THERMAL ANALYSIS ON RECTANGULAR PLATE FIN WITH PERFORATIONS USING ANSYS

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Abstract**:** In this paper, analysis is carried on extended surfaces, which are commonly used to enhance convection heat transfer in a wide range of engineering applications. The conception of introducing perforations on the lateral surface of fin is to enhance heat transfer rate effectively. This analysis helps in deciding the optimal geometry and configuration of perforations on the surface of the fin. Finely perforated aluminum (k=210W/mK), copper (k=410W/mK) fins are selected for investigation because both has higher thermal conductivities and are predominantly used in heat transfer applications.

Index Terms **- Heat transfer, heat transfer coefficient, temperature, fins, and perforations**.

I. INTRODUCTION:

There are numerous situations where heat is to be transferred between a fluid and a surface. In such cases, the heat flow depends on three factors namely [1] (i) area of the surface (ii) Temperature difference and (iii) the convective heat transfer coefficient.

The base surface area is limited by design of the system. The temperature difference depends on the process and cannot be altered. The only choice appears to be the convection heat transfer coefficient and this cannot be increased beyond a certain value. Any such increase will be at the expense of power for fans or pumps. Thus, the possible option is to increase the base area by the so-called extended surfaces or fins. Several shapes of fins are in use. These are (i) Plate fins of constant sectional area (ii) Plate fins of variable sectional area (iii) Annular or circumferential fins constant thickness (iv) Annular fins of variable thickness (v) Pin fins of constant sectional area and (vi) Pin fins of variable sectional area.

Fins are found more valuable when the convective heat transfer coefficient is low. The main aim is to design fins to optimize the heat transfer. For this purpose, it will be desirable that the use of materials of high thermal conductivity like copper or aluminum.

II. PRESENT WORK:

The present simulation analysis investigates the heat transfer enhancement on rectangular lamina using two different materials copper and aluminum without perforations, with different perforation shapes on the above-mentioned two materials by keeping at constant Reynolds number and Power Input. Selecting one optimum perforation shape, material among the different perforation shapes after the analysis.

III. EXPERIMENTAL SETUP:

Figure 1 shows the schematic diagram of the experimental setup. It consists of a rectangular channel made up of metal sheet material. For experimentation different types of perforated fins are used which compared with the solid fins. Different types of perforated fins along with different materials are given in Table 1. Fins are heated uniformly at its base. A fan is used to produce airflow over the fins. The arrangement of fan and direction of airflow is as shown in Figure; thermocouples are used for the measurement of temperature of air at the inlet and outlet of channel. Mass flow rate of air is controlled by controlling the speed of fan. Mass flow rate is measured with the help of anemometer.

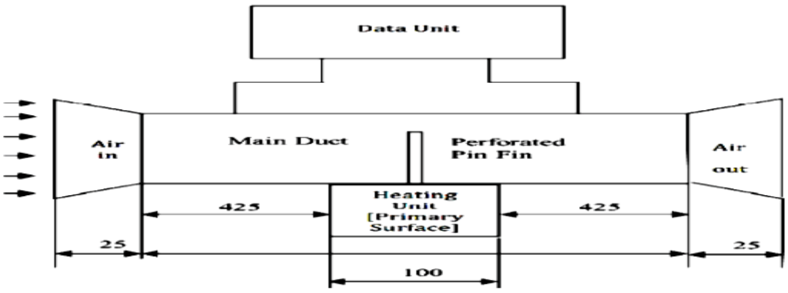


Figure 1: *Pin Fin Apparatus*

IV. RESULTS AND DISCUSSIONS:

4.1 Input parameters:

- Ambient temperature -295 Kelvin
- Root temperature -773 Kelvin
- H =20 W/m^{2}K
- Materials used: Aluminum, Copper
- Time is equal to 500 seconds
- Common shear area is equal to 400 square mm
- Is equal to 150 mm
- Width is equal to 50 mm
- Thickness is equal to 5 mm

4.2 Output observations:

- Value of h
- Percentage increase of h over a blank fin
- Temperature

4.3 Formula correlations:

$$\frac{T_x - T_a}{T_o - T_a} = \frac{\cosh m(L-x)}{\cosh mL}$$

Where m is given by, $m = \sqrt{\frac{h \times p}{K \times A}}$

Where, h is the convective heat transfer coefficient,
P is the perimeter
K is the Thermal conductivity of the material,
A is the cross sectional area of the fin

$$Re = \frac{\rho V L_c}{\vartheta}$$

Where, ρ = density of air,
L_c=Characteristic length of the fin,
V= velocity of air,
ϑ =Kinematic viscosity

$Nu = 0.615 \times Re^{0.466}$ For 40<Re<4000

$Nu = 0.174 \times Re^{0.618}$ For 4000<Re<40000

$$Nu = \frac{h \times L_c}{K_{air}}$$

K_{air} = Thermal conductivity of air

$$Q = \sqrt{h \times p \times K \times A}(\Delta T) \tanh mL$$

$$\eta = \frac{\tanh mL}{mL} \qquad \emptyset_{fin} = \tanh mL \sqrt{\frac{p \times h}{K \times A}}$$

T_x = Temperature at distance x from the root
T_a = Ambient temperature
T_o = Temperature at the root
L = Total length of the fin

4.4 Rectangular Lamina with Lateral Perforations:

The purpose of this analysis is to know the effects of lateral perforation [2] shapes on the thermal performance of fins in comparison with the solid fins. The rectangular lamina with different types of lateral perforations as shown in

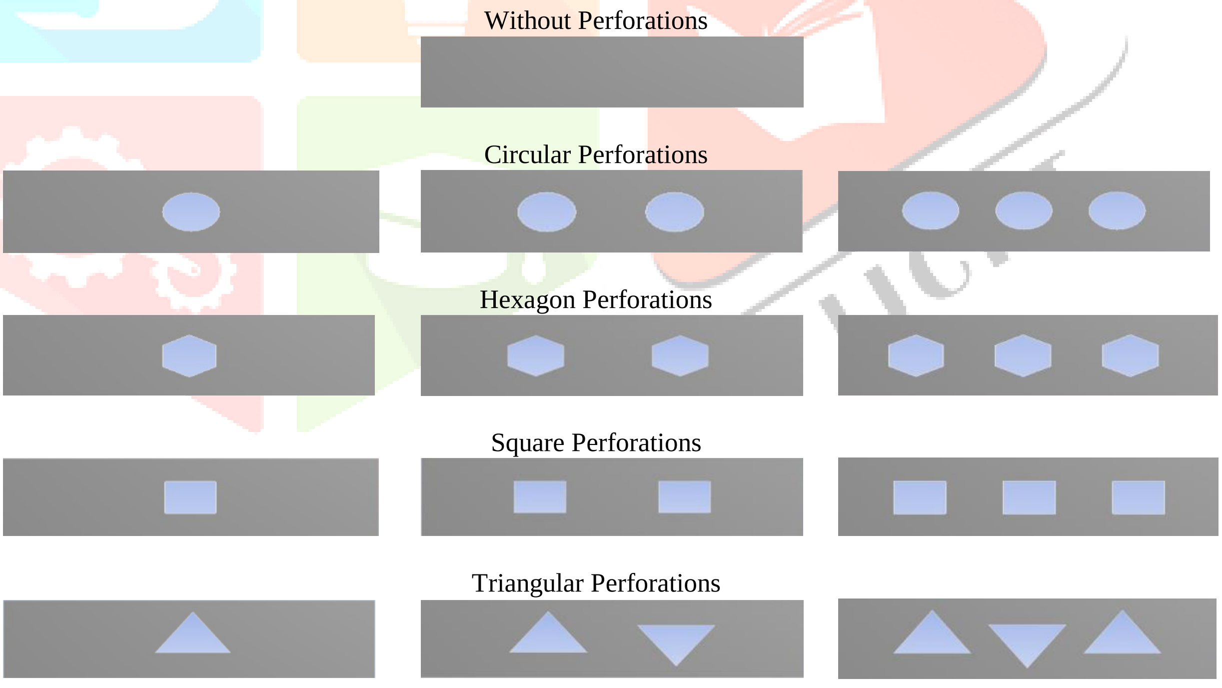


Figure 2: Rectangular Lamina with Lateral Perforations

Table 1: Rectangular Lamina with different types of Lateral Perforations

S.No	Material	With / Without Perforations	No of Perforations		
1	Aluminum	Without Perforations	0		
2	Aluminum	With Circular Perforations	1	2	3
3	Aluminum	With Square Perforations	1	2	3
4	Aluminum	With Hexagon Perforations	1	2	3
5	Aluminum	With Triangular Perforations	1	2	3
6	Copper	Without Perforations	0		

7	Copper	With Circular Perforations	1	2	3
8	Copper	With Square Perforations	1	2	3
9	Copper	With Hexagon Perforations	1	2	3
10	Copper	With Triangular Perforations	1	2	3

4.5 Analysis using ANSYS Software:

The purpose of this analysis is to know the effects of lateral perforation shapes on thermal performance when compared with the regular solid fins. In the present work first we perform analysis on non-perforated fin and then fins perforated by different shapes such as circle, square, hexagon and triangular but all these perforations have the same cross sectional area.

4.5.1 Non-Perforated:

A rectangular lamina of dimensions 150X50X5 mm is considered for the analysis with two materials viz., copper, aluminium as the reference and the following table gives the tip temperature, Convective Heat-Transfer Co-efficient.

Table 2: Non-perforated Rectangular Lamina with different materials

Temperature	Mat.\Type	Tip Temp	'h'(heat transfer coefficient) W/m^{2}K
Root 773 K	Aluminum	620 K	16.21
	Copper	671 K	17.64

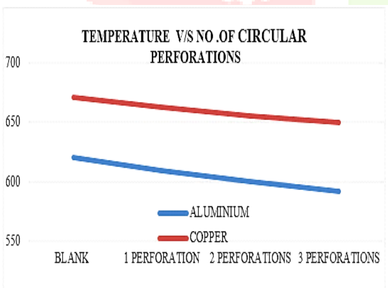
4.5.2 Perforated:

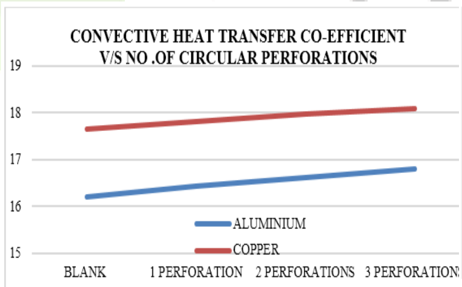
4.5.2.1 Circular Perforations:

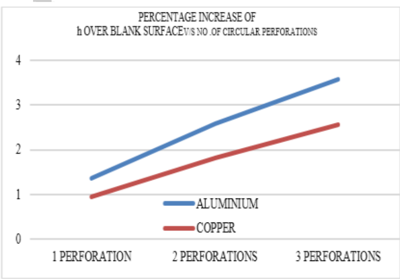
Circular perforations [3] with the shear area of 400mm^{2}and increasing the perforations from 1 to 3 following is the data obtained from the ANSYS simulation. Plots of temperature v/s no. of perforations and Convective Heat-Transfer Co-Efficient V/S No. of Circular Perforations, and Percentage increase of h over blank surface v/s no. of perforations.

Table 3: Circular -perforated Rectangular Lamina varying perforations with different materials

Temperature	Mat.\Type	No. Perforations	Tip Temp	'h'(heat transfer coefficient) W/m^{2}K	Percentage increase of 'h' over blank surface
Root 773 K	Aluminum	1	609.23 K	16.43	1.36
		2	599.77 K	16.62	2.59
		3	592.23 K	16.79	3.58
	Copper	1	663.07 K	17.81	0.94
		2	655.72 K	17.96	1.82
		3	649.66 K	18.09	2.56







***Graph 1:** Temperature V/S No. of Circular Perforations*

***Graph 2**: Convective Heat-Transfer Co-efficient V/S No. of Circular Perforations*

***Graph 3:** Percentage increase of 'h' over blank surface V/S No. of Circular Perforations*

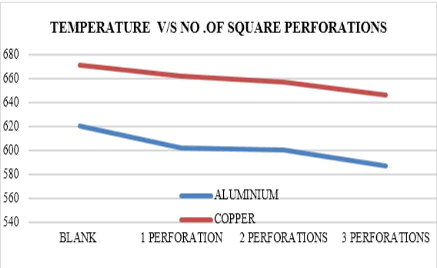
- From graph 1 it can be observed that aluminum has the lowest tip temperature with three perforations in it.
- From the graph 2 it can be noted that though initial copper has maximum 'h' value for three perforations, Aluminum has reached the close value of 'h' at third perforation.
- From the graph 3 it can be noted that aluminum has maximum percentage increase of 'h' over the blank fin for three perforated Aluminum.
- For circular perforation: Considering both temperature and 'h' it is better to select aluminum with three circular perforations in it.

4.5.2.2 Square Perforations:

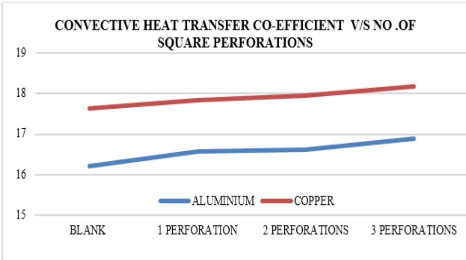
Square perforations [4, 5] with the shear area of 400 mm^2 and increasing the perforations from 1 to 3 following are the data obtained from the ANSYS simulation. Plots of Temperature V/S No. of Perforations and Convective Heat-Transfer Co-efficient V/S No. of Circular Perforations

Table 4: Square -perforated Rectangular Lamina varying perforations with different materials

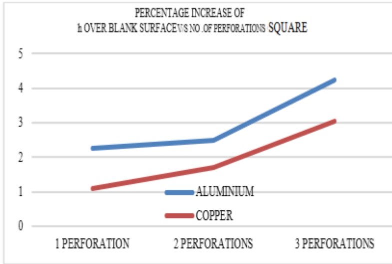
Temperature	Mat.\Type	No. Perforations	Tip Temp	'h'(heat transfer coefficient) W/m^{2}K	Percentage increase of 'h' over blank surface
Root 773 K	Aluminum	1	602.30 K	16.57	2.25
		2	600.44 K	16.61	2.50
		3	587.39 K	16.89	4.23
	Copper	1	661.75 K	17.83	1.10
		2	656.71 K	17.94	1.70
		3	645.81 K	18.18	3.04



Graph 4: *Temperature V/S No. of Square Perforations*



Graph 5: *Convective Heat-Transfer Co-efficient V/S No. of Square Perforations*



Graph 6 *: Percentage increase of 'h' over blank surface V/S No .of Square Perforations*

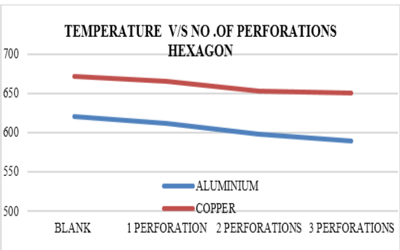
- From graph 4 it can be observed that aluminum has the lowest tip temperature with three perforations in it.
- From the graph 5 it can be noted that though initial copper has maximum 'h' value for three perforations, Aluminum has reached the close value of 'h' at third perforation.
- From the graph 6 it can be noted that aluminum has maximum percentage increase of 'h' over the blank fin for three perforated Aluminum.
- For Square perforation: Considering both temperature and 'h' it is better to select aluminum with three square perforations in it.

4.5.2.3 Hexagon Perforations:

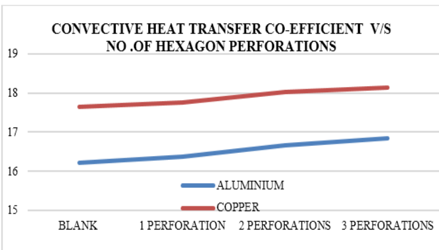
Hexagon perforations [3] with the shear area of 400 mm^2 and increasing the perforations from 1 to 3 following are the data obtained from the ANSYS simulation. Plots of Temperature V/S No. of Perforations and Convective Heat-Transfer Co-efficient V/S No. of Hexagon Perforations

Table 5: Hexagon -perforated Rectangular Lamina varying perforations with different materials

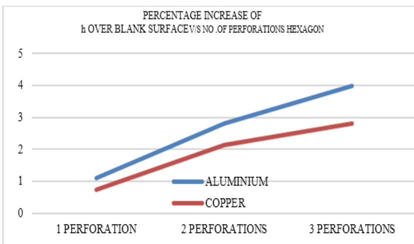
Temperature	Mat.\Type	No. Perforations	Tip Temp	'h'(heat transfer coefficient) W/m^{2}K	Percentage increase of 'h' over blank surface
Root 773 K	Aluminum	1	611.21 K	16.38	1.11
		2	598.12 K	16.66	2.80
		3	589.09 K	16.85	4.00
	Copper	1	664.69 K	17.77	0.74
		2	653.12 K	18.02	2.14
		3	647.68 K	18.14	2.81



Graph 7: *Temperature V/S No. of Hexagon Perforations*



Graph 8: *Convective Heat-Transfer Co-efficient V/S No. of Hexagon Perforations*



Graph 9*: Percentage increase of 'h' over blank surface V/S No. of Hexagon Perforations*

- From graph 7 it can be observed that aluminum has the lowest tip temperature with three perforations in it.
- From the graph 8 it can be noted that though initial copper has maximum 'h' value for three perforations, Aluminum has reached the close value of 'h' at third perforation.

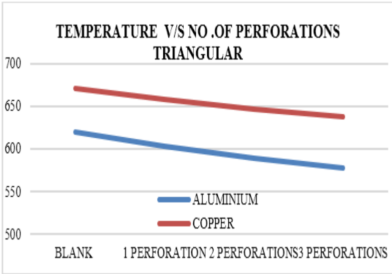
- From the graph 9 it can be noted that aluminum has maximum percentage increase of ‘h’ over the blank fin for three perforated Aluminum.
- For Hexagon perforation: Considering both temperature and ‘h’ it is better to select aluminum with three hexagon perforations in it.

4.5.2.3 Triangular Perforations:

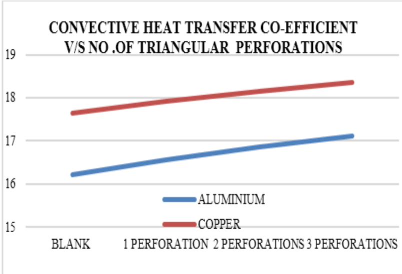
Triangular perforations [6] with the shear area of 400 mm^2 and increasing the perforations from 1 to 3 following are the data obtained from the ANSYS simulation. Plots of Temperature V/S No. of Perforations and Convective Heat-Transfer Co-efficient V/S No. of triangular Perforations

Table 5: Triangular -perforated Rectangular Lamina varying perforations with different materials

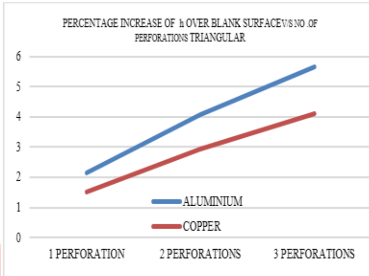
Temperature	Mat.\Type	No. Perforations	Tip Temp	‘h’(heat transfer coefficient) W/m^2K	Percentage increase of ‘h’ over blank surface
Root 773 K	Aluminum	1	603.00 K	16.56	2.16
		2	588.62 K	16.86	4.07
		3	577.06 K	17.12	5.65
	Copper	1	658.18 K	17.91	1.52
		2	646.77 K	18.16	2.92
		3	637.35 K	18.36	4.10



Graph 10: Temperature V/S No. of Triangular Perforations



Graph 11: Convective Heat-Transfer Co-efficient V/S No. of Triangular Perforations

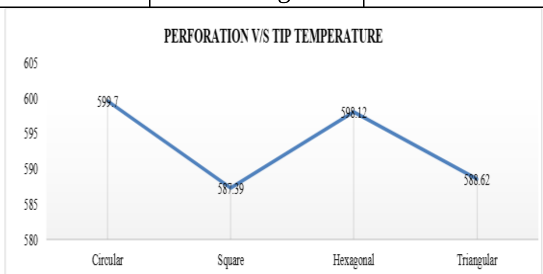


Graph 12: Percentage increase of ‘h’ over blank surface V/S No. of Triangular Perforations

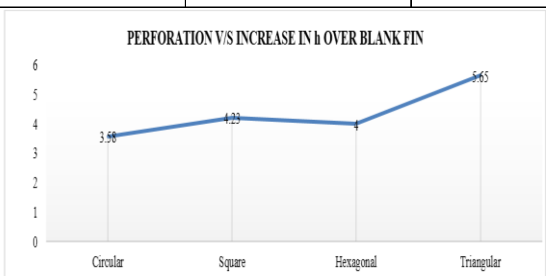
- From graph 10 it can be observed that aluminum has the lowest tip temperature with three perforations in it.
- From the graph 11 it can be noted that though initial copper has maximum ‘h’ value for three perforations, Aluminum has reached the close value of ‘h’ at third perforation.
- From the graph 12 it can be noted that aluminum has maximum percentage increase of ‘h’ over the blank fin for three perforated Aluminum.
- For Triangular perforation: Considering both temperature and ‘h’ it is better to select aluminum with three triangular perforations in it.

Table 6: Different Perforations of Aluminum Rectangular Lamina

Material	Perforation type	Root temperature	No. of perforations	Temperature	Increase of ‘h’ over blank fin
Aluminum	Circular	773K	3	599.7K	3.58
Aluminum	Square	773K	3	587.39K	4.23
Aluminum	Hexagonal	773K	3	598.12K	4
Aluminum	Triangular	773K	3	588.62K	5.65



Graph 13: Perforation V/S Tip Temperature.



Graph 14: Perforation V/S Increase in ‘h’ over blank fin.

IV. CONCLUSION:

In circular perforation when we consider both temperature and ‘h’ it is better to select aluminum with three circular perforations in it when compared with copper. In Square perforation when we consider both temperature and ‘h’ it is better to select aluminum with three square perforations in it when compared with copper. In Hexagon perforation when we consider both temperature and ‘h’ it is better to select aluminum with three hexagon perforations in it when compared with copper. In Triangular, perforation when we consider both temperature and ‘h’ it is better to select aluminum with three triangular perforations in it when compared with copper. From the above research, it is evident that tip temperature is minimum for aluminum triangularly perforated with three perforations in it and h increase is maximum for triangularly perforated with three perforations of aluminum material. From the above research, we can say that convective heat transfer coefficient increases for perforated fin when compared with non- perforated fin. From the above research, we can say that Nusselt’s numbers increases for perforated fin when compared with non- perforated fin. Therefore, a three triangle laterally perforated aluminum is most suitable for the fin applications.

V. REFERENCES:

[1] Md. Farhad Ismail, Muhammad Noman Hasan, Suvash C. Sahac, "Numerical study of turbulent fluid flow and heat transfer in lateral perforated extended surfaces". Elsevier.

[2] Raaid R. Jassem, "Effect the Form of Perforation on the Heat Transfer in the Perforated Fins", Academic Research International, ISSN-L: 2223-9553, ISSN: 2223-9944Vol. 4 No. 3 May 2013.

[3] Isam H. E. Qasem and Abdullah H. M. AlEssa, "One Dimensional Finite Element Analysis of Heat Dissipation from Rectangular Fin with Longitudinal Hexagonal Perforations", RRJET | Volume 4 | Issue 2 | April–June2015.

[4] H, M. AlEssa "Augmentation of Fin Natural Convection Heat Dissipation by Square Perforations”, Journal of Mechanical Engineering and Automation 2012, 2(2): 1-5DOI: 10.5923/j.jmea.20120202.01

[5] Kavita H. Dhanawade, Vivek K. Sunnapwa and Hanamant S. Dhanawade, "Thermal Analysis of Square and Circular Perforated Fin Arrays by Forced Convection", International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

[6] Abdullah H. AlEssa and Mohammed Q. Al-Odat, "Enhancement of Natural Convection Heat Transfer from A Fin by Triangular Perforations of Bases Parallel and Toward Its Base”, the Arabian Journal for Science and Engineering, Volume 34, October 2009.