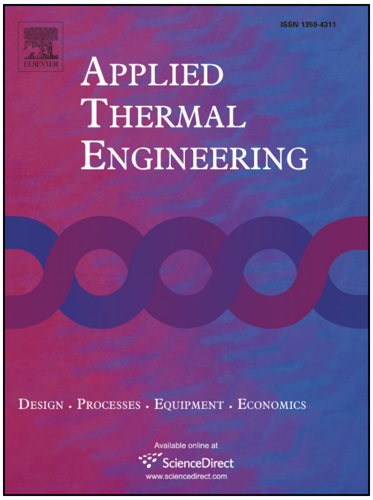

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Single-phase convective heat transfer performance of wavy microchannels in macro geometry

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Abstract: The feasibility of attaining microscale heat transfer effects using macro geometries has been demonstrated. The concentric superposition of two macro geometries, manufactured through conventional machining, yielded an annular microchannel with a microscale gap of 300 µm. In this paper, sinusoidal wave geometrical profiles were introduced on the inner cylinder's surface to enhance convective heat transfer and the overall energy efficiency, for a given heat transfer area. Experimental and numerical studies were conducted on steady-state, single-phase heat transfer, using distilled water as the coolant, with an operating Reynolds number range of 1300 to 4600. Results showed that the enhanced microchannels with higher wave amplitudes and shorter wavelengths performed better in terms of heat transfer, at the expense of heightened pressure losses. Overall, the highest-performing enhanced microchannel is capable of removing 51 percent more heat than the plain annular channel at a given pumping power. In addition, large wave amplitudes coupled with low operating Reynolds number yielded optimal heat transfer efficiency and vice versa. The wavy profiles promote heat transfer efficiency through flow perturbation and the reinitialization of boundary layers along the peaks while keeping pressure losses relatively low. New correlations for the average Nusselt number and friction factor were proposed for the wavy annular microchannels, which can be utilised for future compact heat exchanger designs, exhibiting enhanced microscale heat removal capabilities while employing relatively economical fabrication processes.

Keywords: wavy channel, heat transfer, microscale, single-phase, sinusoidal, macro geometries

1. Introduction

Following the rapid advancement in the semiconductor industry during the turn of the 21st century, the average number of transistors per unit chip area found in modern processors has burgeoned, producing chips with stronger processing power which are also smaller and more efficiently packaged [1]. The miniaturisation of the electronic components causes the accumulation of high heat fluxes at the chip level, demanding augmented heat removal techniques of up to 1000 W cm^{-2} to preserve the material integrity and functionality [2, 3]. The feasibility of employing microscale passages for direct liquid cooling in semiconductor circuits has been demonstrated following its inception by Tuckerman and Pease in 1981 [4]. The water-cooled heat sink possesses a heat removal capacity of up to 790 W cm^{-2},