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EFFECT OF STAGGERED FINS ON HEAT TRANSFER AND PRESSURE DROP IN HEATSINKS

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ABSTRACT

The performance of a heatsink with and without staggered fins is analyzed in the present work. The effect of flow resistance on thermal behavior of staggered plate heatsinks were analyzed in the present study. Ansys FLUENT has been used for the present simulation. Authors have used three different models with and without staggered arrangement. The result shows advantage of staggered heat sink over standard heat sink in terms of heat transfer. The comparison of standard and staggered model were performed by considering quality factor, pumping power and heat transfer rate experienced by the respective fins. It has been observed that use of staggered heat sink always leads to maximization of heat transfer.

Keywords: Electronic cooling, Heatsinks, Heat transfer, Pressure drop, Staggered fins

I. INTRODUCTION

The amount of heat generated per unit volume inside electronic packaging is increasing like a clock speed. Also there is constant push toward reducing size of microelectronic components. It has become important to have microelectronic components which give high performance in terms of hydrodynamic and thermal phenomenon. Heatsinks are devices which are used to remove heat from microelectronic components. So many researchers have studied electronic cooling by considering different fluid like oil, water and nanofluids. Such a solution is very effective way to remove large amount of heat from microelectronic components but it is commercially and economically impractical. For that reason, in most of portable electronic components like mobile, television and laptop etc. force convection air cooling of is main method for cooling of electronic devices.

There are already a number of researchers that have presented papers about staggered fins. Wirtz and Colban [1] simulated electronic packages to compare cooling performance of inline and staggered plate arrays. They found that staggered arrays exhibit higher transfer coefficient and friction factors than inline arrays. Sathyamurthy and Runstadler [2] have numerically and experimentally studied planner and staggered heatsink performance and observed that the thermal performance of staggered fin configuration is superior over planner fin configuration. However, pressure drop requirements for the staggered fin heatsink have been greater than those for the planner case. Soodphakdee et al. [3] found that staggered configuration gives better heat transfer than inline configuration. Also rounded geometries perform better than similar sharp edged fin shapes. Leon et al. [4] have compared a standard heatsink with rectangular fins, with staggered heatsink based on a group of parameters like maximum heat transfer flux, minimum flow resistance, minimum power consumption and minimum heatsink mass. They observed that for given incoming velocity, the use of staggered heatsink always leads to a maximization of heat transfer flux compared with thermal behavior of a standard heatsinks. Zhang et al. [5] have studied numerically inline and parallel plate of heat exchangers. Geometry effects such as finite fin thickness and inline vs. staggered arrangements have been investigated. The objective of the present research work is to compare staggered and non-staggered fins of heatsinks. Also, authors aim to choose a layout which gives maximum heat transfer at minimum flow resistance.

II. NUMERICAL CONSIDERATION

The two-dimensional fluid flow and heat transfer in a rectangular micro channel heatsink is analyzed using air as the cooling fluid. A schematic of the structure of a staggered and non-staggered rectangular micro channel heat sink has been shown in figure 1. A uniform temperature is applied at the bottom surface of the heatsink. Heat dissipated away by convection of the cooling fluid in micro channel. The SIMPLE algorithm has been used for solving air flow past heatsink based on finite volume discretization. The commercial CFD code FLUENT has been used for solving coupled equation by adopting a second order upwinding scheme. A convergence criterion of 10^{-5} has been used for numerical simulation.

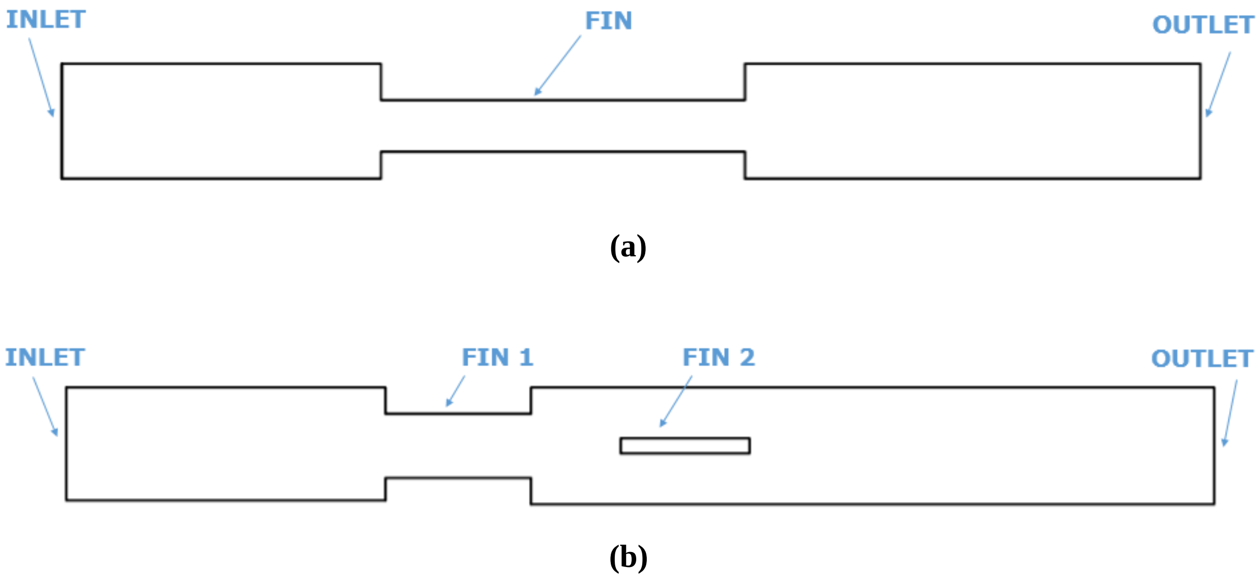


Figure 1: Schematic of (a) standard rectangular model (b) staggered rectangular model

The governing equations for mass, momentum and energy in fluid flow past heatsinks can be presented as follows:

- Conservation of mass (Continuity Equation):

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

where u and v are the velocities in x and y directions respectively.

- Conservation of momentum:

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) + F_b + F_s$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \frac{\mu}{\rho}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + F_b + F_s \qquad (2)$$

where ρ is the mass density, p is the fluid pressure and μ is the dynamic viscosity of the fluid.

- Conservation of energy:

Neglecting the energy transfer due to viscous dissipation and chemical reactions or any other volumetric heat sources, the energy conservation equation is:

$$Cp\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \frac{K}{\rho}\frac{\partial p}{\partial y} + \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \qquad (3)$$

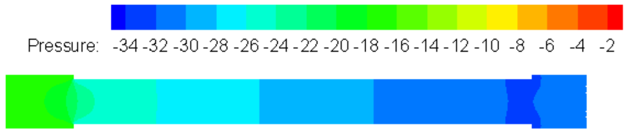
where k is the thermal conductivity and C_p is the specific heat.

III. RESULTS

ANSYS FLUENT has been used to for numerical simulation of heatsinks with standard and staggered fins of three different models. Standard rectangular fins are usually used in many microelectronic components. Experimental and numerical studies on the performance of standard rectangular fins have been performed by many researchers. However, for given incoming velocity, staggered heatsinks always lead to a maximum of heat transfer flux compared with thermal behavior of standard heatsinks. Table 1 shows the value of different parameter like heat transfer rate, pressure drop, pumping power and quality factor. Quality factor is defined as the ratio of the heat removed and the energy spent to drive the coolant flow through the fins. For all simulation air flow velocity is at 5 m/s.

Table 1: Values of heat transfer rate, pressure drop, quality factor, and pumping power obtained with the numerical simulation and the analytical expressions

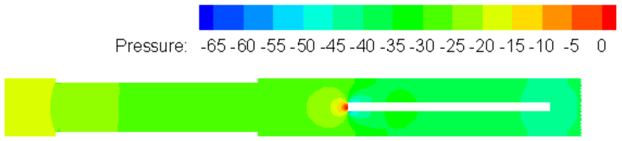
Model	u_0 (m/s)	Q (W)	Δp (Pa)	P (W)	QF
Standard rectangular	5.0	428.58	7.10	0.4487	955.15
Staggered rectangular	5.0	600.77	14.13	0.5892	1019.84
Standard rounded leading edges	5.0	429.72	9.2762	0.4921	873.66
Staggered rounded leading edges	5.0	612.07	13.95	0.5860	1044.48
Standard rounded leading & trailing edges	5.0	435.15	9.262	0.4918	890.83
Staggered rounded leading & trailing edges	5.0	595.84	15.65	0.6194	961.96



(a)

(b)

Fig. 2:Standard rectangular model (a) pressure profile and (b) temperature profile



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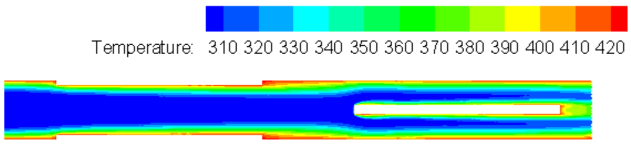
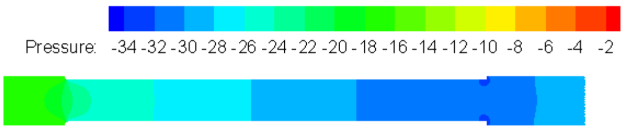


(b)

Fig. 3: Staggered rectangular model (a) pressure profile and (b) temperature profile



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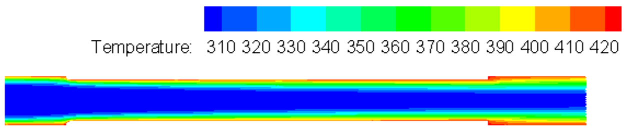
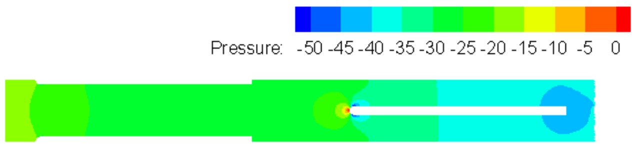


(b)

Fig. 4: Standard rounded leading edge model (a) pressure profile and (b) temperature profile



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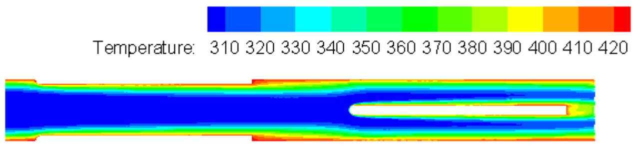
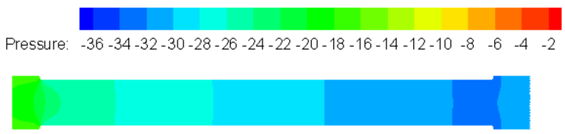


(b)

Fig. 5: Staggered rounded leading edge model (a) pressure profile and (b) temperature profile



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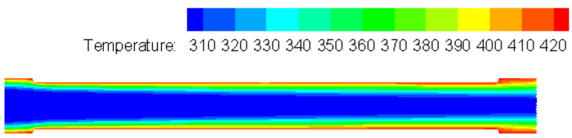
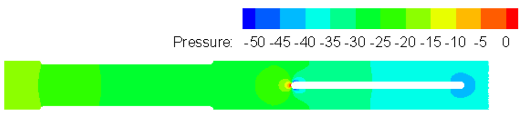
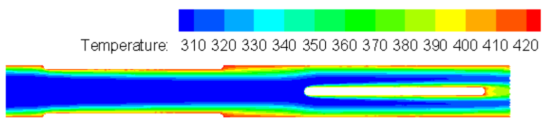


(b)

Fig. 6: Standard rounded leading and trailing edge model (a) pressure profile and (b) temperature profile



(a)

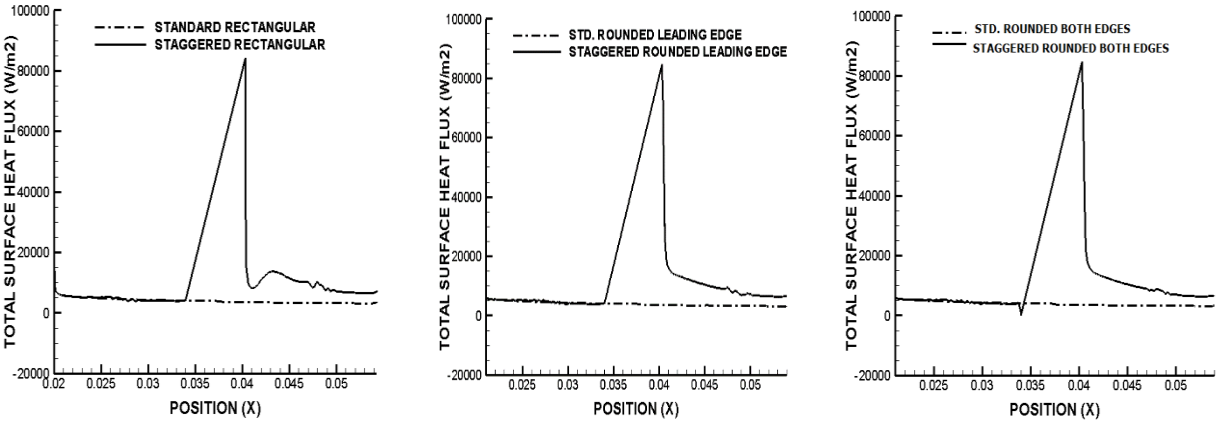


(b)

Fig. 7: Staggered rounded leading and trailing edge model (a) pressure and (b) temperature profile

Figures 2(a), 4(a) and 6(a) show the pressure profile for standard fins of three different configurations. While figures 3(a), 5(a) and 7(a) show the pressure profile for staggered fins of three different configurations. In staggered heatsinks of each cases pressure drop is higher compared to standard configuration due to maximum flow resistance in staggered configuration.

Figures 2(b), 4(b), and 6(b) show the temperature profile for standard fins of three different configurations. While figures 3(b), 5(b) and 7(b) show the temperature profile for staggered fins of three different configurations. In staggered fin heatsinks more heat is removed as compared to standard in heatsinks.



(a) (b) (c)

Fig. 8: Total surface het flux vs. position (a) standard and staggered rectangular (b) standard and staggered rectangular with rounded leading edge and (c) standard & staggered rectangular with rounded leading and trailing edge

IV. CONCLUSION

In this paper, authors have compared standard fins of a heatsink versus staggered fins. This study shows the advantage of staggered configurations compared to standard configurations. Three different models were studied by considering a group of parameter. Staggered fins give better performance than standard fins in terms of heat transfer, pumping power and quality factor.

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