PERFORMANCE ANALYSIS OF CAR RADIATOR

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Abstract:- In Current era, it becomes an need to Design an Automobile with higher efficiency , more life and environment friendly. For that purpose it is necessary to run the engine at favourable condition; so Radiator acts as an catalyst in the functioning of Engine. Radiator is Cross flow type Heat Exchanger which cools the coolant used in heat source (ex. Engine). Generally Staggered type Radiator with Turbulator type of fin and ethylene glycol as a coolant used in radiator. Heat transfer between air and coolant is take place through Convection and Conduction mode. Nano particles (TiO_2) are also used for effective heat transfer. This Paper includes the

- Mathematical calculation for finding the heat transfer parameters by using analytical method andprogramming.
- Temperature and velocity distribution in radiator.
- Analysis about Shape, Coolant and Nano fluids.

Keywords: Staggered, Programming, Coolant, Nano Fluids, Turbulence, Fins.

1.Introduction:

For every automobile it is necessary to maintain engine temperature so these is take care by radiator in more than

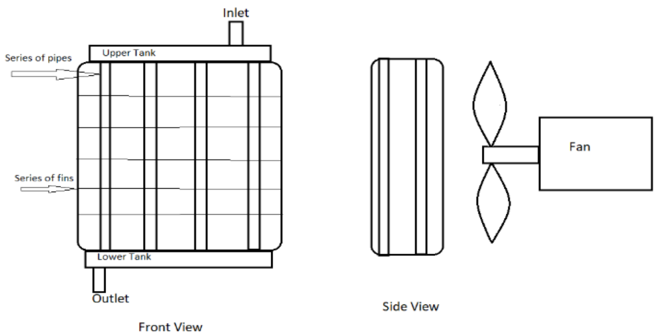
2 wheeler vehicals and in case of 2 wheeler it is done byfins. In an automobile engine rejects 33% of heat produced by combustion of fuel. So if these heat is notget rejected to atmosphere or heat sink it will cause Overheating of engine so following problems can occur.

- breakdown of lubricating oil
- metal weakening of engine parts
- significant wear between engine parts
- undesirable thermal stresses generation.
- Overheating permits the Creep in case higherapplication Component like Boiler.
- Engine struck down

So above issues are addressed by Cooling system inautomobile. Cooling system rejects the excess amount of heat produced in engine. Most automotive cooling systems consist of Radiator, Water pump, fan, pressure cap, and thermostat. The Radiator is the most prominent part of the system because it transfers heat. Radiator is an cross flow type heat exchanger which maintain the temperature of engine in within a adequate limit by reducing temperature of coolant which extract the heat from engine and reject the same heat to atmosphere through air. Mode of heat transfer between coolant and airis convection – conduction – convection.

<u>Applications</u>

- Drying devices in Industry
- Chemical and fire Industry
- pharmaceutical industry
- Devices used in air heating in the leatherindustry



2.Construction and Working of Radiator: Radiator is located under the hood before the engine andat the front of vehicle. Radiator is crossed flow type heatexchanger. Coolant used in many car radiator is mixtureof ethyl glycol (70%) and water (30%) with these TiO_2Nano fluid also used for improving the heat transfer rate.

Working principle: As coolant travels through theengine's cylinder block, it accumulates heat produced in engine; So when coolant's temperature rises above a certain threshold value, the vehicle's thermostat actuate the pump which force the coolant to flow through the radiator. As the coolant flows through the tubes of the radiator, it absorbed the heat from engine through Conduction and convection. Further coolant rejects it heat to atmosphere through air.

Construction: Radiator has inlet tank, outlet tank, tubes, radiator cap, fins, fan transmission cooler. Mostly many Radiator are made up of Aluminum and having aluminum fins provided by brazing.

- Tubes are connected in parallel way between inletand outlet tank.
- Turbulator type of fins are provided over tubes.
- Fan is provided behind the Radiator to pull theair.
- Radiator pressure cap is used to release theexcessive pressure generated by radiator.
- Transmission cooler is provided at bottom or atoutlet tank to cool the oil.

Working: When engine is in running condition about 33% excess amount heat is generate by engine by combustion of fuel; so these heat is need to liberate to atmosphere; so in these sphere radiator function is comesinto picture. Generally, when engine temperature reachesto $70^0$to 80^0 Thermostat valve switch on the fan which sucks the atmospheric air and at same time coolant pump circulating the coolant around the engine blocks; from where it absorbed the heat by conduction and convection mode. Now, Coolant carries the same heat to inlet tank through hose pipe; from inlet tank coolant flow through radiator tubes. **Tabulator** type of fin are provided inside the tubes to create the turbulence effect inside the tubes; because if the fluid flows very smoothly through the tubes; then only the part of the fluid which directly touching the surface of the tubes is cooled rapidly than the part of fluid which do not share the tube surface. So it will cause insufficient heat transfer and hence not effective cooling will takes place; Therefore to addressed these issue Tabulator type of fins are inserted inside the tubes they creates the turbulence effect; all part of fluid is cool rapidly and almost at same rate; Therefore effective cooling will takes place. When coolant flowing through the tubes it reject it's heat to atmospheric air which sucks by fan continuously. Mode of heat transfer between coolant and air is Conduction and convection.After leaving the tubes coolant comes into **Transmission cooler** where coolant cools the oil. Now again it transfers to the engine and cycle is repeat with respect to temperature of engine.

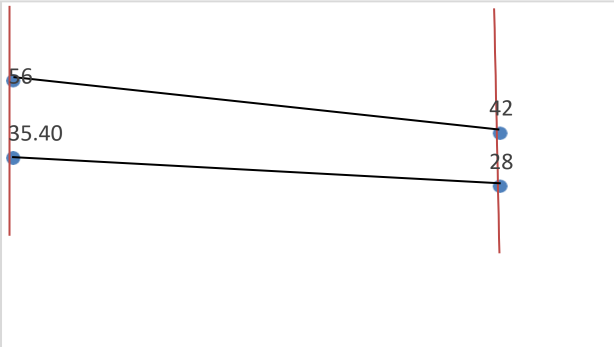
3.Mathematical Calculations

In these Studies; There are 2 methods are used for findingthe Heat Transfer diamension and Heat Transfer Efficiency.

- Analytical Method
- Programming

Analytical Method:

Using Energy balance equation,
$(m_c*Cp_c)(Ti_c - To_c) = (m_a*Cp_a)(To_a - Ti_a)$ $100 \times 2.78 \times (56 - 42) = 525.35 \times 1 \times (To_a - 28)$ $To_a = 35.408°C$
So outlet temperature of air is = 35.408We know that,
$Q = mc \times Cpc \times (Ti_c - To_c) = 3892$ watt



Available Data

- Outer Diameter = 11.25mm = 0.01125m
- Inner Diameter = 10mm = 0.01m
- Thickness = 0.0000625 m
- Overall Heat transfer coefficient (U)= 350W/m2

Sr. No.	observations	Air (Cold)	Coolant
1	Inlet Temperature (°C)	28	56
2	Outlet Temperature (°C)	35.408	42
3	M i.e., mass flow rate (kg/hr)	525.35	100
4	Cp. Specific Heat (kJ/kg °C)	1	2.78
5	K Thermal Conductivity(W/mK)	0.024	0.402
6	ρ Density (kg/m3)	1.1	1036

$\theta_1 = (56-35.408) = 20.592$
$\theta_2 = (42-28) = 14$
$\theta m = (\theta_1 - \theta_2) / \ln(\theta_1/\theta_2) = (20.592-14)/\ln(20.592/14)$
LMTD= 17.084392°C

Now, using the average velocity of coolant in tubes and itsflow rate the total flow area is given as,
$Af = mc / Vc \times \rho c = 100 / 65 * 1036$
$Af = 1.485 \times 10^{-3} m^2$
But we know that,
$Af = n \times (\pi/4) \times d^2$
By substituting all values
$1.485 \times 10^{-3} = n \times (\pi/4) \times (0.01)^2$
we get,

n = 18.90
approximate n=19

f correction factor is 0.96
Now, Heat Transfer area is given as,
$A = Q/(U \cdot f \cdot \theta m)_{(counterflow)}$ = 3892 /(350*0.96*17.08)
$A=0.678007m^2$

Length of the tube is given by
L= A/(pie*D)
L=19.18 m
Effectiveness of Heat Exchanger
$Ch = (m \times Cp_c)coolant$ = (100*2.78*1000)/ 3600 = 77.22 W/K
$Cc = (m \times Cp_a)air$ = (525.35*1*1000)/ 3600Cc = 145.931 W/K
Cmin = 77.22 W/K ; Cmax = 145.931 W/K

Capacity ratio (C):
C = Cmin /Cmax = 77.22/145.931
C=0.52917
NTU = U · A /Cmin = 350*0.678007 / 77.22
NTU = 3.073841

$\varepsilon = ((1-e^{(-(1-C)*NTU)})/(1-(C*e^{(-(1-C)*NTU)})))$

ε=0.873510
So we get effectiveness equal to 0.873510

Max Heat Transfer Rate
$Qmax= Cmin*(Ti_c -Tia)$ = 77.22*(56-28) = 2161.6168 watt
Actual Heat Transfer
Qact= ε*Qmax =1888.193 watt

Heat Transfer efficiency Efficiency= (Qact/Qmax)*100
Efficiency= 87.35%

Programming:

Variables and their meaning

Ti_a= inlet temperature of air in in degree
Ti_c= inlet temperature of coolant in degree
Toc= Outlet Temperature of Coolant in degree
Toa= Outlet Temperature of air in degree
m_a = mass of air in kg/hr
m_c= mass of Coolant in kg/hr
Cp_a= Specific Heat of air in kj/kg C
Cp_c= Specific Heat of Coolant in kj/kg C
K_a = Thermal Conductivity of air in W/mk
K_c = Thermal Conductivity of Coolant in W/mk
D= outside Diameter of tube in m ; d= inside Diameter of tube in m ; t= Thickness in m
U= overall Heat Transfer coefficient in W/m2k
V_c= Velocity of coolant in m/hr
ρa= Enter Density of air in kg/m3
ρc =Enter Density of Coolant in kg/m3
f= Enter value of Correction factor

Start

Input:

Ti_a, Ti_c, To_c, m_a, m_c, Cp_a, Cp_c, K_a , K_c, D, d, t, U, Vc, ρa, ρc, f

$Q = mc * Cp_c * (Ti_c - To_c)$

$Toa = (Q/(m_a * Cp_a)) + Ti_a$

$\theta 1 = Ti_c - To_a$

$\theta 2 = To_c - Ti_a$

$\theta m = (\theta_1 - \theta_2) / \ln(\theta_1 / \theta_2)$

$Af = mc / Vc \times \rho c$

$n = Af/(0.7853*d^2)$

$A = Q/(U*f*\theta m)$

$L = A/(pie*D)$

$Cmin = (m_c*Cp_c*0.2777)$

$Cmax = (ma*Cp_a*0.2777)$

$C = Cmin/Cmax$

$NTU = U \cdot A / Cmin$

$\varepsilon = ((1-\exp^{(-(1-C)*NTU)})/(1-(C*\exp^{(-(1-C)*NTU)})))$

$Qmax = Cmin*(Tic-Tia)$

$Qact = \varepsilon*Qmax$

$Efficiency = (Qact/Qmax)*100$

Print:

Q, Toa, θm, n, A, L, C, NTU, ε, Efficiency

End

4. Temperature and velocity Distribution in Rectangular shape car radiator:-

Velocity Distribution: Velocityof air at the beginning of radiator is high and gradually decreasing towards the end side.

Temperature Distribution: Temperature variation is decline towardsthe end of radiator.

5.Shape of Car Radiator:

Mainly due to following **Reasons Square orRectangular shape car radiator** is used:

1. Space Requirement is less.
2. Provide High Heat transfer area and also have anaccess to Tabulator type of fin so effective cooling is takes place.
3. Easy and lease for design and production.

Spiral or Circular shape of Radiator

Due to following Reasons Circular shape of car Radiatoris not preferred:

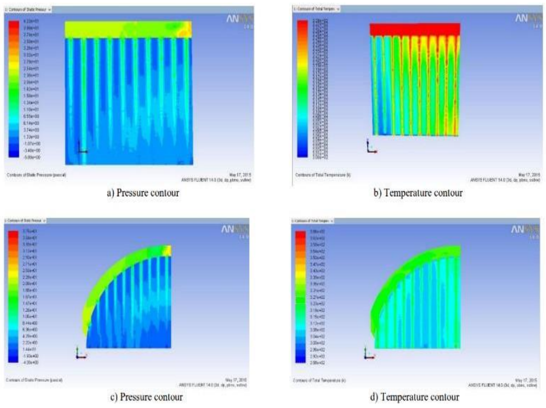
1. Design and Production is Hard.
2. Less surface area get available for heat transfer without fins.
3. Possibility of Direct cooling; so no effective cooling can occur.
4. Inserting of fins is also difficult.

Although Following are the reason for the **scope of Circular shape car radiator.**

- Less material requirement: Since material savingis about 24%, cost saving on mass scaleproduction will be about 20% , once the dies are manufactured.
- For optimum efficiency elimination of corner is essential to reduce pressure drop so it can be doneby Circular shape Radiator.

Pressure and temperature variation for rectangularand optimized circular radiator.

So from shown analysis it is clear that Pressure and Temperature drop in Rectangular shape radiator is high ascompare to circular shape; hence efficiency can be optimize by using Circular shape radiator.



a) Pressure contour b) Temperature contour c) Pressure contour d) Temperature contour

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Advantages of circular shape radiator:

1. It requires less space as compare to Rectangular model by 21.46%.
2. It requires less material, Therefore requires less. production cost once dies get produced.
3. It gives more heat transfer rate by 7.8% than Rectangular model.

6.Coolant used in Radiator:

Function of Coolant is to acts as carrier which carry the heat from engine and discharge it to atmosphere throughConvection mode. Generally, Ethyl glycol is used as a coolant in radiator because

4. it has much lower freezing point than water
5. It keeps the car engine from freezing in winterand reduce overheating in summer.
6. Takes care the corrosion problem

Difference Between antifreeze and Coolant : Antifreeze is an 100% Ethyl glycol While coolant is a mixture of ethyl glycol(70%) and water(30%).

Due to following 3 reasons fully concentrated ethyl glycolis not used in radiator:

1. Antifreeze freezes between 0 degree to minus-5 degree; So to have the protection below zero mark it

is necessary to mix the water in adequate amount prescribed by manufacturer.

2. Heat transfer capacity of antifreeze is less as compare to coolant.
3. In antifreeze; additives (silicates, phosphates and nitrates) are not properly suspended because of more viscosity while in case coolant due to presence of 30% water there is less viscosity and hence additives are properly suspended and hence increases heat transfer rate.
4. If antifreeze is allow to flow through the pump it will damage the pump because of high viscosity therefore coolant is suitable to used.

7.Significance of nano particles

Mostly TiO_2 Nano particles are used in car radiatorbecause it is non toxic in nature.

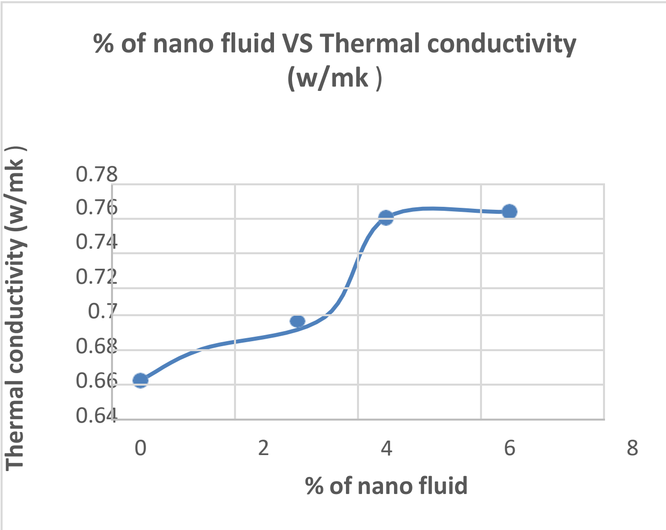
Characteristics of TiO2 nanoparticles

Parameter	Value
Purity	99%
Colour	White
Diameter	42/nm
SSA	1044/m2g
Density	0.45g/cm3

% of Nano fluids and Thermal Conductivity(W/mk)

0	0.660225
1	0.678279
3	0.696671
4	0.753975
6	0.757485

Heat Transfer Coefficient is improves by 0.2% by addition Of nano particles. This happens due to Tio_2 has greater Thermal Conductivity, lower specific gravity, large suface Area and low Thermal Resistance.



Disadvantages about Nano Fluid:-

- Nano Fluids are more viscous in Nature so Causes a problem to coolant flow, in same sense It will reduce the life of coolant pump.
- Homogeneous suspension of nano fluid Causes a technical problem due to strong Vander walls interaction.
- It will increases Pumping power and pressure Drop.

8.Future Scope

- <u>Use of nano-fluids:</u> application of nano fluid with coolant improve heat tarnsfer rate by about 0.2%.Mostly TiO_2 nano fluid is used with Ethyl glycol coolant.
- <u>S-shaped fins</u>: S-shape fins are narrower; Therefore they gives more heat heat transfer area than conventional. If higher is area higher will be heat transfer rate. So it will increase the efficiency of heat transfer.
- <u>Increasing turbulence of coolants:</u> The effectiveness of the radiator can be increased by creating turbulence effect inside the tube. In conventional radiator it is produced by providing tabulator fins. Best way to produced Turbulence effect is Staggered arrangement.
- <u>Use of carbon-foam fins:</u>- Aluminum fins can be replaced by Carbon foam fins because carbon foam has thermal conductivity k is upto 175 w/mk. Therefore it can give high heat transfer rate and hence it can possible to reduce overall size of Radiator.

- Circular Radiator:
    1. It requires less space as compare to Rectangular model by 21.46%.
    2. It requires less material, Therefore requires less. production cost once dies get produced.
    3. It gives more heat transfer rate by 7.8% than Rectangular model.

9. Design criteria:

1. Heat Transfer Rate Q
2. Flow Rates
3. Fouling Factor
4. Outer Shape & Over all Dimensions
5. Strength Factor
6. Pressure Drop & Pumping Power Requirement
7. Cost

10. Conclusion:

1. Radiator maintains the engine temperature and speed up the engine performance as well as cools the oil.
2. Nano fluid with application of coolant improvethe heat transfer by 0.2%; but its high viscositycauses a problem to fluid flow.
3. Ethyl glycol (70%) + water (30%) is found as more effective coolant because it it has lower freezing and higher boiling point; also takes carethe corrosion.
4. Any programming method is used for calculating the heat transfer parameters and efficiency of Radiator by following the same flow chart.
5. Circular shape Radiator will also became anoption in future
6. For effective utilization of Radiator Followingchanges can be made
    - Used of nano fluid
    - S-shaped fins
    - Increasing turbulence of coolants
    - Use of carbon-foam fins
    - Circular Radiator

11. References

1. Study on Performance Evaluation of Automotive Radiator Article in SAMRIDDHI A Journal of Physical Sciences Engineering and Technology ·June 2015
2. Improving Car Radiator Performance By using TiO2-water Nanofluid Article in Engineering Science and Technology an International Journal November 2017 DOI:10.1016/j.jestch.2018.07.008
3. Noise and vibration analysis for automotive radiator cooling fan To cite this article: N F D Razak et al 2017 IOP Conf. Ser.: Mater. Sci. Eng.257 012083
4. Performance Analysis of Automobile Radiator Article · May 2016
5. CFD and Heat Transfer Analysis of Automobile Radiator Using Helical Tubes Kola David1 , Abhishek kumar2 M. Tech Student, QIS College of Engineering and Technology, Ongole, Andhra Pradesh, India1 Associate Professor, Department of Mechanical Engineering, QIS College of Engg &Technology Ongole, Andhra Pradesh, India 2
6. International Journal of Innovative Research in Science, Engineering and Technology.
   Optimization of Circular Shaped Automobile
   Radiator Ebin Jose 1, A.V Ramesh 2 and Nidheesh P 3