

Abstract

The increasing demand for efficient thermal management systems in high-density electronic devices has sparked significant research interest in heat sink design optimization. This research aims to enhance the heat dissipation capabilities of heat sinks, considering the unique challenges posed by components that generate heavy flux. The study begins with an extensive literature review to examine existing heat sink designs, their limitations, and the fundamental principles governing heat transfer in these systems. The comprehensive literature review identifies the critical geometric design parameters that influence heat sink performance. Computational modeling, simulation, and experimental validation are employed to evaluate parameters such as heat transfer coefficients, pressure drop, and thermal resistance. A multi-objective optimization process uses the Box Behnken Design for the Response Surface Method to identify optimal design configurations that maximize heat transfer efficiency while considering other factors such as pressure drop and material cost. Innovative heat sink designs are conceptualized and analyzed using 3D CFD simulations to highlight designs surpassing conventional heat dissipation and thermal performance approaches. A numerical study of the thermal performance of a heat sink with multiple annular discs attached transversely along the length of the fins has been performed, presumably for the first time, using 3D CFD simulations. The study shows an improvement in the heat dissipation rate by 20.68%, although the pressure drop increases by up to 25.81%. In another study, reducing the base thickness from 10 mm to 0.07 mm resulted in a 54.21% increase in the heat dissipation rate, while reducing the weight of the heat sink by 87.17%. It is found that reducing the base thickness significantly improves heat sink performance. The size of the heat sink in relation to the size of the heat source is also found to influence thermal performance. Likewise, designs for uniformly distributing coolant across the heat sink for better contact and higher convective heat transfer have been studied with improved results. Inclining the fins reduced occupied volume by 43.75% and mass by 61.82% at 30°, at the cost of a 7.24% reduction in heat evacuation rate and a 55.07% increase in pressure drop. The performances of various heat sink designs were experimentally analyzed using a commercial mini refrigerator to compare simulation results. An innovative thermoelectric portable personalized air cooler-cum-heater was designed using the optimized heat sinks to study its performance. Many of the aforementioned designs have rarely been studied, if at all. The outcomes of this research may find applications in a broad range of thermal management areas.

Keywords: Thermal management, Coefficient of performance, Annular heat sink, Heat dissipation rate, Heat exchanger design, Design optimization