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Thermal Analysis of Different Perforated Pin Fins by Using ANSYS

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Abstract—*The most commonly used heat exchanging device are Pin Fins. The industries are consistently working with an aim to reduce and change the dimensions and shapes of the fins. The objective of this study is to scrutinize the effects of the different pin fin shapes on the thermal performance by using Ansys. For effective heat transfer the various types of perforation on pin fin are used. The focus 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 whole process is doneby 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 and triangular holes. 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. It's temperature drop is 81.72^0c. After that we find out the heat transfer for each shape and got that solid pin fin with rectangular holes have maximum heat transfer as 24.48 J/s among all other shapes. Their maximum heat transfer allows to transfer more heat and give better performance.*

1. INTRODUCTION

Pin fins is a piece of metal positioned perpendicular from metal base. Most of pin fins are manufactured via cold forging Technology. By the help of this technology pin fins are untouched with any cavities and impurities. In this, the defamation of metal into its predetermined shape by using certain tools and equipment called forging. Cold forging is normally used when metal is soft like Aluminium. It is less expensive and occurs at room temperature. Pin fins is used to maximize the area of device for absorption of heat. Their shapes may be elliptical cylindrical and square. It performs better when placed in tilted position. Generally pin fins are made up of aluminium. Because it has high thermal conductivity, having light weight and better heat dissipation (the process of becoming cooler or falling temperature).The thermal analysis of pin fins is totally depending upon the parameters like shape, size, material and their position etc. There is one more parameter to change heat transfer rate is temperature gradient and it is depending upon the boundary condition and geometry for conduction.

2. LITERATURE REVIEW

Huang *et.al.* studied that drop-shaped pin fins showed asignificant effect on the heat transfer[1]. Saroj Yadav and Krishna M. Pandeyexplained Kite and elliptical shape has greater effect on Nusselt number and heat transfer coefficient [2]. Micheli *et.al.* shows that micro pin fins can improve thermal performance compared to microplate fin arrays[3]. Younghwan Joo and Sung Jin Kimexplained the optimized pin-fin heat sinks perform better than do the optimized plate-fin heat sinks[4]. Bhanja *et.al.* resulted that temperature distribution in the porous pin fin is highly dependent upon the related parameters[5].Bilirgen *et.al.* concluded that as fin height increased, the overall heat transfer increased. The effect of the fin thickness on heat transfer and pressure drop was much less significant than the fin spacing and fin height [6].M.G. Mousa revealed that Square pin–fin array performance is slightly higher than the cylindrical array [7].Tullius *et.al.* allowing for the maximum spacing to the fin width, the thermal performance is better by 6% [8].Rao *et.al.* showed that, compared with the pin fin channel, the pin fin-dimple channel has further improved convective heat transfer performance by about 8.0% [9].Lawson *et.al.* explained heat transfer can be maximized while minimizing pressure drop by increasing the span wise spacing and decreasing the stream wise spacing of pin fins [10]. Ochende *et.al.* concluded that the pin–fins flow structure performs best when the pin–fin diameters and heights are non-uniform [11].E.A.M. Elshafei Experimented that the thermal performance of hollow perforated pin fin heat sink relying on natural convection [12].Li *et.al.* explained that the effect of the fin height on the thermal resistance is not as great as that of the impinging Reynolds number or the fin width [13].M.R. Shaeri and M. Yaghoubi explained Utilization of perforated fins is reduction of fin's weight. Low weight certifies saving material of fins and related equipments such as heat sinks. From the results, practically one goal of fin optimization for low Reynolds numbers and both goals of fin optimization for higher Reynolds numbers are achieved [14].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 [15].Most of the studies showed the beneficial effects of the perforations on the heat transfer rate in the pin fin.

3. THEORY

There are different modes of heat transfer which includes conduction, convection and radiation. Conduction is defined as heat by the direct molecular collision. An area of higher kinetic energy transfers thermal energy towards the area with lower kinetic energy. Heat transfer through conduction is calculated as $\mathbf{Q = [k\ A\ (T_2 - T_1)]/d}$. When fluid is heated, it travels away from the source and carries thermal energy along. This kind of heat transfer is known as convection. Heat transfer through conduction is calculated as Q = h A ($\mathbf{T_s} - \mathbf{T_f}$). In radiation, Heat transfer take place in the form of electromagnetic waves mainly in the infrared region. Heat can be transmitted through empty space by thermal radiation often called 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. Grash of 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.

4. 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

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

Table 2: Parameter of different shapes

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

After selection of shapes and parameters our attention is on selection of material of pin fin. During selection, 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: Material selection

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, Thermal conductivity of copper is high but its cost is also very high. Brass is also costly and stainless steel have low thermal conductivity. Now out of four bullets, 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 good properties. So, we select Aluminum as material of pin fin.

After material selection, accomplishment 3d model of all shapes in solid works. Solid pin fin 3d model is shown in figure 1.

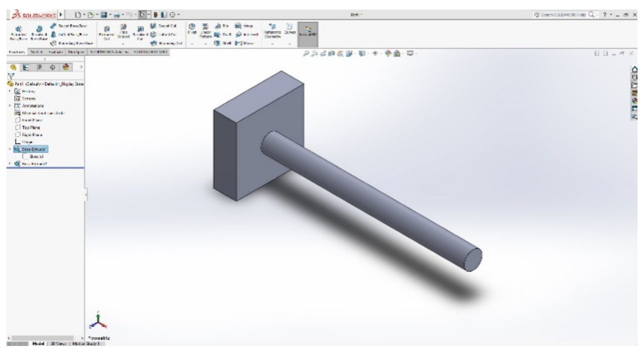


Figure 1: Solid pin fin 3d model

After that extrude cut performs for four circular holes insolid pin fin as shown in figure 2.

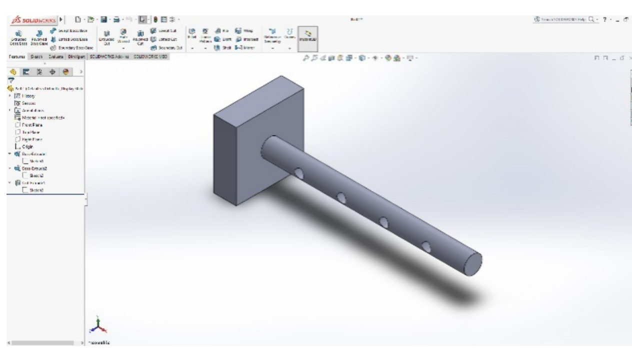


Figure 2: Solid pin fin with circular holes 3d model

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

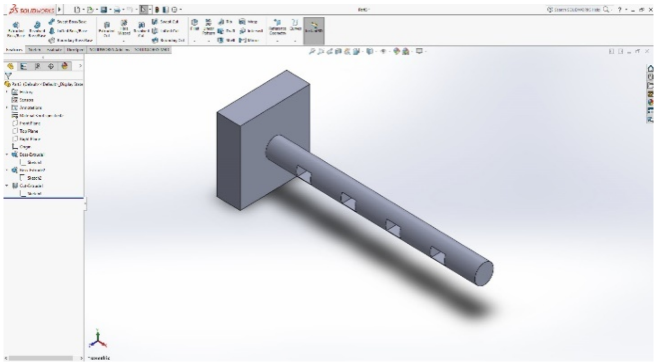


Figure 3: Solid pin fin with rectangular holes 3d model

At last, final perforation is done in the form of four triangular holes in solid pin fin as shown in figure 4.

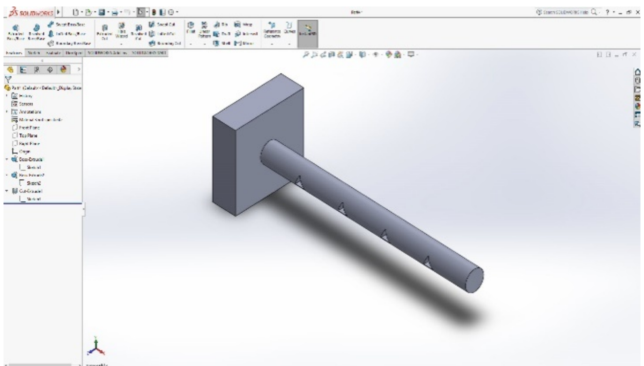


Figure 4: Solid pin fin with triangular holes 3d model

Now, these solid works files save as in step file format that allows to import it into ansys. After import of these 3d models in ansys software, selection of material to model as Aluminium 6061. Then perform meshing of the model and define surface temperature as 105^{o}c and fluid temperature as 25^{o}c. Then we accomplish thermal analysis and get different temperature drop for different shapes. After analysis following temperature distribution is shown. Figure 5 shows the temperature drop for solid pin fin. It is 90.21^{0}c at the end of pin fin.

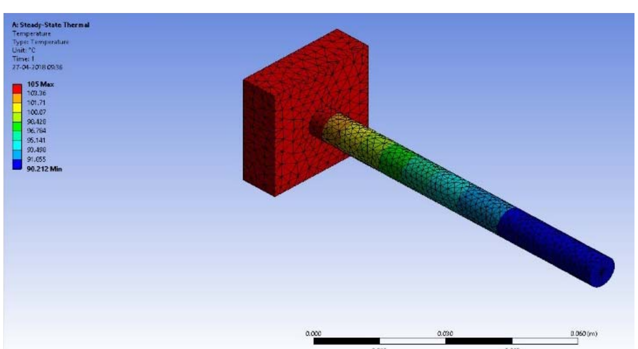
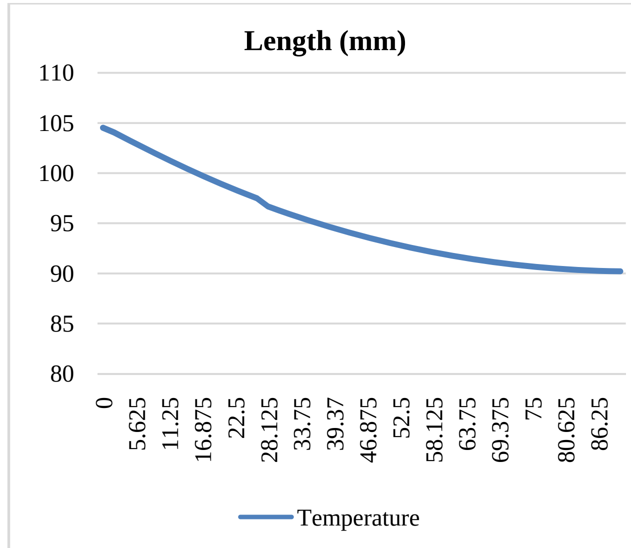


Figure 5: Temperature distribution for solid pin fin

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 turn for solid pin fin perforation, where first target is circular holes. As it is shown in figure 6. It shows the temperature drop as 85.56^{0}c at the end of pin fin.

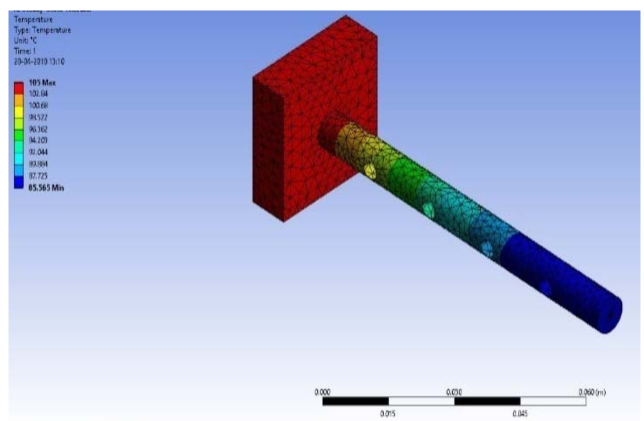
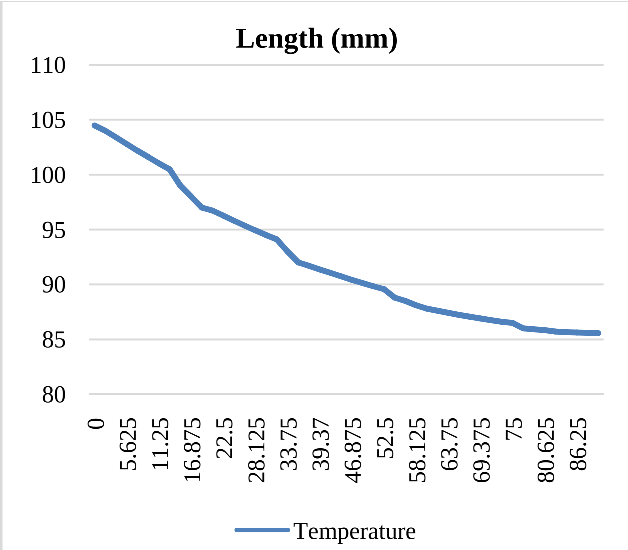


Figure 6: Temperature distribution for solid pin fin with circular holes

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 another solid pin fin perforation, where it is done by rectangular holes. As it is shown in figure 7. It shows the temperature drop as 81.72^{0}c at the end of pin fin.

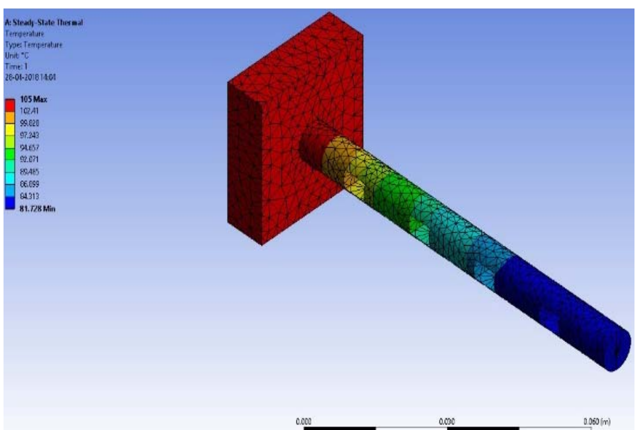
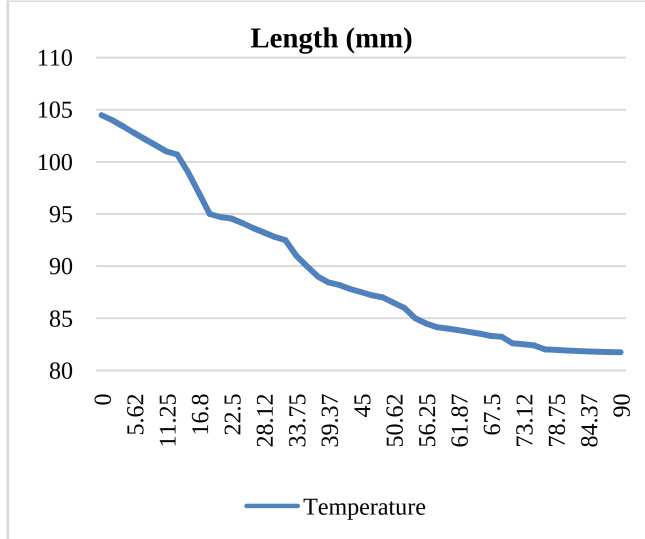


Figure 7: Temperature distribution for solid pin fin with rectangular holes

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, the final target is to analyse solid pin fin perforation with triangular holes. As it is shown in figure 7. It shows the temperature drop as 85.91^{0}c at the end of pin fin.

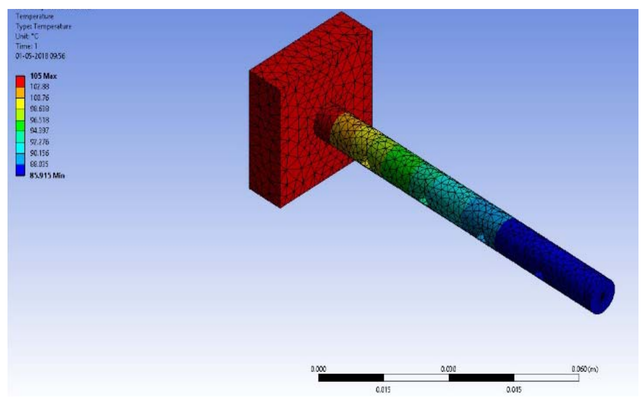
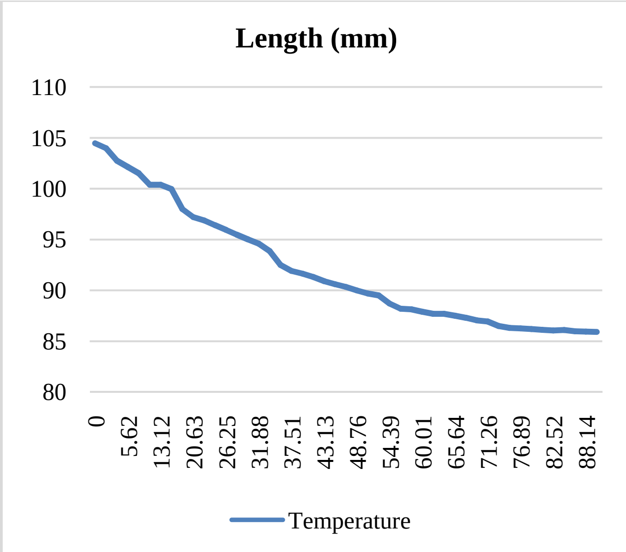


Figure 8: Temperature distribution for solid pin fin with triangular holes

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 3: Temperature distribution for solid pin fin with triangular holes

Here we found that, the maximum temperature drop is in the solid pin fin with rectangular holes. Then it's time for calculation of heat transfer of solid pin fin and their different perforations. It is shown in table below.

Table 4: Comparison table for different shaped pin fin

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

In the table 4, Solid pin fin with rectangular holes perform better than all other shapes. It ruled 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 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 reliably 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 have highest heat transfer rate.

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