COMPARATIVE THERMAL ANALYSIS OF VARIOUS PERFORATED PIN FINS BY USING ANSYS

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Abstract:Pins fins are the most commonly used heat exchanging device. By aiming to change the dimensions and shapes of the fins, industries are consistently working with it. The objective of this study is to examine the effects of the many pin fin shapes on the thermal performance by helpof Ansys software. For effective heat transfer the various types of perforation are used on pin fin. The main attention is to increase the heat transfer rate and temperature drop through the fin surface for better performance. For better performance, copper is used but generally Aluminium are widely used because of its low weight and low cost. The entire process is done by using solid works and ansys software. The 3d model is made on solid works having many shapes like solid pin fin with circular holes, rectangular holes, triangular holes and rectangular holes with slot. Then thermal analysis is accomplished by Ansys. After analysis, we found that the maximum temperature drop is in the solid pin fin with rectangular holes and slot. It's temperature drop is 71.37^{0}c. After that we find out the heat transfer for each shape and got that solid pin fin with rectangular holes and slot have maximum heat transfer as 26.96 J/s among all other shapes. Their maximum heat transfer allows to transfer more heat and give better performance.

***Keywords*- Pin Fins, Heat Exchanger, Extended surfaces, Thermal Analysis**

I. INTRODUCTION

Pin fins is a piece of metal placed perpendicular from metallic base. Most of pin fins are manufactured through cold forging Technology. By the assist of this technology pin fins are untouched with any cavities and impurities. In this Technology, the defamation of metal into its predetermined structure through the usage of certain equipment and tools known as forging. cold forging is commonly used when metal is tender like Aluminium. It is less costly and takes place at room temperature. Pin fins is used to maximize the region of device for absorption of heat. Their shapes may additionally be elliptical cylindrical and Square. It performs better when positioned in tilted position. Generally pin fins are made up of aluminium. Because it has high thermal conductivity, having mild weight and higher heat dissipation (the procedure of turning into cooler or falling temperature), But for better performance sometime copper is also used. The thermal analysis of pin fins is completely relying upon their parameters like shape, size, material and their position etc. There is one extra parameter to change heat transfer rate is temperature gradient and it is depending upon the boundary circumstance and geometry for conduction.

II. LITERATURE REVIEW

Most of the studies showed the beneficial effects of the perforations on the heat transfer rate in the pin fin.Yue-Tzu Yang and Huan-Sen Peng concluded an adequate un-uniform fin height design could decrease the junction temperature and increase the enhancement of the thermal performance simultaneously [1].Bayram Sahin and Alparslan Demir studied that the most effective parameter on the friction factor is found to be fin height [2].A.-R.A. Khaled resulted the increase in heat flow through hairy fin systems is significant enough to allow them to be utilized in the design of thermal systems [3].Hung-Yi Li and Kuan-Ying Chen explained the effect of increasing the fin height on the thermal resistance is less effectively than that by increasing the fin width [4].Tzer-Ming Jeng concluded that the optimal inter-fin pitches are proposed herein based on the largest heat dissipation under the same pumping power [5].Peles et.al. explained heat transfer coefficients for microscale pins are very large and result in decreasing fin efficiencies. To increase efficiencies, pins should be relatively short [6].Ugur Akyol and Kadir Bilen experimented that A slightly better heat transfer was achieved for the staggered array than for the in-line arrangement based on total surface area due to the increase of the turbulence and better mixing of the flow [7].Kou et.al. Explained new approach to calculate temperature distribution and heat transfer rate of a singular fin where thermal properties such as heat transfer coefficient, thermal conductivity can be considered as the position- dependent or temperature- dependent function [8].Chen et.al. studiedthe conjugate gradient method converges very quickly to obtain the inverse solution for estimating the transient 2-D heat flux of a pin fin [9].Sara et.al. explainedthat entropy minimization technique was used to evaluate the performance of the pin-fin array systems [10].Tahat et.al. The steady-state design data correlations facilitate predicting the performancesof aligned and staggered pin fins, when used as arrays in heat exchangers and henceoptimal designs to be chosen [11].

III. THEORY

There are distinctive modes of heat transfer which consists of conduction, convection and radiation. Conduction is described as heat through the direct molecular collision. A place of greater kinetic energy transfers thermal energy in the direction of the place with lower kinetic energy. Heat transfer via conduction is calculated as $Q = [k \cdot A \cdot (T_2 - T_1)]/d$where k is thermal conductivity, A is area, $T_1$and $T_2$are temperature. When fluid is heated, it travels away from the supply and contains thermal energy along. This form of heat transfer is recognized as convection. Heat transfer via conduction is calculated as Q = h · A · (T_s – T_f) where h is heat transfer coefficient, A is area, T_s and $T_f$are temperature of surface and fluid. In radiation, Heat transfer take place in the form of electromagnetic waves commonly in the infrared region. Heat can be transmitted through empty space via thermal radiation frequently known as infrared radiation. The Reynolds number is the ratio of inertial forces to viscous forces and is a convenient parameter for predicting if a flow condition will be laminar or turbulent. Prandtl number, Pr, is a dimensionless parameter representing the ratio of diffusion of momentum to diffusion of heat in a fluid. Grashof number, Gr, is a no dimensional parameter used in the correlation of heat and mass transfer due to thermally induced natural convection at a solid surface immersed in a fluid. Nusselt number (Nu) is the ratio of convective to conductive heat transfer across (normal to) the boundary.

V RESULTS AND DISCUSSION

In this paper, we analyze a solid pin fin and apply different perforation in it. First, weselect the different shapes for perforation on pin fin as shown in table 1.

Table 1 : Selection of different shapes

S. No	Shape	Reason
1	Circular	Under pin fins parameter, Easy to design
2	Rectangular	Easy for manufacturer to design
3	Triangular	Draw under pin fin size
4	Hexagonal	Not easy to draw under pin fin parameter
5	Octagon	Not easy for manufacturer to design

Length of Pin Fin	90 mm
Diameter of Pin Fin	8 mm
Circular Hole Diameter	4 mm
Rectangular Hole Length & Breadth	6mm and 4mm
Triangular Hole Length & Breadth	4mm and 4mm

In the above table, we took eyes on three perforations circular, rectangular and triangular. After selection, It is necessitating to define parameters for continuing the action as shown in table 2.

Table 2: Parameter of different shapes

After selection of shapes and parameters our focus is on selection of material of pin fin. During selection of material, we have two main things to focus. First is thermal conductivity of material and second is its cost. Material with high thermal conductivity allows to transfer more heat. By taking eyes on these properties we focus on few materials as shown it table 3.

Table 3: List of Material

S.No.	Material	Thermal Conductivity (W/mk)	Cost
1	Copper	400	Very high
2	Aluminium	167	Very low
3	Brass	111	Very high
4	Stainless Steel	13.8	Low

As you see in the above table, Copper has highest Thermal conductivity but its cost is also very high. Brass is also costly and stainless steel have low thermal conductivity. Now out of four shells, we have only last one i.e. aluminium, having high thermal conductivity and its cost is low. Aluminium is a chemical element in the group with symbol Al and its atomic number is 13. Its low density, excellent corrosion resistance, good thermal and electrical conductivity etc are the other decent properties. That's why we choose Aluminium as material of pin fin.

After material selection, design of 3d model of all shapes in solidworks. Solid pin fin 3d model is shown in figure 1.

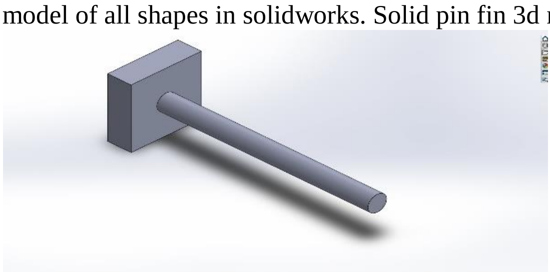


Figure 1: Solid pin fin 3d model

After that extrude cut, accomplishes four circular holes in solid pin fin as shown in figure 2.

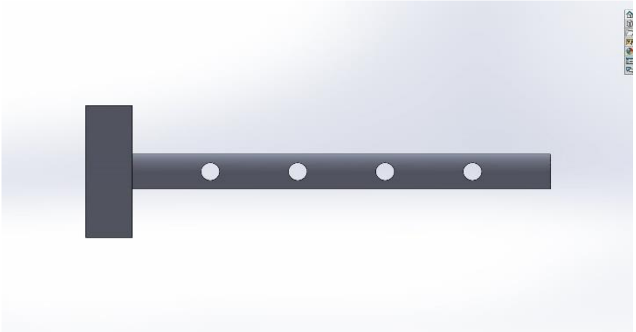


Figure 2: Solid pin fin with circular holes 3d model

Now, take one step frontward and create four rectangular holes in solid pin fin as shown in figure 3.

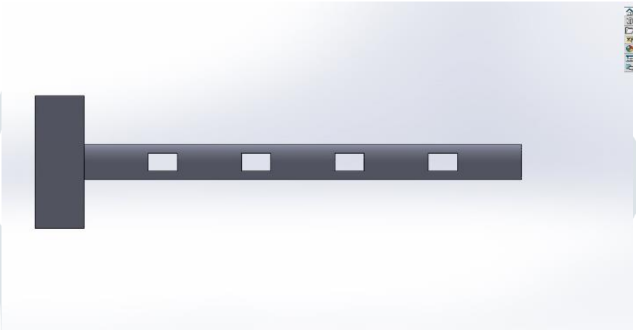


Figure 3: Solid pin fin with rectangular holes 3d model

After that, take one more step in the form of four triangular holes in solid pin fin as shown in figure 4.

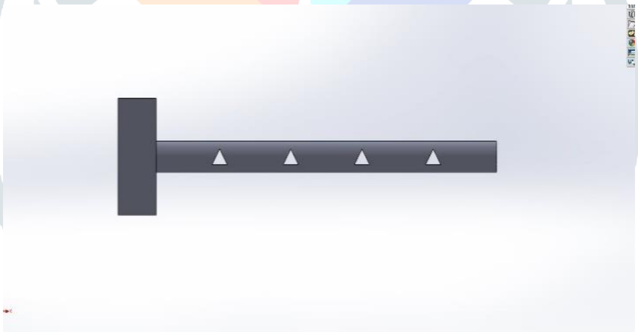


Figure 4: Solid pin fin with triangular holes 3d model

At last, final perforation is done in the form of four rectangular holes with a slot in solid pin fin as shown in figure 5.

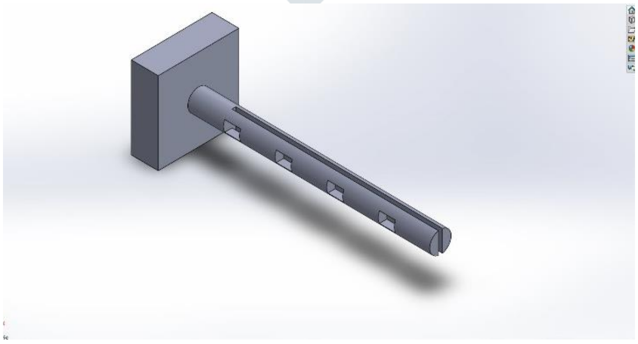


Figure 5: Solid pin fin with rectangular holes and slot 3d model

Now, these solidworks files save as in step file format that permits to import it into ansys. After import of these 3d models in ansys software, selection of material to model as Aluminium 6061. Then do meshing of the model and define surface temperature as 105°c and fluid temperature as 25°c. Then we accomplish thermal analysis and get different temperature drop for different shapes. After analysis following temperature distribution is shown. Figure 6 shows the temperature drop for solid pin fin. It is 90.21^0c at the end of pin fin.

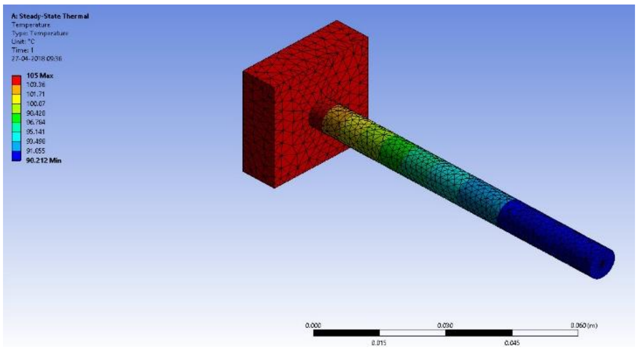
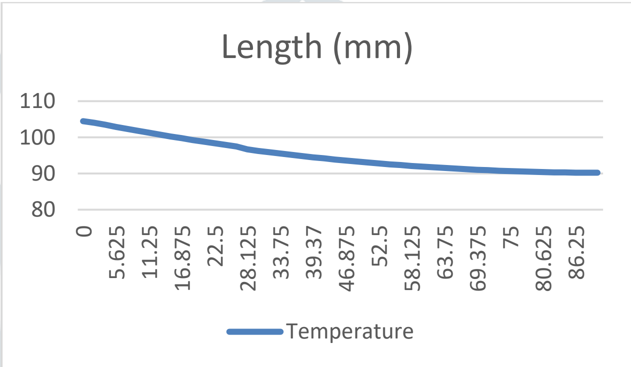


Figure 6: Temperature distribution for solid pin fin

Here after the analysis, we saw that the minimum temperature is 90.2^{0}c. Then calculation of the heat transfer of solid pin fin is done as 15.57 J/s.The graph 1, shows the different temperature drop at different points of pin fin. The vertical values of graph represent the temperature values in ^{0}c and the horizontal values represent the length of pin fin in mm.



Graph 1: Temperature distribution for solid pin fin

After analysis of solid pin fin, its shot for solid pin fin perforation, where first target is circular holes. As it is shown in figure 7. It shows the temperature drop as 85.56^{0}c at the end of pin fin.

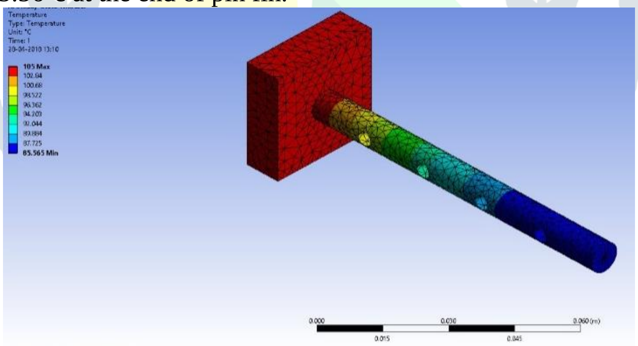
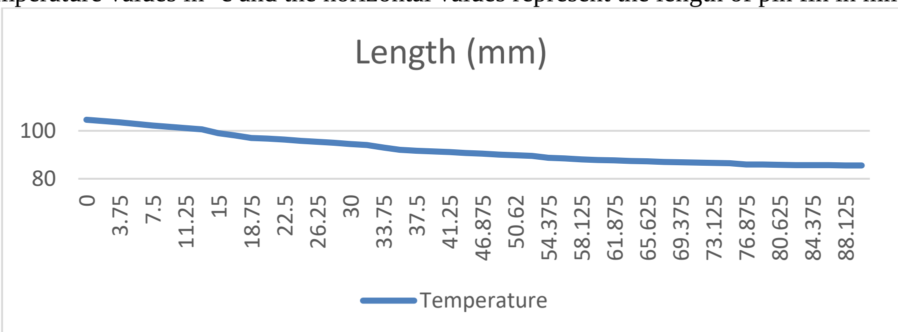


Figure 7: Temperature distribution for solid pin fin with circular holes

we saw that the minimum temperature is 85.56^{0}c. After this analysis, calculation of heat transfer of solid pin fin with circular holes as 20.46 J/s.

The graph 2, shows the different temperature drop at different points of pin fin from its source to free end. The vertical values of graph represent the temperature values in ^{0}c and the horizontal values represent the length of pin fin in mm.



Graph 2: Temperature distribution for solid pin fin with circular holes

After analysis of solid pin fin with circular holes, second target is to analyse one more solid pin fin perforation, where it is done by rectangular holes. As it is shown in figure 8. It shows the temperature drop as 81.72^0c at the end of pin fin.

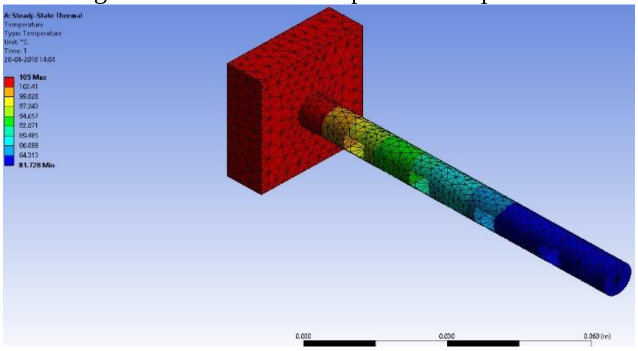
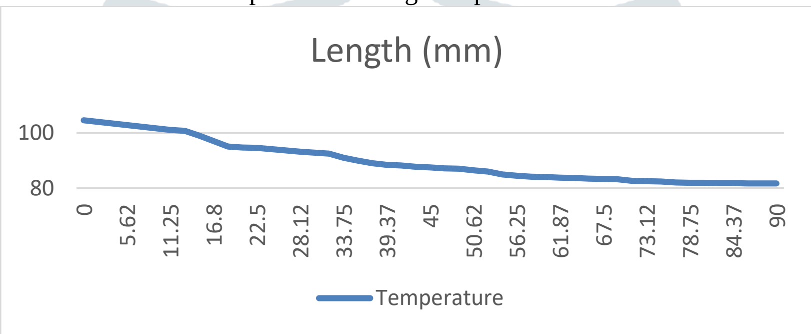


Figure 8: Temperature distribution for solid pin fin with rectangular holes

we saw that the minimum temperature is 81.72^0c. After this analysis, calculation of heat transfer of solid pin fin with rectangular holes as 24.48 J/s.

The graph 3, shows the different temperature drop at different points of pin fin. The vertical values of graph represent the temperature values in ^{0}c and the horizontal values represent the length of pin fin in mm.



Graph 3: Temperature distribution for solid pin fin with rectangular holes

After analysis of solid pin fin with rectangular holes, next target is to analyse solid pin fin perforation with triangular holes. As it is shown in figure 9. It shows the temperature drop as 85.91^0c at the end of pin fin.

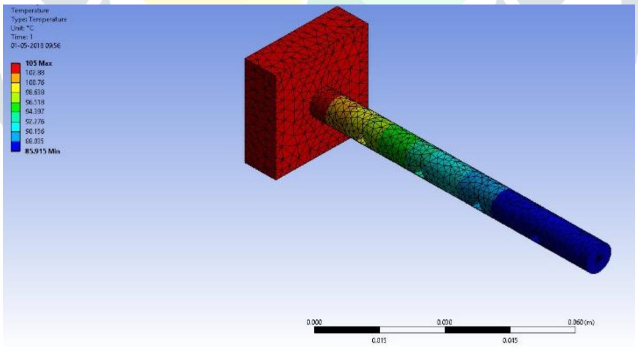
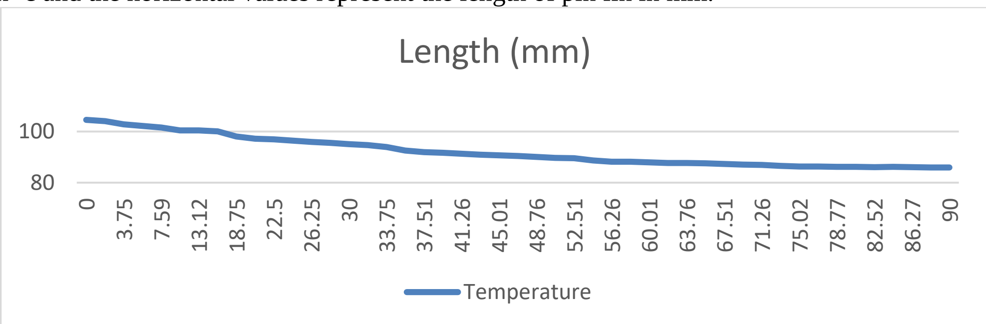


Figure 9: Temperature distribution for solid pin fin with triangular holes

we saw that the minimum temperature is 85.91^0c. After this analysis, calculation of heat transfer of solid pin fin with triangular holes as 20.09 J/s.

The graph 4, shows the different temperature drop at different points of pin fin. The vertical values of graph represent the temperature values in ^{0}c and the horizontal values represent the length of pin fin in mm.



Graph 4: Temperature distribution for solid pin fin with triangular holes

After analysis of solid pin fin with triangular holes, the final target is to analysesolid pin fin perforation with rectangular holes and slot. As it is shown in figure 10. It shows the temperature drop as 85.91^{0}c at the end of pin fin.

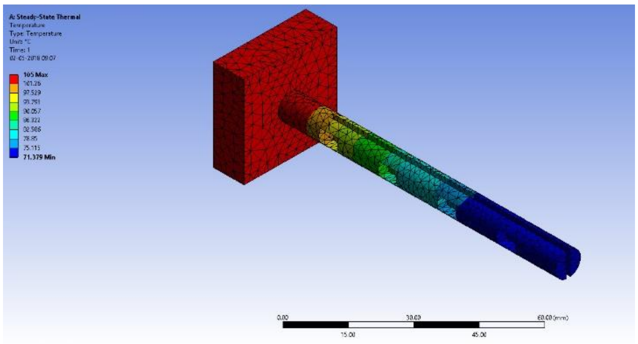
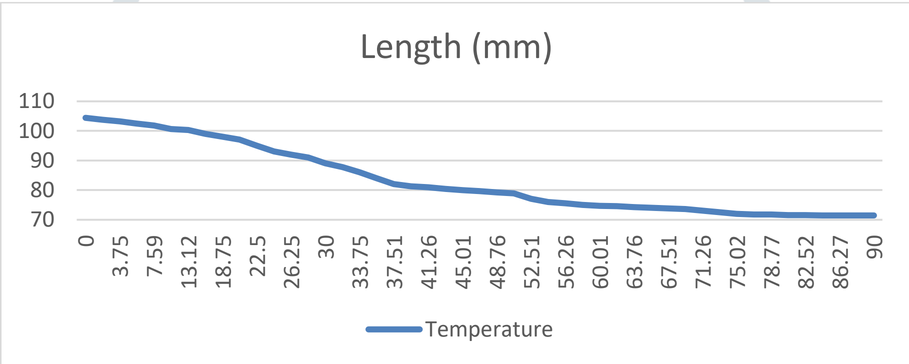


Figure 10: Temperature distribution for solid pin fin with rectangular holes and slot

Here after the analysis, we saw that the minimum temperature is 71.37^{0}c. Calculation of heat transfer of solid pin fin with rectangular holes and slot as 26.96 J/s.

The graph 5, shows the different temperature drop at different points of pin fin. The vertical values of graph represent the temperature values in ^{0}c and the horizontal values represent the length of pin fin in mm.



Graph 4: Temperature distribution for solid pin fin with rectangular holes and slot

NowIt is found that, the maximum temperature dropis in the solid pin fin with rectangular holes and slot. A comparative result table of all shapes of pin fin is shown below.

Table 4: Comparison table for different shaped pin fins

S.No.	Shape	Maximum Temperature (^{0}c)	Temperature drop (^{0}c)	Heat Transfer (J/s)
1.	Solid pin fin	105	90.21	15.57
2.	Solid with Circular holes	105	85.56	20.46
3.	Solid pin fin with Rectangular holes	105	81.72	24.48
4.	Solid pin fin with Triangular holes	105	85.91	20.09
5.	Solid pin fin with Rectangular holes and slot	105	71.37	26.96

In the table 4, Solid pin fin with rectangular holes and slot perform better than all other shapes. It governed on solid pin fin and their other perforations and shows better heat transfer and lowest temperature drop among all of them. But question arises that why is this happened? What are the reasons behind that? It gives good result in rectangular with slot than other because of its size. There is a limitation in increasing size of circle and triangle due to fix or definite size of pin fin. But, it has fewer limitations in rectangular. More space is helpful for fluid to carry heat from it and give better transfer of heat.As you saw that, we made holes in pin fins and these holes change the performance of pin fin. That's because of the medium of fluid. As we know that medium of fluid is air, when air is passing through the holes make some changes. Flowing air grab the heat through pin fin and transfer it to atmosphere.Due to this, value of temperature is low.

From the investigation, the following conclusions were made:

1. It is found that the temperature drop along the perforated pin fins is consistently higher than that for the non-perforated pin fins.
2. It is found that the heat transfer rate is more for different perforated pin fin with compare to solid pin fin.

3. It is also concluded that from various perforated pin fins solid pin fin have minimum heat transfer rate whereas solid with rectangular holes and slot have highest heat transfer rate.

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