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Analytical Modeling and Simulation of Car Radiator

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Abstract: ***In almost every automobile engine, cooling system is necessary. The main aim or purpose of a cooling system of an engine is to remove excess heat from the engine, and to maintain the operating temperature in the engine. Radiator is main or important component in engine cooling system. Aim of this project is to increase Heat transfer rate that can be achieved by changing the design of radiator. The main objective of this project is to calculate the different thermal parameters of the radiator with and without fins and simulation of the car radiator.***

Keywords: Analytical, Simulation, Car radiator, Fin, ANSYS

1. Introduction

Radiator is known as cross flow heat exchanger. Radiators are commonly used in automobiles and automotive industries. Automobile radiator is used for preventing the engine from overheating. The main component of radiator is tube, fin, header plate, top tank and bottom tank. Assembly of tubes and fins are known as radiator core. Different Shape of tubes is used in radiator it may be rectangular or square. Coolant is flowing through this tube. Fins are used which increases total surface area of the metal body. It helps in heat transfer from tubes containing the coolant, to the air passing through the radiator**.** Different shape and size of fins are used in radiator it may be plate type, serpentine type or wavy type fin.

In automobile, more cooling effect is required for better engine performance. And this can be achieved by getting more heat transfer rate in radiator. Radiator design is directly affect the heat transfer rate. Proper material selection is also main problem for designing radiator. Copper is used as a tube and fin material that will increase the radiator weight. Its cost is very high compare to other materials **[4].** Fins are used for increasing the surface area and that will cause more heat transfer rate in radiator. Plate type fins are commonly used in radiator. The main objective of this project is to develop an analytical model for the analysis of plate type fin used in radiator. Computational Fluid Dynamics (CFD) tool of ANSYS is used for simulation and parametric analysis of plate fin used in radiator **[6].** And the results are compared between theoretical calculation and simulated results.

Changing in design of fin and tube will change the heat transfer rate in radiator **[1].** Material of fin and tube will affect on heat transfer rate in radiator **[3].** Coolant with Nano fluid will increase cooling effect [5].

2. Analytical Modeling

For 1-Fin and 1-Tube
Assumptions:

- Mass flow rate of water and air is constant.
- All properties are constant.
- Surface temperature is constant.
- One dimensional flow for water and air.

Tube: - Material- Aluminum,
Diameter (Outer) - 10mm,
Diameter (Inner) - 9.18mm,
Thickness- 0.41mm,
Length- 340mm
Fin: - Material- Aluminum,
Thickness- 0.21mm,
Length- 340mm,
Width- 28mm

Boundary Conditions:

Inlet boundary conditions: - The water is assumed to have the uniform mass flow rate and it is 0.138 Kg/sec. The air is assumed to have the uniform mass flow rate is 5 Kg/sec. Inlet temperature of coolant (water) and air is 368K and 298K respectively.

Wall boundary condition: - The material of tube and fin is Aluminum. The thermal conductivity of aluminum is 204.2 W/m^2K

Calculation of Radiator (1-FIN AND 1-TUBE)
Water:

1) $Dh_c = 4*Ait/Pit$
$= 4*(\pi/4)*d^2/\pi d$
$= 0.010m$

2) $Re = \varrho vd/\mu$
$= (1000*1.75*0.010*100*3600)/107.70$
$= 58732$

3) $Pr = 1.85$

4) $Nu = 0.023*Re^{0.8}*Pr^{0.03}$
$= 153.05$

5) $h_c = (Nu*K)/L$
$= (153.05*68.11)/(0.34*100)$
$= 306.60 w/m^2k$

Air:

$V = m/\varrho A$

$= 5/1.185*0.2461$

$= 17.14$ m/s

1) $Re = \varrho vl/\mu$

$= (1.185*17.14*0.34*100*3600)/6.625$

$= 375305.13$

2) $Pra = 0.702$

3) $J = 0.174/Re^{0.383}$

$=1.07*10^{-3}$

4) $h_a = (J*V*Cpa)/Pra^{2/3}$

$= (1.07*17.14*1000)/ (1000*0.702^{2/3})$

$= 23.37$ w/m^{2}k

5) $m = ((2*h_a)/(k_f*Thf))^{0.5}$

$= 33.01$

6) $\eta = \tanh(mL)/mL$

$= 0.086$

7) $A_o = A_f + A_b$

$= (2*(b*h) +2(L*H)+2(L*b)) + 2\pi r(r+h)$

$= 0.030m^2$

8) $\eta_o = 1 – (A_f/A_o)(1-\eta)$

$=0.4$

9) $1/UA = (1/ \eta_o h_a A_{0\,)} + (Tht/k_t*A_{t\,)} + (1/h_cA_c)$

$= 3.56 + 0.0956 + 0.33$

$1/U = 3.98*0.051$

$U = 4.92$

10) $NTU = (U*A_o)/(C)_{min}$

$= 0.03$

11) $\mathcal{E} = (1/C)*(1-e^{-(1-e\wedge-NTU)})$

$\mathcal{E} = 0.12$

12) $Q = \mathcal{E}*C_{min*}(T_{wi}-T_{ai})$

$= 0.12*5*70$

$= 41.8$KW

13) $T_{wo} = T_{wi} – (Q/C_w)$

$= 368 – 2.06$

$= 365.9K = 366K$

3. Model Design and Simulation

Design a 3D model of Radiator by using CREO Parametric software. And install that model in ANSYS by converting it into IGES form. The 3D Radiator designed model and imported model in ANSYS are shown below.

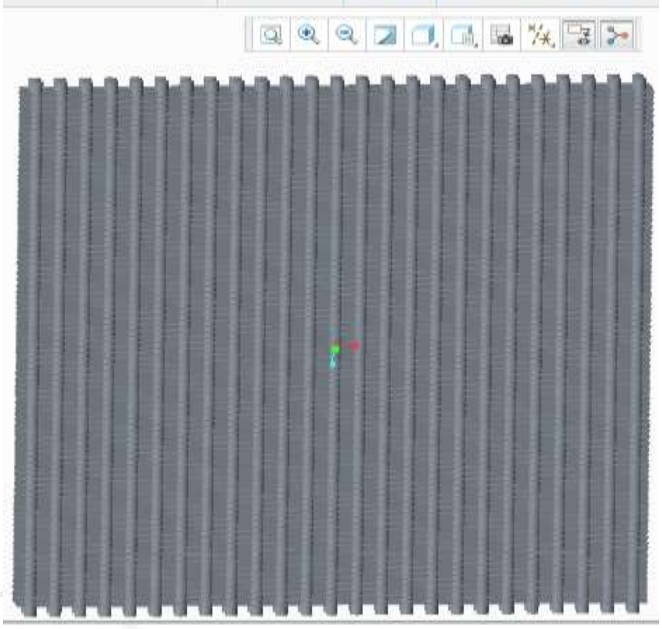

Figure 1: Radiator model designed in PTC CREO Parametric

After importing a radiator model in ANSYS, meshing is done with Applying element size as 2 mm and setup are done with applying different boundary condition. Simulation of one fin with one tube and simulation of only one tube with coolant pass through have done by us. The result of simulation is display below.

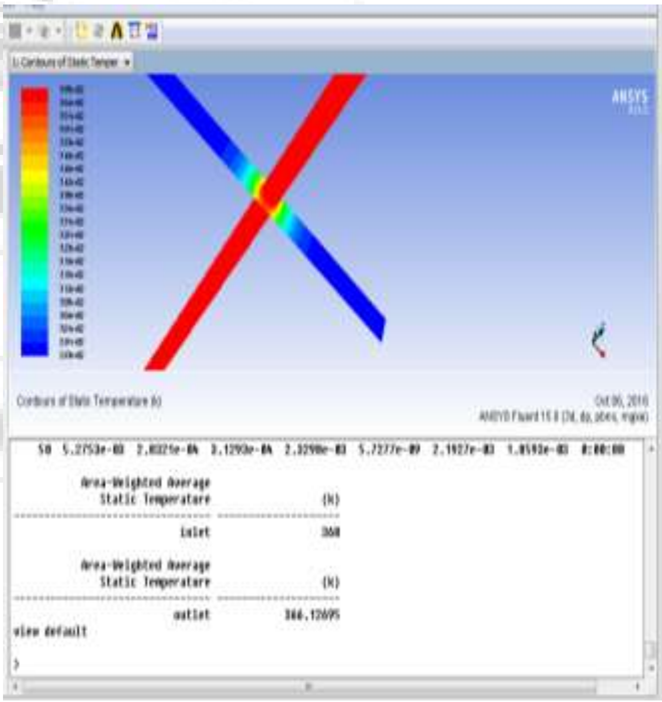

Figure 2: Simulation result of tube and fin

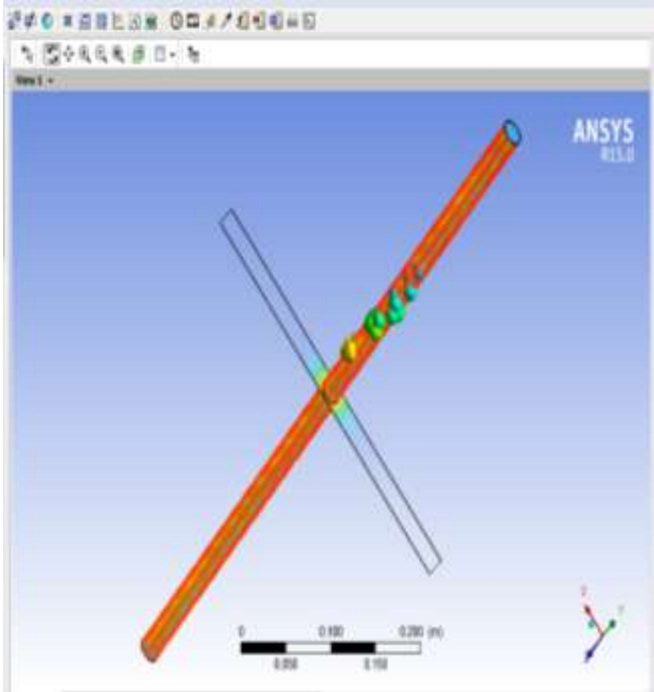

Figure 3: Simulation result of tube and fin with streamline

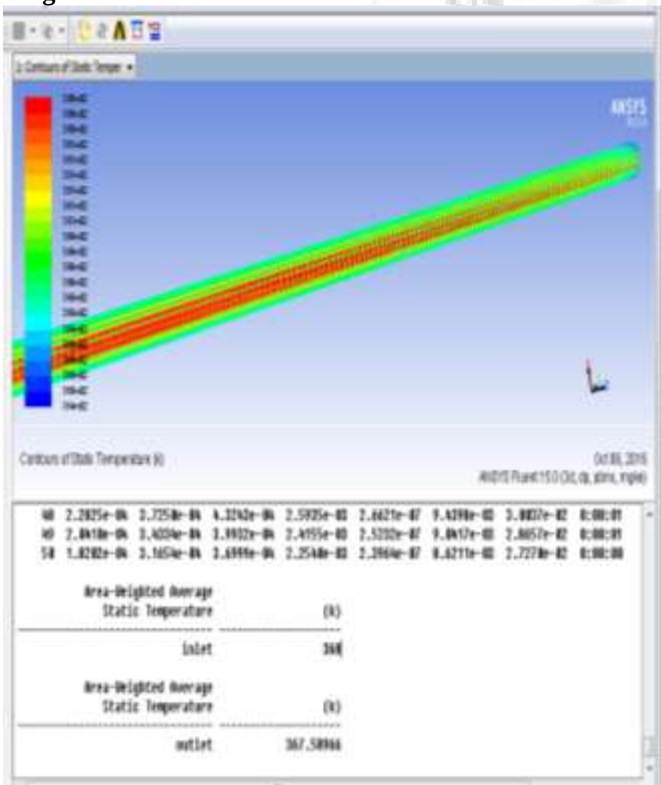

Figure 4: Simulation result of tube without fin

4. Conclusion

Fins increase the surface area which helps in improving heat transfer rate and promote more cooling effect to the radiator. Solution of analytical and simulation shows that the heat transfer rate of radiator is increase by providing the fin. As per simulation and analytical result, outlet of coolant temperature is 366K in with fin radiator and 367.58K in without fin radiator.

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Nomenclature

A Overall heat transfer area
A_b Surface area of the bare tube (m^2)
A_f Surface area of the fin (m^2)
A_o Total surface area of the finned tube (m^2)
P Perimeter(m)
D_h Hydraulic diameter (m)
H Convection heat transfer coefficient (W/m^2K)
K Thermal conductivity (W/m K)
C Specific heat at constant pressure(J/Kg K)
L Length (m)
m Mass flow rate (l/s)
Nu Nusselt Number
NTU Number of Transfer Unit.
Q Heat transfer rate (W)
η Fin efficiency
η_o Surface efficiency
Ɛ Effectiveness
Re Reynolds number
T Temperature (K)
v Velocity (m/s)
U Overall heat transfer coefficient (W/m^2 K
J Colburn factor
Pr Prandtle Number
T_{wi} Temperature of water at inlet.
T_{wo} Temperature of water at outlet.