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Study of Cooling System in I.C. Engine Improving Performance with Reduction of Cost

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Abstract

Background/Objectives: Cooling system of the engine is one of main essential systems for automobiles, which maintains the engine temperature to the sustain conditions. Hence the main objective of this project work is to propose a simple piping design with less number of connecting hoses and also to reduce coolant leakage. It is also proposed to change the piping material from aluminium alloy to mild steel which reduces the overall cost of the engine cooling system. **Findings:** The proposed design addresses the coolant leakage problem and reduces the number of parts used in coolant pipe connections hence leading to cost reduction and simplified design. **Application/Improvements:** The proposed design would benefit with coolant leakage elimination by reduction in hose defects, reduced head loss, cost reduction and improved life of piping system in automobiles heavy vehicles.

Keywords: Automobiles, Cooling System, I.C. Engine, Mild Steel, Piping Design

1. Introduction

The majority of I.C. engines have cooled by air or liquor coolant passing via air fins or radiator. The majority of the liquor-cooled I.C. engines using coolant oil which has been combination of water as well as chemical like anti-freeze and rust inhibitors. The industry word of antifreeze mixture is coolant oil for engine cooling system. Coolant oil based cooling system minimizes the happening of hot spot that difficult to avoid when applying air cool.

The rate of heat transfer when using coolant oil is 47 percentage higher than the clean water[1]. There is a continuing effort to develop fluid flow simulation capability coupled with heat transfer calculations for the analysis of cooling airflows. It is of course important to get an accurate cooling flow simulation, that the aerodynamics is well modeled[2]. The mathematical learn in favor of heating absence of experimental correlation when considering flow as wick[3]. Transitory act in smooth heat tube for cooling various electronics apparatus by calculate the liquid flow in vapor core as well as wick area by passing 2D hydrodynamic method[4]. When added the alumina particle causes linear increment of thermal conductivity in aqueous fluids[5]. The importance of particle size and viscosity of fluid in respect of thermal conductivity enrichment relation of them[6].

The heat transfer performance in super hydrophilic copper to fabricate post wicks in silicon substrates for depositing as well as controlling oxidation[7]. The effect of using unleaded gasoline and additives blends (Ethanol blends and Isobutanol-Ethanol blends) on Spark Ignition engine (SI engine) performance and exhaust emission. The engine used for experimental purpose is Bajaj engine of 5.2 kW (7.2hp). A new multi liquid fuel mixing system has been developed for perfect mixing and hence found better for investigating effects of various ethanol fuel blends (E10, E20, E30) and isobutanol and ethanol gasoline mixture. They found. They found that the CO and HC

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emissions concentrations in the engine exhaust decreases while the NO_X concentration increases. The addition of 5% isobutanol and 10% ethanol to gasoline gave the best results for all measured parameters at all engine torque values[8]. The effect of liquid nitrogen when it is applied to heat generation zones through holes made in the cutting tool insert during the turning of Ti-6Al-4V alloy with PVD TiAlN coated tungsten carbide cutting tool inserts of ISO CNMG 120408 MP1–KC5010. They observed that in the cryogenic cooling method, the surface roughness was reduced to a maximum of 33% over wet machining. Cryogenic cooling provided the substantial benefit in reducing the cutting forces and improving surface roughness through control of the cutting temperature and reduction in adhesion between the interacting surfaces[9].

A variable heat rejection system that uses multiple Loop Heat Pipes (LHPs) to reject large heat loads from a single - phase pumped loop, with high turndown ratios[10]. The performance characterization of the nano fluid coolant in engine radiator. They also reported that the performance of the nano fluid compared with ordinary coolant fluid used in radiator[11]. The performance analysis of single cylinder, air cooled diesel engine using fish oil biodiesel (B20) with diesel[12]. The specific fuel consumption as well as brake thermal efficiency increases also decreasing exhaust emission considerably due to the blends of Tamanu Methyl Ester and DiEthyl Ether with diesel[13].

This research paper proposed a simple piping design with less number of connecting hoses and also to reduce coolant leakage. It is also proposed to change the piping material from aluminium alloy to mild steel which reduces the overall cost of the engine cooling system. The proposed design addresses the coolant leakage problem and reduces the number of parts used in coolant pipe connections hence leading to cost reduction and simplified design.

2. Cooling System in an I.C. Engine

A simple schematic of thermo siphon cooling system is shown in Figure 1.

This type of cooling system is employing in recent automobile vehicles. The coolant water presents in the system circulated by pump through water passage in the head and block of the engine. The heat generated by engine is absorbing by coolant water method of heat conduction. The hot coolant water allows into the radiator for cooling

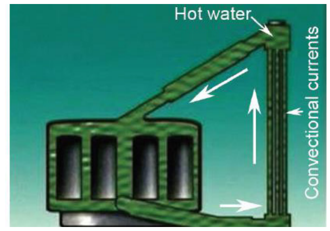

Figure 1. Thermo siphon cooling system.

after that this cycle is repetitive. Thus temperature of the engine is detached to avoid overheating and maintain the engine with working temperature.

2.1 Hoses in Cooling System

Figure 2 shows the hoses fitted in an I.C. engine.

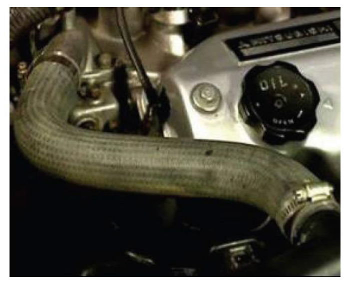

Figure 2. Hoses fitted in an I.C. engine.

The radiator and the engine are connected by the hoses for flexible operation. The hoses are tightly fitted by using hose clip. The radiator hoses should able to withstand and carrying hot water in the system.

2.2 Thermostat Valve in Cooling System

Figure 3 shows the thermostat used in cooling system.

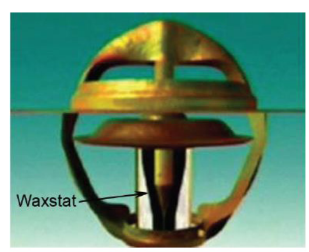

Figure 3. Thermostat valve in cooling system.

It is important to keep engine always in working temperature. In order to maintain the engine function at working temperature the thermostat valve is fitted in between the engine water outlet and the radiator water inlet. When the engine becomes exceed the working temperature the valve is open and allowing water to the radiator for cooling. When the engine operates below the working temperature valve does not allow the water to the radiator and its circulating water to the engine through bye pass line.

2.3 Radiator in Cooling System

The schematic of radiator in cooling system is shown in Figure 4.

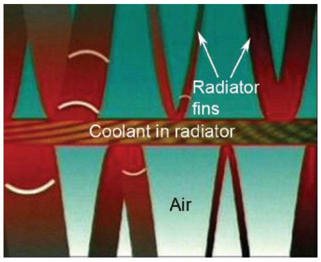

Figure 4. Radiator in cooling system.

The radiator is located in front of the engine. It has a top and bottom tanks to accommodate coolant water. The cooling fins in the form of tube are arranged vertically in between these two tanks. When the engine attains above normal temperature the thermostat allows the coolant water into the radiator top tank. Then coolant water flows to the bottom tank of the radiator via cooling fins. The heat presents in the coolant water transfer to the atmosphere by conduction and convection methods by the fin materials and cooling fan air respectively. Thus the radiator is acts as a heat exchanger of the cooling system in I.C. engine.

2.4 Radiator Cap

Figure 5 shows the pressure cap in radiator.

Figure 5. Pressure Cap in Radiator.

This cap is tightly fitted using pressure spring at the top of the radiator. It prevents the flow of water outside the radiator. It keeps the working pressure and temperature at constant in the system of cooling. Air vent is also providing at the top of the cap.

2.5 Water Pump in Cooling System

The schematic of water pump in cooling system is shown in Figure 6.

Figure 6. Water pump in cooling system.

It is fitted in front of the engine. It is connected with the engine crank shaft pulley by means of belt for its rotation. It gives the required pressure for circulating the coolant water throughout the system of cooling. The lubrication provision is given to the bearing of the water pump. Also it gives seating location of the fan blade.

2.6 Recovery System to Maintain Coolant

Figure 7 shows the recovery system to maintain coolant.

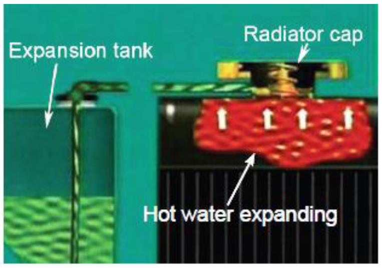

Figure 7. Recovery system to maintain coolant.

The extra coolant water is stored in the recovery system. Whenever the level of the coolant water in the system of cooling becomes lowering due to evaporation it maintains the constant level during the operation of engine. It is connected to the top tank of the radiator. It supplies the required coolant water through one way valve.

2.7 Indicator for Indicating Engine Temperature

The Indicator for indicating engine temperature in cooling system is shown in Figure 8.

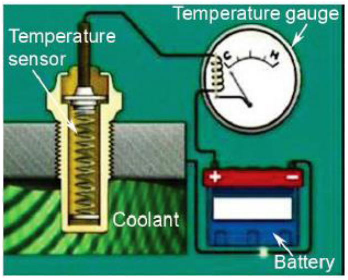

Figure 8. Temperature indicator in cooling system.

It has a sensing plug which is immersed in the coolant water presents in the engine block water jackets. The view of the Sensing Plug in the system of cooling is shown in Figure 9.

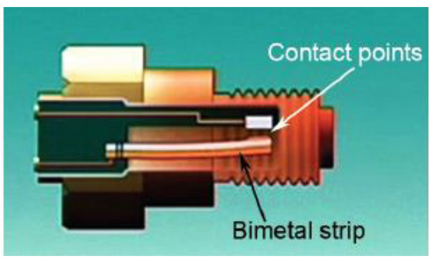

Figure 9. Sensing Plug in the system of cooling.

It senses the temperature of coolant water and indicates through temperature gauge. Whenever engine gets experienced temperature in serious condition due to the sudden failure of water pump and leakage through hoses it gives danger sound for pre caution to engine failure due to overheating.

3. Engine Coolant and its Composition

In earlier I.C. engine system of cooling was using only water. In order to improve the cooling effect and suitable for weather condition such as winter and summer coolant oil is added with water to avoid boiling and freezing of cooling water in the system during operation.

Now a days in modern I.C. engine cooling system water is mixed with Monoethylene Glycol fluid to improve system of cooling performance with low cost. In addition propylene glycol also added with coolant water for the application of automotive and heavy duty I.C. engine in view of obtaining effective cooling system performance. Mixing of coolant oil also prevent the corrosion, rust formation, oxidation of the engine parts. It also avoids bubble formation during the circulation to improve the performance.

4. Piping in Existing Cooling System

Figure 10 shows the already existing cooling system piping hoses design used in Ashok Leyland vehicle for the model Eagle 814 LHD is more defective.

Figure 10. Existing cooling system piping and hoses (Ashok Leyland vehicle - model Eagle 814 LHD).

Because in these type of design there will be coolant leakages occurred. It uses too many parts to connect the pipes and hoses in the cooling system. In this design there is more number of bends which leads to losses in pipe that will affect the cooling efficiency. Then the pipe material is aluminium which is more cost and it have blowholes while moulding that also leads to coolant leakage. It is not feasible to manufactures while in assembly section and not easy for customers while replacing it. This design is doesn't withstand for the long period of life.

4.1 Problems in Existing Cooling System Pipes and Hoses

4.1.1 Rubber Hoses Defects

Hardened hoses will become brittle and will break and leak. Under the pressure during the circulation of coolant water through inflated hoses may losses its suppleness and causes crack and leakage of coolant water.

4.1.2 Head Loses in Pipe and Hoses

Inlet pressure is 2 bar, inner diameter of pipe is 0.035m and length of the pipe is 0.850 m.

$$P = \rho * g * h$$

The liquid flowing through the pipe is engine coolant which is usually ethylene glycol. And the density of ethylene glycol is 1100 kg/m3. Therefore, Pressure is 1100*9.81*h,

$$h = 2*10^5 / 1110 * 9.81$$
$$h = 18.37$$
$$\text{Velocity} = \text{sqrt}(2 * g * h)$$
$$\text{Velocity} = \text{sqrt}(2 * 9.81 * 18.37) = 19 \text{ m/s}$$
$$\text{Flow rate } Q = A * V = \pi/4 * 0.035^2 * 19$$
$$Q = 0.0186 \text{ m}^3/\text{s}$$

4.2 Losses in Pipe Flow

4.2.1 MajorLosses

According to Darcy Weisbach's equation the head loss for a flow across a pipe is given to be

$$\Delta h = f*l*v^2 / 2 * g * d$$

Where, f is Darcy friction coefficient, l is length of the pipe, v is velocity, g is the gravity force and d is pipe diameter.

4.2.1.1 Reynolds Number

$$Re = V * d / V$$
$$Re = 19*0.035 / 17.8 * 10^{-6}$$
$$Re = 37360. \text{ Hence the flow is turbulent.}$$
Therefore,
$$\text{Friction factor } f = 0.316 / Re^{0.25}$$
$$= 0.316 / 37360^{0.25}$$
$$= = 0.0227$$
$$\Delta h = 0.0227 * 0.85 * 19^2 / 2 * 9.81 * 0.035$$
$$\Delta h = 11.36$$

4.2.2 Minor Losses in Pipe

The minor losses in this case is mainly due to bends in the pipe, let us discuss upon it. In the previous pipe arrangement as shown in the figure we could see a four elbow 90 degree bends and hence the losses are given as,

$$Hb = K * v^2 / 2*g$$

Where, K is loss coefficient and the value depends upon the angle of bend, V is velocity across the flow. The value of K for the elbow plain 90 degree is given to be 0.3. Hence,

$$h_b = 0.3 * 19^2 / 2* 9.81$$
$$hb = 5.52$$

Since there are four similar bends in the figure the total value of h^b will be

$$h_b = 5.52 * 4 = 22.08$$

Hence the total loss is given to be

$$h_L + h_b = 11.36+22.08 = 33.44$$

Hence the total loss of energy is given to be 33.44 for the existing design.

Due to pipe material, in existing design aluminium is used as a pipe material which is more cost and in casting of aluminium pipe blow holes are occurred which also lead to coolant leak. Then in the design we using washers for tightening purpose these washers are made of metals due to shear may occur in the aluminium pipe. While using this design we want to use adapters the adapters are also cause coolant leak. For that we want to change the pipe material.

4.3 Pipe Material: Aluminum

4.3.1 Pipe Weight Calculation

Volume of pipe (v) = $\Pi/4*(D_1^2 - D_2^2)*L$
Where, D_1 is 0.045m, D_2 is 0.035m, L is 0.06m, Mass of the pipe (m) =v*ρ, Density of aluminum = 2860kg\m³ and weight of the pipe (w) = m*g.

Weight of aluminum pipe (w) is 0.89kg
Cost of aluminum = Rs.224/kg
Cost for making existing design = 0.89*224;
= Rs.200.

5. Proposed Cooling System Piping Design

The 3D view of the proposed cooling system piping design is shown in Figure 11.

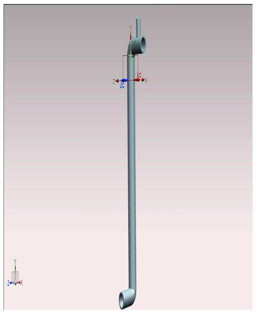

Figure 11. 3D view of the proposed cooling system piping design.

5.1 Problems Rectified

5.1.1 Rubber Hose Defects are Rectified

The new proposed design has minimum number of bends, which reduces the use of rubber hose. In other words, Use of rubber hose is avoided in high heat radiating areas. Thus hardening of hose, cracking of hose, swollen of rubber hose is minimised. This would increase the life of working rubber hose.

5.1.2 Head Loss Calculation

Inlet Pressure = 2 bar
Inner diameter of pipe = 0.035m Length of the pipe = 0.850 m

$$P = \rho * g * h$$

The liquid flowing through the pipe is engine coolant which is usually ethylene glycol. And the density of ethylene glycol is 1100 kg/m^3. Therefore, Pressure = 1100*9.81*h.

$$h = 2*10^5 / 1110 * 9.81; h = 18.37$$
$$\text{Velocity} = \text{sqrt}(2 * g * h)$$
$$\text{Velocity} = \text{sqrt}(2 * 9.81 * 18.37) = 19 \text{ m/s}$$
$$\text{Flow rate } Q = A * V = \pi/4 * 0.035^{2 * 19}$$
$$Q = 0.0186 m^3/s$$

5.2 Losses in Pipe Flow

5.2.1 Major Losses

According to Darcy Weisbach's equation the head loss for a flow across a pipe is given to be

$$\Delta h = f*l*v^2 / 2 * g * d$$

Where, f is Darcy friction coefficient, l is length of the pipe, v is velocity of the flow, g is gravity force and d is pipe diameter.

5.2.1.1 Reynolds Number

$$R_e = V * d / V$$
$$R_e = 19*0.035 / 17.8 * 10^{-6}$$
$$Re = 37360. \text{ Hence the flow is turbulent.}$$
$$\text{Friction factor } f = 0.316 / R_e^{0.25}$$
$$f = 0.316 / 37360^{0.25}$$
$$\Delta h = 0.0227 * 0.85 * 19^2 / 2 * 9.81 * 0.035$$
$$\Delta h = 11.36$$

5.2.2 Minor losses in pipe

The minor losses in this case is mainly due to bends in the pipe, let us discuss upon it. In the previous pipe arrangement as shown in the figure we could see a four elbow 90 degree bends and hence the losses are given as,

$$h_b = K * v^2/2*g$$

Where, K is loss coefficient and the value depends upon the angle of bend, V is velocity across the flow. The value of K for the elbow plain 90 degree is given to be 0.3.
Hence, $h_b = 0.3 * 19^2 / 2 * 9.81$

$$h_b = 5.52$$

Since there are four similar bends in the figure the total value of hb will be

$$h_b = 5.52 * 4 = 22.08$$

Hence the total loss is given to be

$$h_L + h_b = 11.36 + 22.08 = 33.44$$

Hence the total loss of energy is given to be 33.44 for the existing design.
Now for the new improved design as shown in Figure 11.

$$h_b = 5.52 * 2 = 11.04$$

The total energy loss in this case will be

$$h_L + h_b = 11.36 + 11.04 = 22.4$$

Hence the minor loss for the new modified design is reduced to half the loss in energy.

6. Results and Discussion

Mild steel widely used various industrial application because of its various percentage of carbon content depends upon the requirement of yield stress. The various properties of mild steel and carbon percentage are tabulated in Table 1.

When a material having two yield points such as lower and upper would experienced yield point run-out while content low carbon steel. While the amount of mild steel 7.850 g/cm^3 the correspondent Youngs modulus is 210 GPA. Generally upper yield point having higher yield drop than the lower yield point and frequently utilized during huge amount of steel required.

6.1 Pipe Weight Calculation

$$\text{Volume of pipe } (v) = \Pi/4*(D_1^2 - D_2^2)*L$$

Table 1. Material properties of mild steel

% of carbon in steel	Density In $10^3 Kgm^{-3}$	Thermal Conductivity in $Jm^{-1}k^{-1}s^{-1}$	Thermal Expansion in $10\text{-}6k^{-1}$	Young's Modulus in GNm^{-2}	Tensile strength in MNm^{-2}	% of Elongation
0.20%	7.8600	50	11.7000	210	350	30
0.40%	7.8500	48	11.3000	210	600	20
0.80%	7.8400	46	10.8000	210	800	8

Where, D_1 is 0.040m, D_2 is 0.035m, L is 0.08m, Mass of the pipe (m) = v*ρ, Density of mild steel = 7850kg\m³, Weight of the pipe (w) = m*g, Weight of aluminum pipe (w) = 1.8kg, Cost of mild steel = Rs.64/kg,

Cost for making existing design:
= 1.8*64
= Rs.115

Thus from the new design the cost of making per piece is reduced to Rs.115

The new redesign of cooling system increases the efficiency of cooling system, reduces the rubber hose defects, reduces the bend losses in pipe, reduces the cost by changing the pipe material, brings long period of life and prevent from leaks due to less connecting components.

7. Conclusion

The existing piping in cooling system of Ashok Leyland Eagle 814 LHD is modified with reduced number of bends, number of connecting hoses and also the material is changed from aluminium alloy to mild steel. The proposed design would benefit with coolant leakage elimination by reduction in hose defects, reduced head loss, cost reduction and improved life of piping system.

8. Acknowledgement

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