Experimental and Numerical Analysis of Cylindrical Pin Fin

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ABSTRACT

A Pin Fin heat sink is a normal heat sink, but it differs from other heat sinks as it consists of pins that are extended from its base. These pins are in various shapes including elliptical, cylindrical and square shapes. A plate-fin heat exchanger is a type of heat exchanger design that uses plates and finned chambers to transfer heat between fluids. It is often categorized as a compact heat exchanger to emphasise its relatively high heat transfer surface area to volume ratio. The fin efficiency is defined as the ratio of the actual heat transfer rate through the fin base divided by the maximum possible heat transfer rate through the fin base, which can be obtained if the entire fin is at base temperature.

In this project we explored the design power of mechanical engineering through Solid Works which plays crucial role in taking simulations on 3D models. Here in this project, we choose Pin fin apparatus in our HT lab as case study to compare the experimental results with simulation results of Solid Works graphically. Results and outputs of this project can be used as inputs to create different type of CFD and Thermal analysis of heat exchangers and other equipment.

INTRODUCTION

Fins are surfaces that extended from an object for increasing the rate of heat transfer to or from the environment by convection. The amount of heat transfers depends on the heat transfer through conduction, convection, or radiation of an object. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems. In this project we took reading from our Pin Fin Set up and simulated with solid works with neat calculations andconversions to compare with original data.This project will also give readers scope of analytical modelling of thermal behaviours of heat emitting equipments and parameters like Nusselt number,Reynold's number,Grashoff's number.

APPARATUS AND METHODS

Analytical modeling of pin device involves determining thermal parameters like convection coefficients and dimensionless numbers like Grashoff's Number, Nusselt Number, Biot Number, Prandlt Number to determine fin efficiency and other parameter like flow behaviour etc.

The experimental data are taken from the Pin Fin Apparatus and are applied in the relations to obtain the effectiveness of the pin fin.

Sl.No.	Voltage (V)	Current (amp)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6(°C) (ambient)
Distance of thermocouple, x=			3cm	6cm	9cm	12cm	15cm	36
1	120	0.7	91.3	81.2	77.6	75.8	67.2	
			91.4	81.3	77.8	76.1	67.4	
			91.6	81.6	77.9	76.2	67.5	
2	140	0.8	112.5	90.3	84.1	81.2	74.2	
			112.7	90.5	84.2	81.4	74.9	
			112.9	90.8	84.6	81.6	75.2	
3	160	0.93	120	94.6	87.5	84.4	77.9	
			120.4	94.9	87.9	84.6	78.3	
			120.8	95.3	88.4	85.1	78.9	

Table 3.1: Experimental data obtained from pin fin apparatus.

Fin effectiveness=tanh (mL)/mL
Where L= Length of fin and $m=\sqrt{(h^*C/K_bA)}$
K_b=Thermal Conductivity of brass fin =95 kcal/hm°C
C=Perimeter, m
A=Cross section area of fin, m^2
h= convective heat transfer co-efficient that can be estimated from following equation of free convection.
$Nu= 1.1(Gr\ Pr)^{1/6}$ for $0.1<Gr\ Pr<10000$
$Nu=0.53\ (Gr\ Pr)^{1/4}$ for $10000<Gr\ Pr<10^9$
$Nu=0.13\ (Gr\ Pr)^{1/3}$ for $10^9 <Gr\ Pr<10^{12}$
T_1 =91.3°C T_2 =87.2°C T_3 =81.2°C T_4=77.6°C T_5=75.8°C T_6=36°C
T_m =Mean temperature of the fin = T_m= [91.3+ 87.2+81.2+ 77.6+ 75.8]/5 = 82.62°C
Ambient air temperature= T_6= T_f=Fluid temperature
Mean temp of the fluid= T_{mf}= $(Tm+ T_f)/2$=(82.62+36)/2=59.31=60°C
Find properties of air at its mean fluid temperature like ρ,K,μ,C_p etc.
$\beta = 1/ T_{mf}$, where T_{mf} in K =1/60=0.0166
$Pr =\mu C_p/K$ (all air properties at given temp)=0.709
$Gr = [\beta.g.(T_m- T_f).D^3]/\varphi$= 0.322 => Gr * Pr=0.228
Using the co-relation for free convention
$Nu = 1.1(Gr.\ Pr)^{1/6}$=0.859 => Nu = 0.859

hD/k = Nusslet Number
where h=1.92 Kcal/ m^2 K
Fin parameter m = $\sqrt{[hP/K.A]}$
L = length of the fin = 150 mm=0.15m
Fin effectiveness = $\frac{\tanh(mL)}{mL}$= 0.5628= 56.28%

Figure 3.1 Pin Fin Apparatus

Figure 3.2 Thermocouple attached on fin

CREATION OF FIN 3D MODELS

Figure 3.3: Design of a cylindrical fin

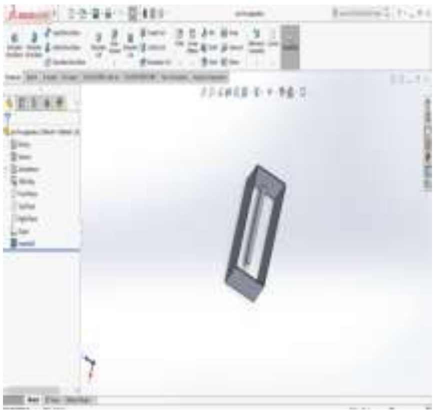

Figure 3.4: Design of duct

Duct size- 150x100x1000 mm^3; Diameter of the fin -12.7 mm; Length of the fin- 150mm

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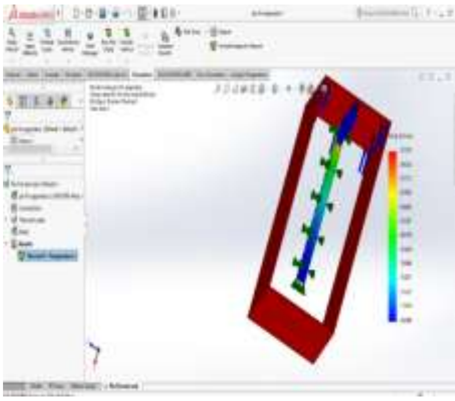

Figure 3.5: Thermal properties of the duct and fin

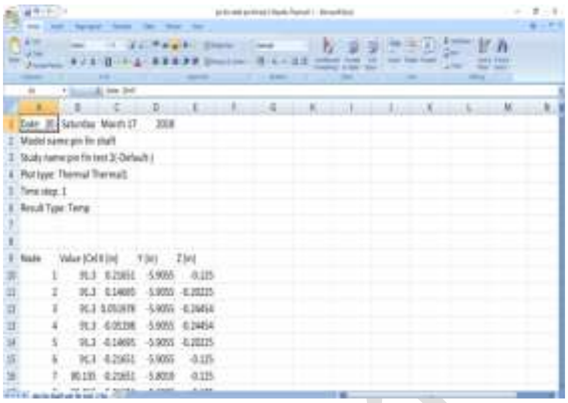

Figure 3.6: Values for the graphical representation

RESULTS AND DISCUSSIONS

There are three different graphs obtained for three different sets of base temperature reading.

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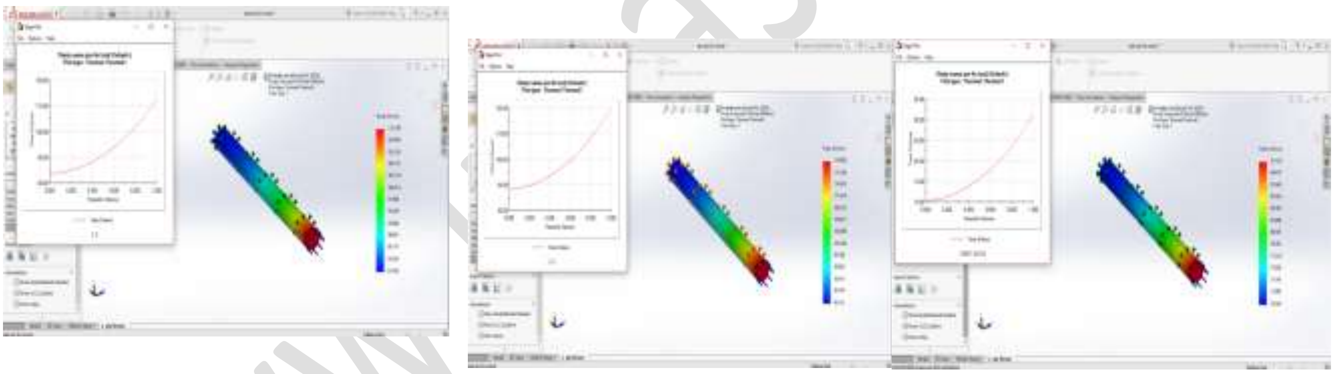

Figure 3.7: Graphical representation of the Fin stimulation (112°C,120 °C and 91.3 °C)

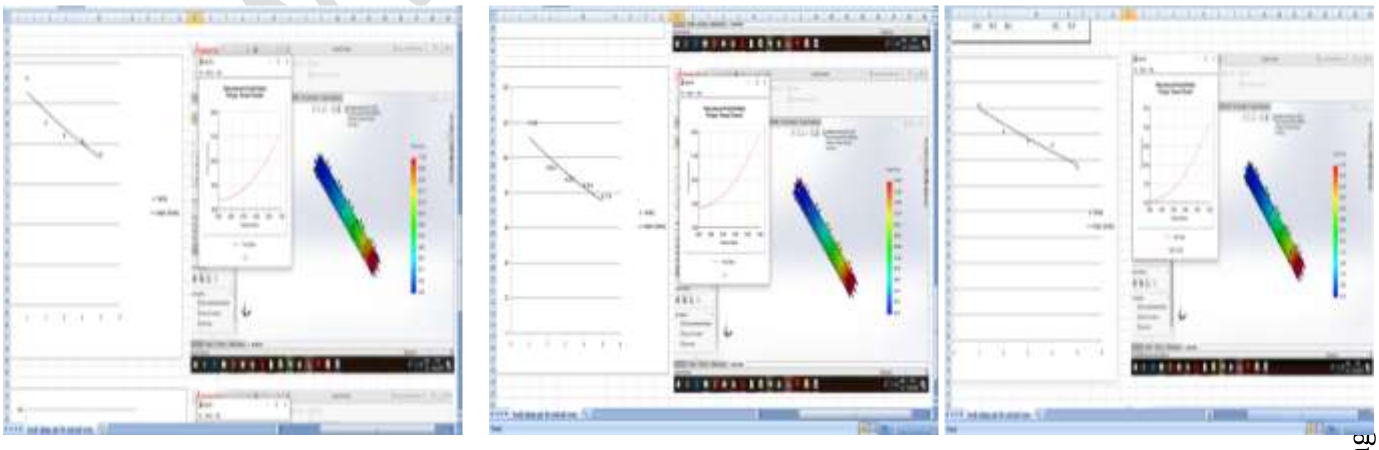

Figure 3.8: Compare of graphs between the experimental data with the software data (112°C, 120 °C and 91.3 °C)

From the above temperature profile, almost a mirror image is obtained. From the stimulated data the temperatures were considered and the effectiveness of fin was calculated and it was observed that there is a difference of almost 5 percent between experimental data and stimulated data. The average effectiveness of fin obtained considering the stimulated temperatures is 75.21%.

CONCLUSION AND FUTURE SCOPE OF PROJECT WORK

During this project we gained hands on practice on SolidWorks 2016 workbench and CATIA V5 workbench, conducted investigation using simulation. In this project it is observed that the graph is exponential form and is almost mirror image of the analytical one. The small amount of error is due to heat loss due to conduction and convection to the surrounding. The error may be due to the sensitive error of temperature sensor. The heat transfer through a cylindrical fin is studied by analytical and experimentally and it is concluded that the heat transfer takes place mostly in longitudinal direction or parallel to the contact surface.

The thermal properties of other fin material can be experimentally performed by using this software. In the future work, different fin materials of cylindrical shape will be taken and the temperature profile is to be observed and the fin effectiveness can be calculated. This skill can be used as ground work for gaining other skills like CFD, Structural Analysis for checking thermal and mechanical behaviour of mechanism and also numerical modeling of equipments subjected to heat flux.

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