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Numerical Investigation of Electrode Configuration in Heat Transfer Enhancement Caused by Onsager-Wien Effect in a Minichannel

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Extended Abstract

Rapid developments in miniaturization technologies have led to the development of compact and high-power density electronic devices [1]. An effective and flexible thermal management system is vital to ensure the reliability of these high-performance electronic systems. Micro/minichannel heat sinks with various active and passive techniques are widely used as cooling systems due to its high surface area to volume ratio [2]. Electrohydrodynamics (EHD) based techniques have gained popularity in recent years as a suitable active method for heat transfer enhancement because of its quick response and simple design [3]. The effect of one such EHD phenomenon called the Onsager-Wien effect in heat transfer enhancement is explored in the present study.

A 3D minichannel undergoing conjugate heat transfer along with an external electric field that can trigger the onset of the Onsager-Wien effect is numerically analysed. A series of flat plate electrodes flushed on the walls of the fluid passage is used to impart an electric field in the system. Different electrode configurations are considered in the present study by varying the inter-electrode distance. The governing equations of the problem, Navier-Stokes equation, energy equation and charge transport equation are incorporated into the OpenFOAM framework and numerically solved.

The interaction between flow field and the electric field leads to the formation of a unique steady state flow structure in the system. Localized high velocity zones and eddies are formed in the vicinity of the electrodes. These secondary flow structures act as a disturbance to the primary external flow leading to the disruption of velocity and thermal boundary layers accounting for the enhanced mixing in the system. The nature of the vortex generated from each electrode configuration is studied. These configurations are compared to understand the mechanism of heat transfer enhancement both qualitatively and quantitatively. The net heat transfer rate of the minichannel is quantified by the average Nusselt number. A 50% increment in the average Nusselt number is observed with EHD assisted forced convection process. The thermal hydraulic performance factor (THPF) is analyzed to study the overall effectiveness of the heat sink. THPF greater than 1 signifies an effective heat sink, and a maximum THPF value of 1.32 is obtained here using the additional electric body force. The results of this study indicates that the introduction of an external electric field in the system can augment the heat transfer in all electrode configurations with a minimal usage of additional power source.

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