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Heat transfer augmentation in a rectangular channel with a vee-shaped vortex generator

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Abstract

The unsteady flow and heat transfer are simulated using LES and DNS for a channel with two angled ribs as a vee-shaped vortex generator to augment heat transfer. The vortex generators are attached on the bottom wall of the channel and their angles in respect to the main flow are between 10° and 30°. The Prandtl number is 0.71 and the Reynolds numbers based on the inflow velocity and the height of channel are from 200 to 2000. Based on the results of this work, the variations of the Nusselt number, pressure coefficient, bulk temperature, friction factor and Colburn factor with the Reynolds numbers and the incidence angles are provided.

The relation between the key parameters of the velocity (friction factor f) and thermal (Colburn factor J) boundary layers is calculated for all cases and their values are compared with the predicted values by the Chilton–Colburn analogy.

A comparison between the DNS and LES results is performed and it is found that relatively similar results are obtained from a LES simulation with fine grid and a DNS simulation with finer grid.

Thermal performance parameter, JF, is used as a measure for the amount of the heat transfer enhancement relative to the pressure drop. The JF value increases as the Reynolds number or the incidence angles increase.

The structure of the heat transfer and fluid flow are studied using the kinetic energy, pressure, velocity and temperature fluctuations.

Keywords: Heat transfer augmentation; Vortex generator; Thermal performance parameter; LES; DNS

1. Introduction

During recent years, serious attempts have been made to apply different active and passive mechanisms for heat transfer enhancement in compact heat exchangers for the automotive industry, air-conditioning and refrigerant applications, internal cooling for gas turbine blades, electrical circuits in electronic chipsets, etc. Achieving higher heat transfer rates through various augmentation techniques can result in substantial energy savings, more compact and less expensive apparatus with higher thermal efficiency. Different mechanisms such as creating electric or magnetic fields, jets, forced oscillations, fluid additives and special surface geometries, may be used for heat transfer enhancement. It can be categorized in two groups, main-flow and secondary-flow enhancement in active or passive way, see Webb (1994), and Jacobi and Shah (1995, 1998). Methods such as electric or acoustic fields, surface vibration and mechanical devices are called active because they require external power, whereas passive methods use special surface geometries or fluid additive, and do not require external power. Wavy walls, louvered and strip fins are examples of passive main-flow enhancement methods, while flow pulsation is an active main-flow method. The use of surface protuberances is a passive secondary-flow method and is based on developing boundary layers or stream-wise fluctuations, creating swirl or vortices and flow destabilization or turbulence intensification. In general, mixing the main flow, reducing the flow boundary layer, raising the turbulent intensity, creating rotating and secondary flow are the main reasons for the increase of the heat transfer. Vortex generation is a

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