Analysis of Thermal Hydraulic Performance of Semicircular Pin Fin Heat Sink by using Computational Fluid Dynamics

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Abstract— The study was conducted by using the Computational Fluid Dynamics (CFD) method. The heat sinks are used with high power semiconductor devices such as power transistors, electronic devices lasers and light emitting diodes (LED’S). The major study was done on semicircular pin fin heat sink, a radii is taken as parameter. The heat transfer media was taken as an air & Aluminum (Al) as pin fin material. In our analysis, CFD was used and the model was developed on NX-5. In order to verify the present CFD model, the thermal resistance and the pressure drop are compared with the available experimental results present in the literature. And the design of semicircular Pin fin heat sink (SCPFHS) having radii is 0.5mm, 1.0mm and 1.0 mm. In this study, the simulations of SCPFHS at various wind velocity i.e., 6.5, 9.5, 12.5 & 15m/s and the configurations of pin-fins design are proposed. The results show that increasing wind velocity could reduce the thermal resistance and increase the pressure drop simultaneously.

Key words: Plane pin fin heat sink, Electronics cooling simulation, Pressure Drop, Thermal Resistance

I. INTRODUCTION
The effective use of an electrical component is limited by its maximum operational junction temperature. To achieve a desired component temperature, excess heat dissipated by the device must be transferred to the environment [19]. The most common method for transferring heat from the component to the environment is to use a heat sink. To estimate a component’s junction temperature, a required value is the heat sink’s thermal resistance. The thermal resistance of heat sink can be determined analytically or experimentally. In electronic systems, a heat sink is a passive component that cools a device by dissipating heat into the surrounding air. In computers, heat sinks are used to cool electronic components. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronic devices such as lasers and light emitting diodes (LEDs), wherever the heat dissipation ability of the basic device package is insufficient to control its temperature.

II. OBJECTIVE OF WORK
The main objective of the current work is:
1) Validation of the CFD models by comparing the present simulated results with the Experimental result by Yue-Tzu Yang & Huan-Sen Peng [7].
2) To predict velocity profiles and temperature for different wind velocity (6.5, 8, 10, 12.5 & 15 m/s) on the heat sink.
3) To simulate the heat sink of the semi circular pin fin having different radii and different velocity (6.5, 8, 10, 12.5 & 15m/s) for constant heat input.
4) Parameter sensitivity study of micro channel.
5) To define average heat transfer coefficient, thermal resistance and pressure drop for the heat sink of the different semi-circular pin fin profile and different velocity and constant heat input 10w.
6) To predict temperature distribution along the channel.

III. PROBLEM FORMATION
The study of various literatures we find the thermal resistance and pressure drop is higher as compared to present study. The purposes of this study reduce the thermal resistance, profit factor and increase the pressure drop at various wind velocity. Thus chosen semicircular pin fin in place of circular pin fin

IV. RESULT AND ANALYSIS
A three-dimension al model is developed to investigate flow and conjugate heat transfer in the heat sink for electronic applications. A series of numerical calculations have been conducted by FLUENT and the results are presented in order to show the effects of temperature distribution, overall heat transfer coefficient, Thermal Resistance, Surface Nusselt number in the heat sinks.

A. Validation of the Experimental Result:
The validation of the Experimental result is done by carrying out the simulation work on the Ansys Fluent 14.0 Work bench.

B. Experimental and Simulation Result:
The thermal resistance of the heat sink, Rth, can be defined by-

\[ R_{th} = \frac{\Delta T}{Q} \]…………………………..(1)

Where \( \Delta T \) is temperature difference between the highest temperature on the fin base and the ambient air temperature, and Q is heat dissipation power applied on the fin base. Properties of the working fluid are the same as those of ambient air at 294 K, and the material of heat sinks is aluminum with thermal conductivity of 202 W/(m·K).

The pressure drop (\( \Delta p \)) from the inlet to the outlet of the flow passage, which reflects the hydraulic performance of the heat sink, is calculated by

\[ \Delta p = p_{in} - p_{out} \]…………………………..(2)

Both simulation results and Yue-Tzu Yang, Huan-Sen Peng experiment results [7] for thermal resistances and pressure drops of the PFHS are plotted in Fig.1 and 2 respectively. As can be seen in these figures

C. Observation Table:

<table>
<thead>
<tr>
<th>Wind Velocity (m/s)</th>
<th>Experimental Result</th>
<th>Simulation Results</th>
<th>Error</th>
</tr>
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Table 1: Experimental and Simulation Result for the Plate Fin Heat Sink

<table>
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<tr>
<th>Type</th>
<th>Air Velocity(v)</th>
<th>Fin base Temp. T (k)</th>
<th>Temp. Diff. (AT)</th>
<th>Pressure Drop (ΔP)</th>
<th>Thermal resistance, Rth (k/w)</th>
<th>Pumping power, E (w)</th>
<th>Profit factor, J (Q/E)</th>
<th>Nusselt Number (Nu)</th>
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Table 2: Simulation of various Heat sinks Pin Model

Fig. 7: Temperature distribution in 1mm Semicircular pin fin heat sink with 6.5m/s velocity

Fig. 8: Temperature distribution in 1mm Semicircular pin fin heat sink with 8 m/s velocity

Fig. 9: Temperature distribution in 1mm Semicircular pin fin heat sink with 10 m/s velocity

Fig. 10: Velocity distribution in 1mm Semicircular pin fin heat sink with 6.5 m/s velocity

Fig. 11: Velocity distribution in 1mm Semicircular pin fin heat sink with 8 m/s velocity

Fig. 12: Velocity distribution in 1mm Semicircular pin fin heat sink with 10 m/s velocity

Fig. 13: Temperature distribution in 2.0 Semicircular pin fin heat sink with 6.5 m/s velocity

Fig. 14: Temperature distribution in 2.0 Semicircular pin fin heat sink with 8 m/s velocity
Fig. 15: Temperature distribution in 2.0 Semicircular pin fin heat sink with 10m/s velocity

Fig. 16: Velocity distribution in 2.0 Semicircular pin fin heat sink with 6.5m/s velocity

Fig. 17: Velocity distributions in 2.0 Semicircular pin fin heat sink with 8 m/s velocity

Fig. 18: Velocity distribution in 2.0 Semicircular pin fin heat sink with 10m/s velocity

Fig. 19: Temperature distribution in 2mm Semicircular pin fin heat sink with 6.5m/s velocity

Fig. 20: Temperature distribution in 2mm Semicircular pin fin heat sink with 8 m/s velocity

Fig. 21: Temperature distribution in 2mm Semicircular pin fin heat sink with 10m/s velocity

Fig. 22: Velocity distribution in 2mm Semicircular pin fin heat sink with 6.5m/s velocity
V. CONCLUSION

1) The CFD model was developed on NX-5 and analysis was done by Fluent 14.0.

2) The prediction of CFD model show good relation with experimental result present in literature [7].

3) The internal consistency of the results confirms the validity of the CFD model.

4) Simulated the heat sink of Semicircular pin fin having different diameter (i.e. type1, type2, type3mm & type4) and different velocities (i.e. 6.5, 8,10,12.2 & 15m/s) for constant heat input.

5) From the above result we have least thermal resistance in semicircular pin fin with different diameter (Type-1) i.e. 1.4 K/W, after that (Type-2) i.e. 1.1 K/W,(Type-3) i.e. 1.6 subsequently with (Type-4) i.e. 1.5 K/W.

6) From the above result we have higher pressure drop in semicircular pin fin with (Type-1) i.e. 218Pa, after that (Type-2) i.e. 203, subsequently with (Type-3) i.e. 197Pa and (Type-4) i.e.202Pa

7) So, from the above we can conclude that the Type-2 Semicircular pin fin at all velocity having better thermal resistance and pressure drop compared to Type-3 and Type-4 thermal resistance and pressure drop.

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