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Numerical prediction of heat transfer and pressure drop in three-dimensional channels with alternated opposed ribs

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ABSTRACT

Nusselt numbers and friction factor of a ribbed channel have been calculated for several Reynolds numbers and geometric parameters, by the mean of three-dimensional incompressible computational fluid dynamics. The geometry is a rectangular duct with streamwise-periodic transverse rectangular ribs, alternated on its two smaller walls. Reynolds numbers from 75 to 2000 have been investigated. Pressure drop is found to increase monotonically with *Re*, whereas heat transfer is enhanced only when *Re* is greater than a critical value. Heat transfer enhancement interpretations, such as the interruption of developed thermal boundary layers and vortex shedding phenomena are discussed.

1. Introduction

In the past decades, energy price increase has motivated a lot of interest for Heat Transfer Enhancement (HTE) techniques, in order to increase the overall performance of heat exchangers, leading to energy savings. Moreover, the need for a more efficient energy management that allows the integration of intermittent (renewable) energies has generated researches on various energy storage processes, including Thermal Energy Storage (TES). Heat exchangers are an essential part of any TES process based on forced convection. The present work is motivated by the optimization of a new TES process relying on regenerative heat exchangers [1], and is aimed at low-Reynolds regenerative exchanger optimization. While "fully turbulent" HTE studies are numerous, there is a lack of data on forced convection in the laminar and transition regime for non flat channels. No studies have been found that mention the validity of turbulence models in the laminar and transition regime for non flat channels. Moreover, two-dimensional numerical results exist but are not applicable to real rectangular channels, except for high aspect ratio channels. HTE techniques for heat exchangers are commonly based on periodic disturbance promoters set up along the streamwise direction [2]. Typical geometries consist in channels with grooved parts [2] [3], transverse or oblique ribs [4–11], dimples [12–15], corrugated pseudo-channels in plate heat exchangers [15–18], or a flat channel with inserts, such as wire coils or twisted tapes [15] [19–23]. Such promoters are meant to help flow mixing and to break thermal boundary layers development. In most configurations, they lead to an increase of the heat transfer (typically 300%–800%) but also of the pressure drop. Therefore, exchanger performance is improved only if the thermal performance gain due to HTE overcomes thermal performance losses due to pressure drop. In papers where sufficiently low-Reynolds numbers are studied, a critical Reynolds number Re_c is often defined. It generally corresponds to oscillatory flow appearance and departure from "laminar laws". Here, "laminar laws" means that Nusselt number is constant and friction factor is inversely proportional to *Re*.

This paper presents a numerical study aimed at the prediction of heat transfer and pressure drop in low-Reynolds exchangers, with improved channel walls. Hereafter, HTE will mean enhancement with respect to the well-known flat channel in the *laminar* regime. The proposed geometry consists of a rectangular channel (aspect ratio = 1/2) with periodic transverse rectangular ribs, alternated on

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