Abstract—Thermal problems can be solved by a cheapest, simple and best means by using heatsinks. Where there is a need to dissipate the heat from a hot body to another medium, heatsinks are used. The heatsink application is widely spread across many domains. In this paper, we would like to understand the thermal benefits of using a porous pin fin heatsink when compared to a conventional pin fin heatsink. The cross section of the heatsink used in the analysis is square shaped. The Heatsink is to be analyzed numerically for natural convection assuming steady state condition. Finite volume method is considered for doing the thermal analysis using a Computational Fluid Dynamics tool called FloTHERM.

Keywords— Cheapest; electronic component; heat sink; porous fin; thermal analysis; natural convection; FloTHERM; finite volume method

I. INTRODUCTION

The heat can be dissipated by attaching the heatsink to the surface of the hot body [1]. Several design parameters needs to be taken into account before designing a heatsink [2-5]. The parameters in the design of heatsink include arrangement of fins along with the cross sectional shape, number of fins, material, surface finish in case of natural convection solutions, inclination of fins etc., [6-14]. The parameters of the heat sink are determined based on nature of fluid flow. The fluid flow parameters into consideration are air flow properties, quantity of power dissipation, design for manufacture, cost for manufacture, type of fluid, pressure drop, etc.,

Pin fin heatsinks are predominantly used in natural convection problems. Modest cooling requirements are highly dependent on pin fin heat sinks for heat dissipation. Pin fin heatsinks are advantageous in natural convection solutions as the heat per unit mass heat dissipation is high [16]. There are many studies being conducted for improvisation in the efficiency of pin fin heat sinks [17-21]. Advancement in the performance is done by modifications in length and diameters of pins, void fractions of pins, aspect ratio of pins and distance between adjacent fins [22-27].

Based on the need for providing effective thermal solutions various kinds of pin fin optimization were considered in the recent decade or so and thus lead to the design of porous or slotted square fins, hollow pin fins and splayed-pin fin heatsinks. The pin fin heat sink design is purely based on the deployment circumstances in the design of the heatsinks.

II. MODELLING

The proposed model of the pin fin heatsink is that of an unconventional modelling of heatsink. It can be known as porous or slotted fin heat sink. The base of the new pin is same as before but there are slots or pores in the fins of the heatsink. More vividly, it can be considered as a porous pin fin heatsink.

In Fig. 1, the isometric view of conventional square shaped fin pin fin heat sink with material as Aluminum is shown and in Fig. 2, the isometric view of porous pin fin heatsink with material as Aluminum is shown. In Fig. 3, the isometric view of porous pin fin heatsink with material as Aluminum is shown. It can be seen that the only difference is the pores in the fins of the heatsink. In Fig. 2, the porous pins are slotted with a pore of 11 mm in length and 3 mm in width.

Heat transmission is considered to be started from the heatsink base. It is assumed that no other heat source is connected to the heatsinks.

The heat is transferred to the heatsink in the form of solid conduction. There is a thermal interface material added in between the surface of the hot body and the heatsink to deflect the thermal barrier in between them. The heat transmission between the solid body and the ambient air is happened by convection.

The heat source also is modelled with the dimension of 54 mm in length and 54 mm in width. The thermal resistances that are considered for the hot device is the resistance from junction to board is taken as 3.5 K/W and the resistance from junction to case is taken as 0.2 K/W.

The interface material is modelled as a conducting block and it is placed in between the hot device and the pin fin heatsink in all the cases of the design. The thermal interface material was modelled to eliminate the surface irregularities arising due to micron level unevenness in the flatness due to the manufacturing of the components.

The modeling was done with Computational Fluid Dynamics tool known as FloTHERM.
A. Physical Model and the Geometric Parameters

The physical model of the conventional square shaped pin fin heatsink, used here, is expressed with isometric view of the model as shown in Fig. 1. The length, width and height of the sink are expressed with $L$, $W$ and $H$ respectively. Under fixed volume condition, these three parameters will exactly be the same for the slotted or porous pin fin heat sink.

The geometric parameters used for both of the models are as follows:

- Sink length, $L = 88$ mm
- Sink width, $W = 52$ mm
- Sink height, $H = 31$ mm
- Thickness of the baseplate, $t = 2$ mm
- Fin number, $N = 54$
- Length and width of the square fin edge attached to the base of the heatsink, $L_f = 5$ mm, $W_f = 5$ mm.

The pins dimension are the same for the porous heatsinks except that there are two pores or slots with a dimension as follows:

- Pore length, $L_p = 5$ mm
- Pore width, $W_p = 3$ mm
- Pore height, $H_p = 11$ mm
- Pores are distanced at 2.9 mm from the base of heatsink.
- Two pores are kept apart from each at a distance of 3.2 mm

The thermal interface material used in the design in between the heatsink and heat source is as follows:

- Interface length, $L_i = 45$ mm
- Interface width, $W_i = 45$ mm
- Interface height, $H_i = 0.2$ mm
B. Assumptions
The subsequent conditions are assumed to be true for the analysis:

- The working medium, air is incompressible throughout the process.
- The air flow is happened by natural convection.
- Convection heat transfer coefficient is uniform.
- The temperature of the sink does not change with time.
- No existence of heat source is included in the sink itself.
- Bottom face of the baseplate receives the heat from the heat source first.
- The bottom face of the baseplate has uniform temperature.
- Heat transfer by radiation is considered with an emissivity of 0.8.
- Contact resistance between the baseplate and the fin material is considered.
- Sink material used for the analysis is isotropic and homogenous.

C. Boundary Conditions
The following boundary conditions are applied for the analysis:

- Bulk ambient temperature. \( T_a = 303 \text{ K} \) (i.e. 30°C)
- Convective heat transfer coefficient, \( h = 22 \text{ W/m}^2\text{.K} \)
- Power of the heat source, \( P = 20 \text{ W} \)

D. Material Properties
Frequently used heatsink materials such as Aluminum alloys and Copper alloys have been used to continue the analysis.

Some common parameters related to the properties of Aluminum alloy 6061 are mentioned as follows:

- Thermal conductivity: 170 W/m.K
- Density: 2700 Kg/m3
- Specific Heat: 1300 J/Kg.K
- Thermal expansion coefficient: 24×10⁻⁶ K⁻¹
- Melting point: 650°C

Some common parameters related to the properties of pure Copper are mentioned as follows:

- Thermal conductivity: 385 W/m.K
- Density: 8930 Kg/m3
- Specific Heat: 385 J/Kg.K
- Thermal expansion coefficient: 17×10⁻⁶ K⁻¹
- Melting point: 1085°C

III. THERMAL ANALYSIS

The simulation, used for the thermal analysis, was carried out in an environment of FloTHERM Simulation with the help of finite volume method. Three steps had to be executed to complete the analysis: pre-processing, solver execution and post-processing.

In Fig 4, the side view of the convectional inline pin fin heatsink is shown and in Fig 5, the side of porous inline pin fin heatsink is shown. The heatsink are same for both material heatsinks.

In the Fig 6, the temperature monitor graph is shown. The graph has the number of iterations and the Temperature (°C) in the x-axis and y-axis respectively.

After the selection of material, boundary conditions were specified. Then, solid mesh was created. Standard mesh with
fine quality was selected for the mesh generation. The simulation was run afterward.

The temperature is taken as the measurement of the heatsink from the graph, once the curve has stabilized.

These graphs show us the temperature stabilization during the performance of thermal simulation for a given condition in the FloTHERM solver.

As a result, the temperature contours of the different heatsinks that simulations were performed have their temperature contours displayed in the figures shown.

In Fig 7, the thermal simulation results of the aluminum conventional inline pin fin heatsink are shown.

In Fig 8, the thermal simulation results of the aluminum porous inline pin fin heatsink are shown.

In Fig 9, the thermal simulation results of the copper porous inline pin fin heatsink are shown.

These temperature contours from the thermal results help us to interpret the results of the analysis carried out.

![Figure 7: Thermal simulation results of Aluminum conventional pin fin heatsink](image.png)
Figure 8: Thermal simulation results of Aluminum porous pin fin heatsink

Figure 9: Thermal simulation results of Copper porous pin fin heat
IV. RESULTS AND DISCUSSION

The final results obtained from the FloTHERM Simulations are visually illustrated in Fig. 7, Fig 8 and Fig 9. The color of the solid body indicates the temperature of it. As the body gets more red, the more temperature it indicates and the more violet it gets, the less temperature it indicates.

A more detailed illustration of the whole simulation is provided in Table I & II. It is seen that the finite volume method was carried out with acceptable characteristics. The maximum temperature of the conventional pin fin heat sink with aluminum as material is found to be 93.5 °C and that of the porous pin fin heat sink with aluminum as material is found to be 92.1 °C. Further, the porous pin fin heat sink with copper as material is found to be 90.8 °C. So, the porous pin fin heat sink with copper as the material has mitigated the temperature roughly about 2.5 °C.

<table>
<thead>
<tr>
<th>TABLE I.</th>
<th>Heat sink characteristics</th>
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<tbody>
<tr>
<td>Information, Properties and Studies</td>
<td>Description</td>
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<tr>
<td>Solid body properties</td>
<td>Model type</td>
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<td>Material</td>
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<tr>
<td>Mesh Information</td>
<td>Mesh quality</td>
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<td>Total elements</td>
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<td></td>
<td>Maximum aspect ratio</td>
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<td></td>
<td>Maximum heatsink temperature</td>
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<tr>
<td>Temperature</td>
<td>Maximum hot source temperature</td>
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</table>

V. CONCLUSION

In the present study, the designed model of the porous pin fin heat sink has been devised using the virtual tools. The conventional model of pin fin heat sink was also created in the same virtual tool for comparison. Thermal analysis of the conventional model and the porous model was analyzed and studied successfully. It is clear from the study and numerical analysis that in the practical environment the porous pin fin heat sink will perform better than the conventional one. This kind of modification can be applied for special conditions, especially, when there is no possibility of changing the physical dimensions of the heatsink due to the placements constrains.

Future work of this study may include the optimal size of the pore, performance with good thermal conductivity materials for the porous pin fin heat sink and performance of porous pin fin heat sink for forced convection.

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