Flow and Heat Transfer Characteristics of Circular Micro-Pin-Fin Heat Sinks with Different Porosities: Postprint

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Date: 2017-10-31T00:00:00+00:00

Abstract

This study employs CFD numerical simulation software to numerically investigate the flow and heat transfer characteristics of staggered circular micro-pin-fin heat sinks with an equivalent diameter of 200 m at various porosities. The simulation results indicate that as the Reynolds number increases, vortices of various morphologies appear at the tail of the pin-fins. In channels with different porosities, due to the influence of downstream pin-fins, the vortices in the wake region of the pin-fins exhibit variations in morphology and scale. For micro-pin-fin heat sinks with different porosities, changes in heat flux density have different effects on the Nusselt number Nu of the heat sink; when the porosity is small, heat flux density has little effect on the Nusselt number Nu of the heat sink, whereas when the porosity is large, an increase in heat flux density leads to an increase in the Nusselt number Nu of the heat sink.

Full Text

Preamble

JOURNAL OF ENGINEERING THERMOPHYSICS
August 2017, ChinaXiv Cooperative Journal
Vol. 38, No. 8

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3. SCP-0.743 Configuration

Figure 3 [Figure 3: see original paper] presents the variation of the Nusselt number (Nu) with Reynolds number (Re) for the SCP-0.743 micro pin-fin heat

sink configuration. The results demonstrate the thermal performance characteristics across a range of flow conditions, showing how convective heat transfer enhancement scales with increasing Reynolds number.

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5. Flow Field Analysis at Rein = 60

Figure 5 [Figure 5: see original paper] illustrates the computed flow field patterns in different heat sink geometries at an inlet Reynolds number of 60 (Rein = 60) under a constant heat flux of 4×10 W/m². The visualization reveals the complex fluid dynamics within the micro pin-fin arrays, including wake structures and inter-fin flow behavior that govern thermal performance. The streamline distributions highlight regions of flow separation and recirculation that significantly influence local heat transfer coefficients.

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4. SCP-0.836 Configuration

Figure 4 [Figure 4: see original paper] shows the variation of Nusselt number with Reynolds number for the SCP-0.836 configuration. Comparative analysis indicates that the SCP-0.743 design consistently achieves higher Nu values across the examined Reynolds number range, suggesting superior convective heat transfer performance. The figure includes data for multiple Reynolds numbers, with subplots (a) and (b) showing detailed flow characteristics at Rein = 100, while subplots (c) through (f) extend the analysis to Rein = 160 and Rein = 200, respectively.

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8. Heat Flux Effects on Flow Field

Figure 8 [Figure 8: see original paper] demonstrates the influence of varying heat flux on the flow field structure within the SCP-0.836 micro pin-fin array. The computational fluid dynamics (CFD) simulations, conducted with a 200 m computational mesh, reveal how thermal boundary conditions affect flow patterns and vortex formation. The results show that increasing heat flux modifies the local fluid properties and flow stability, which in turn impacts the overall thermal-hydraulic performance of the heat sink.

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Note: Figure translations are in progress. See original paper for figures.