = $0.046946\times5\times1.166= 0.4098$kg/sec

$m_a = 0.4098$ kg/sec

$C_{pa} = 1.005$ KJ/kgK

$C_c = 0.4098\times1.005 = 0.411891$KW/K

$C_{min} = C_c = 0.411891$ KW/K

$C_{max} = C_h = 5.6$ KW/K

$$NTU = \frac{UA}{\text{Cmin}} = \frac{1545.859\frac{W}{m2K}\times2.0817m2}{0.41189\times1000\ W/K}$$

$= 7.813$

$$\frac{Cmin}{Cmax} = \frac{0.41189}{5.6} = 0.07355$$

$\epsilon = 0.9$

$Q = \epsilon\times C_{min} \times(T_h-T_c)$

$= 0.9\times0.41189\times(90-30) = 22.24$ KW

This is the sample calculation for the previous radiator design.

Conclusion:

Failures of the cooling systems were, by far, the leading cause of engine failures. Therefore design and manufacturing of a reliable cooling system is must for smooth and efficient running of a car.

Future Line of Action:-

1. Radiator material selection
2. Radiator size calculations
3. Radiator design finalisation
4. Routing design finalisation
5. Testing heat load produced by the engine
6. Routing and radiator placement considerations
7. Ensuring leak proof system