Fin geometry effect on the thermal performance of radial heat sink under natural convection

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ABSTRACT: The objective of the present study is to investigate the effect of fin length-to-height (LTH) ratio on the thermal resistance of radial heat sink under natural convection. The CFD computation models the convection heat transfer of a circular base radial heat sink of varying fin LTH ratio under the constrain of a fixed heat sink mass. By increasing the LTH ratio of the fin, both the mass flow rate of airflow passing through the fins and fin surface area decrease, whereas the thermal resistance increases. Therefore, under the constrain of fixed heat sink mass, it is preferable to extend the fin height over fin length for better thermal performance.

Keywords: *CFD; heatsink; heat transfer*

1. INTRODUCTION

Heat sink are commonly used for regulating the junction temperature of LED lamps. Studies suggest that an improvement in the thermal performance of heat sinks can be accomplished by increasing the fin length, fin height, or fin number, which requires an increase in the total heat sink mass [1-3]. Therefore, under the constraint of heat sink mass, the question remains whether the fins should be make longer at the expense of the other dimensions or wise versa. To address this question, the objective of the present study is to investigate the effect of fin length to height ratio on the thermal resistance of radial heat sink subjected to natural convection.

2. METHODOLOGY

The heat sink considered is a radial heat sink with a circular base and fins of two different lengths placed alternately and radially about the center of the base (Figure 1). This particular fin configuration which is known as the LM-type radial heat sink, is introduced by Yu et al [4]. Therefore, the fin dimensions used by [4] are served as the benchmark case for comparison.

Due to axis-symmetry condition of the flow, only a segment of the radial heat sink was modelled in the CFD by applying periodic boundary condition to the two lateral sides of the domain (Figure 1). The remaining vertical side of the domain is set as pressure-inlet boundary condition with zero gauge total pressure, while the top of the domain is set as an outflow boundary condition with zero gauge pressure. A constant heat flux of 1000 W/m^2 to simulate the heat generation of LED chip is assigned to the bottom wall of the heat sink. The other bottom surfaces of the domain were set as adiabatic walls.

The pressure-velocity coupling was realized by the SIMPLE algorithm. All the derivative terms in the governing equations were estimated by the second-order node-based upwind discretization scheme. The turbulence model adopted was the renormalization group (RNG) k-e.

For all the simulation cases, tetrahedral mesh was used to discretized the domain volume. The total cell numer was around 1 million.

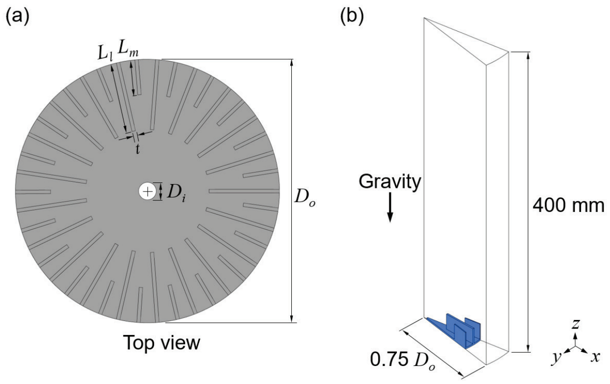

Figure 1 Radial heat sink geometric parameters (a) and computational domain (b)

3. RESULTS AND DISCUSSION

Figure 2 shows the effect of fin LTH ratio on thermal resistance, surface area, and mass flow rate. As shown, the thermal resistance of the radial heat sink increases with increasing fin LTH ratio. Thus, given a fixed heat sink mass, taller fins would perform better than longer fins for the purpose of thermal management.

Comparing to the benchmark case (LTH ratio = 2), the fin configuration with the lowest LTH ratio investigated has achieved an improvement in thermal resistance by about 19%. Note that at such LTH ratio the mass of the heat sink has shifted towards the outer region of the heat sink.

Meanwhile, despite the fixed heat sink mass, the heat sink surface area decreases with increasing fin LTH ratio. In principle, heat transfer rate is proportional to surface area. Thus, the decrease in surface area is one of the contributing factors for the increase in thermal resistance tendency.

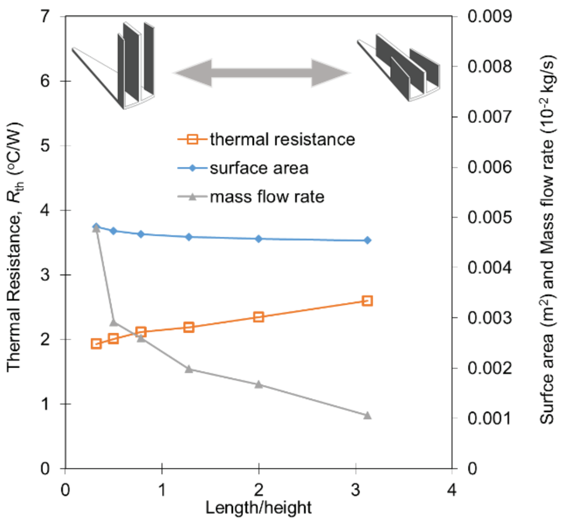

Figure 2 Effect of LTH ratio on thermal resistance, surface area, and mass flow rate

Figures 3 and 4 respectively compares the velocity and temperature distributions in the vertical and horizontal planes between the two heat sink configurations. In general, the region of higher velocity is found to exhibit lower temperature. The good correlation between the two quantities demonstrates that changes in the geometric configuration of heat sink could affect its thermal resistance performance not only by modifying the surface area, but also by modifying the flow properties around it.

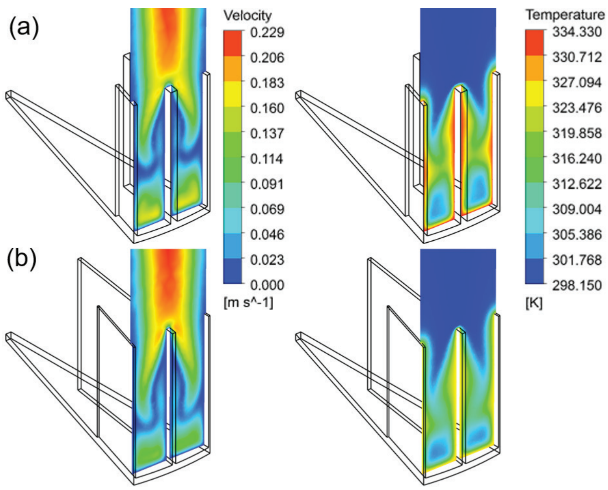

Figure 3 Comparison of velocity and temperature distributions between two different heat sink configurations; a) Fin thickness = 2 mm, Long fin length = 20 mm; b) Fin thickness = 1 mm, Long fin length = 40 mm

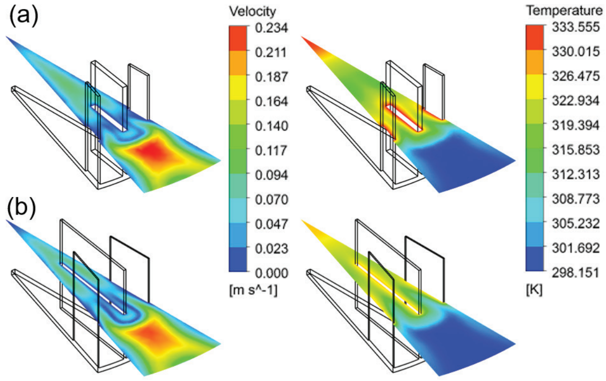

Figure 4 Comparison of velocity and temperature distributions in a horizontal plane at the mid fin height between two different heat sink configurations; a) Fin thickness = 2 mm, Long fin length = 20 mm; b) Fin thickness = 1 mm, Long fin length = 40 mm

4. CONCLUSION

The present study investigated the effect of fin configuration on the thermal performance of plate-fin radial heat sink subjected to natural convection by a CFD computation method. The thermal resistance of the heat sink can be affected by varying fin geometry due to modification in the fin surface area and the surrounding flow. Given a fixed heat sink mass, the LM-type radial heat sink with lower fin LTH ratio would produce greater heat sink surface area and mass flow rate, as well as lower thermal resistance. Therefore, under the constrain of fixed heat sink mass, it is preferable to extend the fin height over fin length for better thermal performance.

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