Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

PERFORMANCE ANALYSIS AND DESIGN OF AUTOMOBILE RADIATOR

Urvi Tushar Nagar [1], Bharatkumar Manharlal Trivedi [2]

[1]*Student of Govt.Engg.College, Bhavnagar.*
[2] *Asst. Professor , Mechanical Engineering Department, Shantilal Shah Engg. College, Bhavnagar*

Abstract — *Recently due to advancements, methods like water cooling and oil cooling have also been used with the method of air cooling that has been implemented since many years. The cooling mechanism mainly involves radiator, pipes for supplying coolant, fittings and thermostat. But the whole mechanism works mainly on the design of automobile radiator. Nowadays many improvements have been made like using of a specific coolant having desired properties, or using a radiator of definite cross-section, or using nano fluids for effective cooling. But here this research mainly focuses on units employing air cooling and using aluminum tubes in radiator. This design focuses mainly on usage of circular cross-section of the radiator which offers many advantages. Hence this portion would be deeply discussed in the paper.*

Keywords- *Radiator, Heat Exchanger, Water Pump, Fins, Deformation, Stress Concentration*

1.INTRODUCTION

Radiators, also called heat exchangers are used to transfer heat from one medium to another with the sole purpose of cooling and heating. Automobile radiator is generally used to cool down the automotive engine that is used in two-wheelers. If this is not accomplishes properly, various troubles like knocking, piston deformation, and cylinder deformation etc. take place in the system. If the radiator functions properly, the cooling system would function properly and hence the engine performance would improve greatly.

It has been observed that in internal combustion engines, the coolant is generally water-based as well as also oil based. A water pump is employed to force the engine coolant to circulate, as well as for an axial fan to force air through the radiator. Thus an optimization process becomes necessary to achieve the best design including best performance, size, shape, and cost as well as its effectiveness.

The combination of fuel and air is used for combustion process in an engine of the automobile. It has been noted that of the total power that is produced, only a portion of the total generated power is actually supplied to the automobile and the remaining gets wasted in the form of exhaust gas and heat. But if this excess heat is not ejected from the engine, then the engine temperature would rise too high resulting in overheating of the engine. This also leads to problems like decrease in viscosity of the lubricating oil, weakening of the overheated engine (metal) parts, and increase in stress between the engine parts resulting in quicker wear of various engine parts. Hence a cooling system becomes vital here to remove this excess heat produced in the engine. Major automotive cooling systems mainly comprises of various components like radiator, water pump, electric cooling fan, radiator pressure cap, and thermostat. Of all these components, the radiator is the most prominent part of the system as it is the one to transfer heat from the engine.

The most common material used in the manufacture of the radiator is aluminum and the most common type of arrangement used is that of the cross-flow type of design. The most general coolant is the usage of two working fluids, generally air and coolant (50-50 mix of water and ethylene glycol). As the air starts flowing through the automobile radiator, the heat gets transferred from the coolant to the air. The main purpose of the air is to eliminate the heat from the coolant, which in turn causes the coolant to exit the radiator at a quite lower temperature than it entered at.

In this current radiator design, a common arrangement is used having parallel tubes on which aluminum fins are attached on them. These designs include basic three modes of heat transfer i.e. conduction between tube walls and fins, and two modes of convection. Of these, one mode of convection is due to the coolant flowing through the tubes and the second one is caused by the air flowing through the radiator. Among these we have associated with each type of heat transfer, a thermal resistance which hinders the heat transfer rate.

It has been noted that radiators of various cross-section are available in the market and these are used depending on the parameters like effectiveness, material requirement, cost, type of coolant involved etc. Hence through various experiments it has been noted that circular cross-section of radiator requires least material as compared to various other cross-sections. Here this design mainly focuses on the radiator having circular cross-section and having tubes made up of aluminum. The circular cross-section of radiator requires least material as well as the problems of stress concentration also get solved.

Figure .1.1 Automobile Radiator

2. DESIGN CALCULATIONS FOR RADIATOR:

First of all the collected data are tabulated below,

Sr.No.	Observations	(Cold Fluid)	(Hot Fluid)
1	Inlet Temperature (^{O}C)	28	52
2	Outlet Temperature (^{O}C)	?	44
3	m i.e. Mass flow rate (kg/hr)	525.35	100
4	C_p, Specific Heat (kJ/kg ^{O}C)	1	4.187
5	K, Thermal Conductivity (W/mK)	0.024	0.66
6	ρ, Density (kg/m$^{3)}$	1.1	1000

Table 2.1 Input data

Here we have assumed cross-flow type of heat exchanger having aluminum tubes of dimensions:
Outer Diameter = 11.25 mm
Inner Diameter = 10.00 mm
Thickness =1.25/2= 0.0625 mm

From the various typical values of overall heat transfer coefficient, we know that for air cooled heat exchanger value of overall heat transfer coefficient (U) ranges from 300-450 W/m^{2}K. So here we consider it to be equal to 350W/m^{2}K.

$\boxed{U= 350W/m^2K}$

Using Energy balance equations, we have

$$m_c C_{pc}(T_{ce}\text{-}T_{ci})\text{=}m_h C_{ph}(T_{hi}\text{-}T_{he}) \quad \text{-(Eq 2.1)}$$

525.35× 1× (T_{ce}-28) = 100× 4.187× (52-44)

$\boxed{T_{ce} = 34.376°C}$

So outlet temperature of air is = 34.746 °C.

Assuming the Heat Exchanger (Automobile radiator) to be of counter flow type we get,

q = $m_w \times C_{pw} \times \Delta T_w$ -(Eq 2.2)

q = 100× 4.187× (52-44)

$\boxed{q = 3349.6 \text{ Watts}}$

Now,

θ_1=17.624°C

θ_2= (44-28)

θ_2=16°C

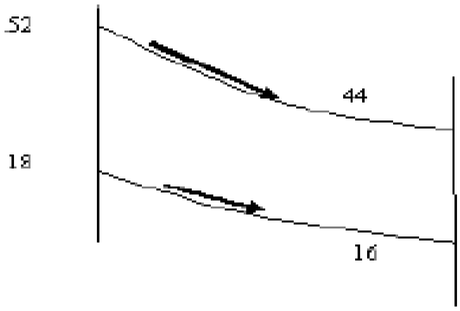

Figure 2.1 Temperature Readings

Substituting these values, we get

$\theta_m = \frac{(\theta_1 - \theta_2)}{ln\frac{\theta_1}{\theta_2}}$ -(Eq 2.3)

$\theta_m = \frac{(17.624-16)}{ln\frac{17.624}{16}}$

θ_m = 16.8°C i.e. 289.8°K

$\boxed{\text{LMTD=16.8}}$

Now, using the average velocity of water in tubes and its flow rate the total flow area is given as,

$A_f = \frac{m}{V \times \rho}$ -(Eq 2.4)

Where A_f represents total flow area
V represents the average velocity of water
ρ Represents the density of water

Here we have velocity of water as 65 m/hr, $A_f = \frac{100}{65 \times 1000}$

Hence,

$\boxed{A_f = 1.538 \times 10^{-3}\ m^2}$

But we know that,
A_f = n×$\frac{\pi}{4}$× d_i^2 -(Eq 2.4)

Where,
n= number of tubes and,
d_i=Inlet diameter of tube

Substituting respective values, we get
$1.538\times 10^{-3} = n\times\frac{\pi}{4}\times(10\times 10^{-3})^2$
Solving this equation we get n=19.58

$\boxed{n=20.}$

Now taking the value of correction factor F as 0.96 and substituting in the following equation,
The area of heat transfer after considering the correction factor is as follows,

$$A=\frac{q}{U\times F\times\theta_{m\,(counterflow)}} \quad \text{-(Eq 2.5)}$$

$$A=\frac{3349.6}{350\times 0.96\times 16.8}$$

$\boxed{A=0.5934\ m^2}$

Effectiveness of heat exchanger,

$$C_h=(m\times C_p)_{water} \quad \text{-(Eq 2.6)}$$

$$C_h=\frac{(100\times 4.18\times 1000)}{3600}$$

C_h =116.306 W/K

Now the Capacity Ratio can be given as follows,

$$C=\frac{C_{min}}{C_{max}} \quad \text{-(Eq 2.7)}$$

Hence the equations that follow are,

$$C_c=(m\times C_p)_{air} \quad \text{-(Eq 2.8)}$$

$$C_c=\frac{(525.35\times 1\times 1000)}{3600}$$

C_c = 145.931 W/K

C_{min} = 116.306 W/K

C_{max} = 145.931 W/K

Hence we get C as 0.797

$$NTU=\frac{U\times A}{C_{min}} \quad \text{-(Eq 2.9)}$$

$$NTU=\frac{350\times 0.5934}{116.306}$$

$\boxed{NTU = 1.786}$

Using NTU method for cross flow HE with both fluids unmixed, we have the following equation,

$$\varepsilon=1-\exp\left[\left(\frac{1}{C}\right)(NTU)^{0.22}\{\exp[-C\,(NTU)^{0.78}]-1\}\right] \quad \text{-(Eq 2.10)}$$

$$\varepsilon = 1 - \exp\left[\left(\frac{1}{0.797}\right)(1.786)^{0.22}\{\exp[-0.797\,(1.786)^{0.78}] - 1\}\right]$$

$$\boxed{\varepsilon = 0.6388}$$

Hence we get effectiveness as 0.6388.

ADVANTAGES:

1. Since the corners are eliminated there is no problem of stress concentration.
2. The design becomes compact.
3. Hence the material requirement decreases.
4. Since material saving increases, the cost saving on mass scale production will also increase, once the dies are manufactured.

LIMITATIONS:

1. Bending of tubes in circular cross-section could lead to various losses.
2. Dies that are to be constructed for circular radiators are comparatively expensive.

2. Conclusion

This design offers various advantages with respect to using aluminum tubes as well as using circular cross-section of radiator. First of all, the main advantage is that the circular section has least perimeter among all the other cross-sections and the problem of stress concentration is also eliminated. Various shapes like rectangular have the major problem of stress concentration, hence it gets resolved here. Also the manufacturing of circular shape is quite easier.

As the material requirement for the circular radiator decreases, the overall cost of the project implementation reduces. But the problem occurs only when there is a bend in shape of radiator. Hence this needs to be encountered only when there is sudden change in area. Also using the aluminum tubes decreases the overall weight of the radiator, making the system easy to handle.

REFERENCES

1. Cihat Arslanturk & A. Feridum Ozguc, (2006), “Optimization of Central heating radiator,” Applied Engg, Vol.no. 83, issue 11, pp. 1190-1197.
2. William H Crouse,”Automotive Mechanics” 10th edition pp no 318-321
3. T Kuppan “Heat Exchanger Design Hand book” pp no 145-160.
4. Incropera, DeWitt, Bergman, Lavine 2007. Fundamentals of Heat and Mass Transfer, Sixth Edition. New Jersey: John Wiley & Sons, Inc.
5. Kays, W.M. and London, A.L. (1984) Compact Heat Exchangers. 3rd Edition, McGraw-Hill, New York.
6. http://www.academia.edu/4400629/Automotive_Radiator__Design_and_Experimental_Validation

