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Computational fluid dynamics and multi-objective response surface methodology optimization of perforated-finned heat sinks

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Abstract

Background

This study analyses turbulent flow and heat transfer characteristics of a three-dimensional perforated finned heat sink using computational fluid dynamics (CFD) and response surface methodology (RSM) methods.

Methods

The effects of perforation geometry, including size ($1.85 \leq \sigma \leq 2$) and cross-sectional shape (square, circular, hexagonal, and triangular), as well as the Reynolds number ($25,000 \leq Re \leq 40,000$) as design variables, on parameters such as friction drag force, pressure drag force, total drag force, and Nusselt number were investigated. In addition, using the well-known RSM technique, three accurate models were proposed for the percentage of heat transfer enhancement (PHTE), percentage of drag reduction (PDR), and percentage of weight reduction (PWR) as the most significant design objectives for any heat sink. RSM models served as the foundation for two- and three-objective optimizations.

Significant Findings

Results indicate that fins with square perforations in high σ and fins with circular perforations in low σ could achieve exceptional thermal performance (PHTE > 70%). Compared to solid fins, fins with square perforations demonstrated improved PDR performance with a 20–40% reduction in total drag force. In addition, using fins with circular perforations can reduce the heat sink's weight by 45–65% compared to solid fins. Moreover, the optimal condition for the perforated finned heat sink can be attained by considering the values 40,000 and 1,946 for Reynolds number and σ, respectively, and by selecting a circular shape for the perforations. PHTE, PDR, and PWR increase in the optimal case by 68.98%, 35.87%, and 58.86%, respectively, compared to the base case (solid fin).