Proceedings of the Canadian Society for Mechanical Engineering International Congress 2022
CSME Congress 2022
June 5-8, 2022, Edmonton, AB, Canada

Horizontal Chimney Effect

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ABSTRACT

An analysis of natural convection in horizontal slots exposed to patterned heating and equipped with grooves has been carried out. The relevant field equations were solved with spectral accuracy and the geometric irregularities were handled using the immersed boundary concept. Heating and groove patterns were represented using Fourier expansions providing the flexibility required for efficient handling of multiple configurations. It has been demonstrated that heating patterns combined with groove patterns can force horizontal fluid movement, i.e., create a horizontal chimney effect. It has further been shown that it is the pattern interaction effect which drives this flow. Spatially periodic heating creates pairs of counterrotating rolls with a corresponding periodic pressure field. Changes in the position of the heating pattern with respect to the groove pattern result in different projections of the pressure field onto the plate topography, creating a horizontal component of the pressure force acting on the fluid at the plate. This force creates net flow in the horizontal direction which can be directed either to the right or to the left, depending on the position of the heating pattern, and appears despite the absence of any externally imposed mean pressure gradient. Triangular and trapezoidal grooves, which can be easily manufactured, were considered in this study. Heating patterns emulating electrical heating wires were used as such heating can be easily created in practical applications. It has been shown that the heating and groove patterns must be properly tuned to get a significant flow rate. The direction and magnitude of the flow can be changed by moving the heating pattern with respect to the grooves using a system of heating wires which can be selectively turned on and off. The magnitude of the flow rate is proportional to the groove amplitude and increases non-linearly with an increase of the intensity of periodic heating. There exists an optimal heating wave number which produces the maximum flow rate. Changes of the groove geometry can alter this flow rate by up to 100%. Simultaneous use of grooves and heating at both plates can nearly double the system effectiveness. The magnitude of the flow increases with reduction of the Prandtl number.