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Multi-objective optimization of a laterally perforated-finned heat sink with computational fluid dynamics method and statistical modeling using response surface methodology

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Abstract

The present paper examines turbulent flow and heat transfer characteristics of a three-dimensional laterally perforated finned heat sink (LPFHS) using response surface methodology (RSM) and computational fluid dynamics (CFD) approaches. The effects of the Reynolds number and perforations geometry, such as porosity (size) and cross-sectional shape (square, circular, hexagonal, and triangular), were investigated on the average friction factor and average Nusselt number. RSM is an applicable approach to improve process conditions by analyzing the impact of different factors and their interdependence on the measured outcomes during a specific technological operation. Three accurate models for the percentage of heat transfer enhancement (PHTE), the percentage of friction factor reduction (PFCR), and the percentage of weight reduction (PWR) as the most important design objectives for heat sinks were proposed using the RSM technique. RSM models served as the foundation for two- and three-objective optimizations. Results demonstrate that fins with square perforations exhibited the highest PHTE value. Additionally, fins with square, circular, and hexagonal perforations experienced increased PFCR with rising porosity at different Reynolds numbers. Fins with square perforations were particularly effective in PWR because the perforations matched well with the lateral surfaces of the fin. The optimal conditions for the LPFHS were achieved using square perforations with Reynolds number and porosity values of 2101 and 0.494, respectively. In the optimal case, PHTE, PFCR, and PWR increased by 7.965%, 24.198%, and 49.367%, respectively, compared to the base case (solid fin). In addition, the optimization strategy implemented in the present study allows weighting