International Journal of Engineering Technology and Applied Science
(ISSN: 2395 3853), Vol. 1 Issue 5 October 2015

DESIGN FABRICATION AND ANALYSIS OF ADVANCE COOLING SYSTEM

Sujeet Kumar Singh[1], Sanjay Kumbhare[2]

M-tech scholar[1], Asst. Prof. Dept. of Mechanical Engineering[2]
singh.sujeet200@gmail.com[1], sanjaykumbhare2709@gmail.com[2]

ABSTRACT:- Internal combustion engines are fitted with a cooling system which is responsible for removing certain heat from the engine and keeps the engine from overheating. This cooling system requires a large space to meet cooling need and also have limited heat dissipation. The goal of this concept is to design an advanced engine cooling system that will be compact in size and dissipate more heat. The compact shape will allow for alternate system placement options within the engine compartment and better heat dissipation maintain engine thermal efficiency. New concepts will be considered and a testing set-up will be built to demonstrate the chosen design.

KEYWORDS:- radiator, cooling rate, carbon form, design of advanced radiator, application.

Nomenclature

H = height of radiator
W = width of radiator
Th_{fin} = thickness of fin
P_{fin} = pitch of fin
D_{fin} = separation between two adjacent tubes or height of fin
L_{out} = depth of radiator
D_{out} = height of tube
Th = tube wall thickness
m_h = rate of water flow through a tube
$T_{H\,in}$ = hot fluid inlet temperature
$T_{H\,out}$ = hot fluid outlet temperature
$T_{C\,in}$ = cold fluid inlet temperature
$T_{C\,out}$ = cold fluid outlet temperature
N_t = total number of tubes
V_c = average velocity of air in the core

I. INTRODUCTION

Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500 ℃. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200 ℃ at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. It is also to be noted that cooling system is design to remove 30-35% of total heat.

II. OBJECTIVE

The goal of this project is to design an advanced concept for the engine cooling system used in automobiles and will explore concepts of next-generation engine cooling system that will;

(a) Dissipate more heat

Better heat dissipation maintains engine thermal efficiency even at high engine output.

(b) Compact in size

The compact shape will allow for alternate system placement options within the engine compartment.

III. IDEA & CONCEPT

By the use of carbon foam fins instead of aluminium fins on current radiator design, more heat dissipation can be obtained. Because carbon foam increases the surface area exposed to the air. This is mainly due to the fact that the carbon foam is porous and allows the air to flow through it in addition to allowing the air to flow around it.

To apply and test our ideas onto an actual model we select a car brand. The selected model is "**TATA**

INDIGO "fitted with **"TATA 475 IDI TCIC**" (or **TATA 1.4 L DIRECT INJECTION ENGINE).**

The reasons why this model selected is From the last few years, this vehicle is very popular in travelling sector, which means company have to ensure its liability even on long and continuous journey.

IV. BASIC ELEMENT OF COOLING SYSTEM

Radiator

A radiator is a type of heat exchanger. It is designed to transfer heat from the hot coolant that flows through it to the air blown through it, by the fan or due to forward motion of vehicle, through conduction and convection.

Construction of radiator

Automotive radiator consists of two tanks and a core. The core is really the heart of the radiator. The core is built from several rows of flat or oblong tubing that connect between the two tanks. Between each row of tubes, very thin fins are attached perpendicular to each of the tubes; the fins are same width as the tube. The fins provide a large amount of surface area in which heat can disperse.

Most radiators also make use of oil-to-water coolers. These are small tanks that are located within the tanks of radiator. Hot oil is circulated through the cooler, causing the fluid to give up some of its heat to the engine coolant. In vehicles equipped with automatic transmission, an oil cooler is placed in the outlet tank radiator. Some vehicles also make use of an engine oil cooler placed in one of the tanks, usually the inlet tank. In vehicles that use both transmission and engine oil coolers, each radiator tank has an oil cooler inside.

Material of radiator

Most modern cars use aluminium radiators. These radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The tubes sometimes have a type of fin inserted into them called a turbulator, which increases the turbulence of the fluid flowing through the tubes. If the fluid flowed very smoothly through the tubes, only the fluid actually touching the tubes would be cooled directly. The amount of heat transferred to the tubes from the fluid running through them depends on the difference in temperature between the tube and the fluid touching it. So if the fluid that is in contact with the tube cools down quickly, less heat will be transferred. By creating turbulence inside the tube, all of the fluid mixes together, keeping the temperature of the fluid touching the tubes up so that more heat can be extracted, and all of the fluid inside the tube is used effectively.

Properties of Aluminium

Aluminium is a silvery white member of the boron group of chemical elements. Its atomic number is 13. It is not soluble in water under normal circumstances. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust.

Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulphates.

Coolant

The engine coolant is the lifeblood of the cooling system. Coolant is circulated through the engine where through conduction and/or convection it absorbs the heat that is transferred to the metal engine components during the combustion process. The coolant is then transferred to the radiator where the heat energy is given up to the atmosphere through convection.

V. CALCULATION FOR ALUMINIUM FINNED TUBE RADIATOR

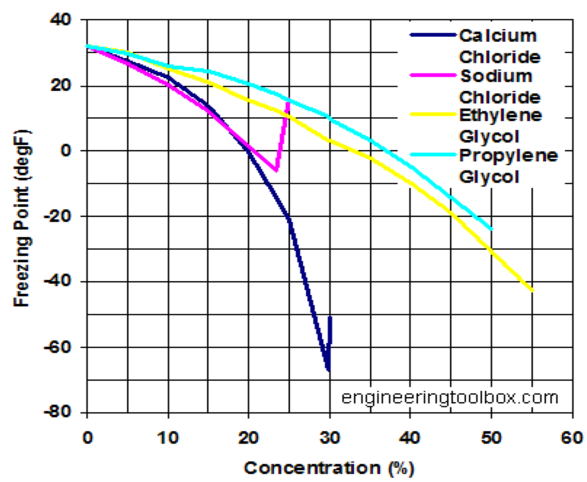


Figure1. Variation between freezing point & concentration of coolant

V	B.P. (W	I.P. (W)	E.S. (W	Q (W)
0	0	0	0	0
5	408	510	1275	382
10	875	1071	2627	803
15	1354	1692	4230	1269
20	1896	2370	5925	1778
25	2483	3104	7760	2328
30	3125	3906	9765	2930
35	3816	4770	11925	3578
40	4556	5695	14237	4271
45	5359	6699	16747	5024
50	6215	7769	19422	5827
55	7142	8127	22317	6695
60	8104	10130	25325	7598
65	9141	11426	28565	8570
70	10257	12821	32052	9616
75	11406	14257	35642	10693
80	12639	15799	39497	11850
85	13960	17450	43625	13088
90	15343	19179	47947	14384
95	16757	20946	52365	15710
100	18298	22872	57180	17154
105	19906	24882	62205	18662
110	21580	26975	67437	20231
115	23319	29149	72872	21862
120	25166	31457	78642	23593
125	27083	33854	84635	25390
130	29070	36337	90842	27253
135	31172	38965	97412	29224
140	33347	41684	104210	31263
145	35595	44494	111235	33071
150	37969	47471	118652	35596

$H = 365 \times 10^{-3}$ m
$W = 610 \times 10^{-3}$ m
$Th_{fin} = .35 \times 10^{-3}$ m
$P_{fin} = 1.52 \times 10^{-3}$ m
$D_{fin} = 8 \times 10^{-3}$ m
$L_{out} = 22 \times 10^{-3}$ m
$D_{out} = 1.9 \times 10^{-3}$ m
$Th = .4 \times 10^{-3}$ m
$N_t = 36$
$T_{H\,avg} = 90^0$ C
$T_{C\,avg} = 40^0$ C
$N_{water} = .326 \times 10^{-6}$ m^2/s
$M_{water} = .315 \times 10^{-3}$ N-s/m^2
$K_{water} = .7$ W/m-K
$Cp_{water} = 4.208 \times 10^3$ J/kg-K
$R''_{f\,in} = .0001$ m^2 ^{o}C/W
$R''_{f\,out} = .002$ m^2 ^{o}C/W
$K_{aluminium} = 250$ W/m-K
$V_c = 150$ km/hr
$N_E = 3904$ rpm
$N_{air} = 16.97 \times 10^{-6}$ m^2/s
$\mu_{air} = .19 \times 10^{-4}$ N-s/m^2
$c_{p\,air} = 1.005 \times 10^3$ J/kg-K
$k_{air} = .0271$ W/m-K

$D_{in} = 1.1 \times 10^{-3}$
$L_{in} = 21.2 \times 10^{-3}$
$L_{tubes} = 21.96$ m
$A_{total,\,in} = .979416$ m
At 4000 rpm, $Q_{d\,tubes} = 80$ l/min
For every 1000 rpm, discharge varies by 20 l/min
Therefore, at 3904 rpm

$Q_{d\,tubes} = 80 - 1.92$ l/min
$=1.30 \times 10^{-3}$ m^3/sec
$Q_{row} = 1.30 \times 10^{-3}/36$ m^3/sec
$W_{ater} = 1.55$ m/s
$Lc = 4A_c / P$
$= 2.09 \times 10^{-3}$ m
$L_c / W = 3.42 \times 10^{-3}$
$N_{f\,row} = 400$
$N_F = 14800$
$A_{total,out} = A_{s,fin,total} + A_{s,unfin}$
$A_{s,fin,total} = 5.2096$ m^2
$A_{s,unfin} = .827928$ m^2
$A_{total,out} = 6.037528$ m^2
$V_{air} = 150$ km/hr
$= 41.67$ m/s

Q= U x A x ϴm
$\theta m = T_{H\,avg} - T_{C\,avg}$
$= 90 – 40 = 50^OC$
$UA= 1 / R_{total}$

$\mathbf{R_{total} = R_{in} + R_{f,\,in} + R_{cond} + R_{out} + R_{f,\,out}}$
$R_{in} = 1/ (\bar{h}_{in} \times A_{total,\,in})$
$A_{total,\,in} = .979416$
$Re = (\rho \times v \times L_c) / \mu$
$= .9937 \times 10^4$
$Pr = (\mu \times c_p) / k$
$= 1.8936$

$\mathbf{\overline{Nu} = 3.66 + [(0.668 (D/W) \times Re \times Pr) / (1 + 0.04 ((D/W) \times Re \times Pr)^{2/3}]}$
$\overline{Nu} = 6.3366$
$\overline{Nu} = (\bar{h}_{in} \times L_c) / k$
$\bar{h}_{in} = 2122.3$ W/ m^2 K
$R_{in} = 4.81 \times 10^{-4}$ ^{0}C W^{-1}
$\mathbf{R_{f,\,in} = R''_{f,\,in} / A_{total\,in}}$
$= 1.021 \times 10^{-4}$ ^{O}C W^{-1}
$\mathbf{R_{f,\,out} = R''_{f,\,out} / A_{total\,out}}$
$= 3.3126 \times 10^{-4}$ ^{O}CW^{-1}
$\mathbf{R_{cond} = Th / [k_{tube} \times A_{total\,in}]}$
$= 0.0163 \times 10^{-4}$ ^{O}CW^{-1}
$\mathbf{R_{out} = 1 / (\eta o \times \bar{h}_{out} \times A_{total,out})}$
$\mathbf{A_{total\,out} = 6.037528\ m^2}$
$\mathbf{\eta_o = 1 – [(As_{fin\,tot} / A_{tot}) (1-\eta_{fin})]}$
$\eta_{fin} = .983$
$\eta_o = .985$
$\mathbf{Re = (\rho \times v \times L_{out}) / \mu}$
$= 5.4 \times 10^4$
$\mathbf{Pr = (\mu \times c_p) / k_{air}}$
$= .7046$
$\mathbf{\overline{Nu} = 0.036 \times (Re)^{4/5} \times (Pr)^{1/3}} = 195.67$

$\overline{Nu} = (\bar{h}_{out} \text{ x } L_{out}) / k_{air}$

$\bar{h}_{out} = 241$ W/m^{2}K

$R_{out} = 6.977 \times 10^{-4}$ ^{O}C W^{-1}

$R_{total} = 16.13693 \times 10^{-4}$ ^{O}CW^{-1}

$UA = 1 / R_{total}$

$= .6197 \times 10^{-3}$ W/ ^{O}C

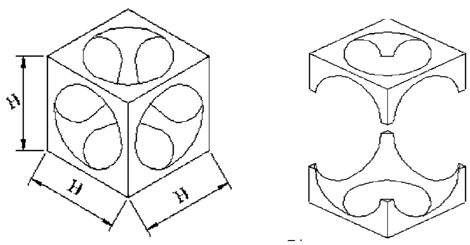
Therefore, the rate of heat transfer for the radiator is

Q = 30984 W

And the difference in heat rate,

$\Delta Q = Q_{req} - Q_{act}$

$\Delta Q = 4612$ **W**



VI. REPLACEMENT OF ALUMINIUM FIN BY CARBON FOAM IN FINNED TUBE RADIATOR

The interest stems from the notion that the unique thermodynamic properties of the foam would serve to reduce the thermal resistance of a heat exchanger without significant additional pressure drop. As will be described in detail below, porous carbon foam has an open, interconnected internal structure and a very high specific thermal conductivity, which combined, renders the foam an interesting alternative material in heat transfer devices.

We use of porous carbon-foam fins in a conventional air–water heat exchanger and describes the influence of the foam on the thermal and resistances. Porous carbon foam is a material developed at Oak Ridge National Laboratory (ORNL).

The effective conductivity of the carbon foam is in the range 40–180 (W/mK) due to the very high specific conductivity of the carbon material (k = 900–1700 [W/mK]) depending on the porosity which is normally 0.7 using in the existing radiator. In contrast, similar porosity aluminium foams have effective conductivities of approximately 5–20 (W/mK), which result from specific conductivities of 160–230 (W/Mk) for aluminium alloys. As such, the carbon foam has a much higher capability to conduct heat into its internal structure so that infiltrated fluid can convert heat away. It is because of this high effective conductivity that porous carbon foam is considered for use as a fin material. Fins of moderate height can be constructed and bonded to flattened metal liner tubes to increase the available surface area.

The open structure at the air–foam interface acts as a sub-layer interrupter, which produces near-wall turbulent eddies that actively exchange energy with the porous foam surface. This, combined with the overall pressure drop across the edges of the fin leads to enhanced convective heat transfer.

VII. CALCULATION FOR CARBON FOAM FINNED TUBE RADIATOR

Air–water heat exchangers are commonly employed in high output internal combustion engine cooling. The resistance to convective heat transfer on the air side of the heat exchanger dominates in the design of these heat exchangers. Large numbers of metal fins are used to provide additional surface area on the air side of the heat exchanger to lower the total convective thermal resistance.

Porous carbon-foam fins can be used to replacement the aluminium fins in finned tube radiators. The unique thermodynamic properties of the foam would serve to reduce the thermal resistance of a heat exchanger. As porous carbon foam has an open, interconnected internal structure.

Porosity = 70 %

$D_{void} = 350 \times 10^{-6}$ m

$\beta = 9000$ m^2/m^3

$\alpha = .653$

$Re = (V \text{ x } D_{void}) / \nu$

$= 859.42$

$Pr = (\mu \text{ x } c_p) / k$

$= .7046$

$\overline{Nu} = 1.064 \times (Re)^{.59} \times (Pr)^{1/3}$

$= 50.9813$

$\overline{Nu} = (\bar{h}_{out\,void} \text{ x } D_{void}) / k$

$\bar{h}_{out\,void} = 3947.40$

$R_{out\,void} = 1 / (\bar{h}_{out,void} \text{ x } A_{s,fin,void})$

$= .20312 \times 10^{-4}$ ^{o}CW^{-1}

$R_{out} = 1/(\eta_o \text{ x } \bar{h}_{out} \text{ x } A_{total\,out})$

$A_{total,out} = A_{s,fin,total} + A_{s,unfin} - A_{s\,front\,void}$

$A_{s,fin,total} = 5.2096$ m^2

$A_{s,unfin} = .827928$ m^2

$A_{s\,front\,void} = A_{s,fin,total} \text{ x } \alpha$

$= 3.40186$ m^2

$A_{total,out} = 2.635668$ m^2

$\eta_o = .86$

$R_{out} = 18.3060 \times 10^{-4}$ ^{o}CW^{-1}

$1/R_{out\ eff} = 1/R_{out} + 1/R_{out,\ void}$
$R_{out\ eff} = .20077 \times 10^{-4}\ {}^{O}C\ W^{-1}$
$R_{total} = 9.3607 \times 10^{-4}\ {}^{O}C\ W^{-1}$
$UA = 1/R_{total} = 1068.296$
Therefore**,** rate of heat transfer from this design
$Q = U \times A \times \Theta_m$
$Q = 53414\ W$

VIII. CONCLUSION

(1) Rate of heat transfer from this design much greater than the required value $Q_{req} = 35596$ W. Hence, the existing radiator can be made smaller in size by 203 mm (33 %) in width. That's means there is an extra availability of 1630 cm^3 space in engine compartment.

(2) In India, the atmosphere remains hot at least 10 months so this design will play an important role in order to keep cool of engine during its operation.
Radiator based on its design will be light in weight so engine's power to weight ratio will be increased.

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