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Large Eddy Simulation of the flow and heat transfer in a half-corrugated channel with various wave amplitudes

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ABSTRACT

Large Eddy Simulation (*LES*) of turbulent flow and convective heat transfer over a half-corrugated channel is presented in this paper. Simulations are performed for various ranges of the normalized wave amplitudes, $AM = 0$—0.15 (the ratio of wave height to wave length). The Reynolds number based on the bulk velocity is chosen as $Re_b = 10000$ and the Prandtl number is $Pr = 0.71$. A comparison between the *DNS* and *LES* results of a plane channel ($AM = 0$) at $Re_\tau = 395$ is also performed. The obtained results indicate that the region of recirculating flow depends strongly on the wave amplitude. This study shows that the Nusselt number (Nu) increases by increasing the wave amplitude until a specific value then it remains approximately constant. The thermal performance parameter (JF) is used as a measure for the heat transfer enhancement relative to the pressure drop and it is found that the maximum values of Nu and JF appear at $AM = 0.1$, which hence correspond to the optimum value of the wave amplitude.

1. Introduction

Considerable attention on different methods to increase the rates of heat and mass transfer in compact heat exchangers has been reported. One geometry of the flow passage that is simple to fabricate and has been extensively used to enhance the heat exchanger performance is known as wavy (corrugated) walls. Wavy walls are recognized as effective devices to provide significant heat transfer enhancement. The corrugated channels can be considered to be fully-corrugated (fully-waved or sinusoidal) or half-corrugated channels. In a fully-corrugated channel, the corrugation is applied to the entire channel length whereas, in a half-corrugated channel, part of the channel becomes corrugated and a part remains smooth (see Fig. 1). The half-corrugated channel (or wavy channel) is chosen as the configuration under consideration in this work.

A number of numerical and experimental investigations have been reported on turbulent flow over fully-corrugated walls with different wave amplitudes (the ratio of the wave height to wave length, AM) [1–6]. Hudson et al. [1] provided extensive measurements of the turbulent characteristics such as the Reynolds stresses, turbulent intensities and production over a fully-corrugated wall with a wave amplitude equal to $AM = 0.05$ and a Reynolds number of 6760 based on the bulk velocity (u_b) and the mean height of the channel (H). They showed that the turbulence production near the wavy surface is mainly associated with the shear layer separated from the wavy surface. In 1998, Cherukat et al. [2] presented a comprehensive numerical simulation of turbulent flow over a sinusoidal wavy surface by direct numerical simulation (*DNS*) using a spectral element technique. In their simulation they chose the wave amplitude as 0.05 and Reynolds number based on bulk flow velocity and half of the channel height ($H/2$) as $Re_b = 3450$. They presented both instantaneous and mean flow results for various characteristics. The instantaneous results showed a large variation of flow pattern in the spanwise direction in the separated bubble at any given time and both the separation and reattachment points varied in time and space. Different turbulent parameters such as turbulence shear stress and turbulence intensities were provided in their studies and a good agreement with the experimental results of Hudson et al. [1] was reported. Tseng et al. [3], Choi et al. [4], Pham et al. [5], Asai and Floryan [6] and Chang et al. [7] conducted numerical and experimental results over the wavy channel. In all studies mentioned above only one wave amplitude was considered.

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