International Journal of Heat and Mass Transfer 54 (2011) 4823–4833

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

# Detailed measurements of heat transfer coefficients in a 180-deg rectangular turned channel with the perforation divider

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ARTICLE INFO

*Article history:*
Received 20 April 2011
Received in revised form 24 June 2011
Accepted 24 June 2011
Available online 20 July 2011

*Keywords:*
180-deg rectangular turned channel
Transient liquid crystal method
Perforation
Heat transfer

ABSTRACT

This work measured the heat transfer coefficients of air flow through the 180-deg rectangular turned channel by using the transient liquid crystal method. The cross section of the channel was square. The divider of the 180-deg rectangular turned channel had several perforations with equal interval, then the fluid in the first duct can early flow into the second duct through the perforations to adjust the local heat transfer. Variable parameters were the Reynolds number ($Re$ = 2468–12,340), the ratio of the perforation's diameter to the channel hydraulic diameter ($d/D_h$ = 1/4 and 2/4), the angle of perforations ($\theta$ = −45°, 0° and +45°), and the number of perforations ($n$ = 1, 2 and 3). The results indicated that, at the turn and the neighborhood, the effects of the flow inertia and impingement induced the peak values of heat transfer on the bottom and outer side surfaces. Excluding the heat transfer amount at the inner side surface and the perforations of the divider, the non-perforation configuration had the best total heat-transfer performance ($\overline{Nu}$) among all the test configurations. The $\overline{Nu}$ declined when the number or size of perforations increased; while the angle of perforations was insensitive to $\overline{Nu}$. Besides, the distribution of the Nusselt number ($Nu$) was strongly influenced by the angle of perforations ($\theta$) as $d/D_h$ = 2/4. Different from others configurations, the one with ($d/D_h$ = 2/4 and $\theta$ = +45°) grew the $Nu$ along the main flow direction in the second duct due to the bigger amount of bypass fluid from perforations, greatly improving the heat transfer at the downstream of the second duct. It demonstrated that the perforations of the divider did adjust the spatial heat transfer of the 180-deg rectangular turned channel.

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## 1. Introduction

The power machines often use the rotation of the transmission shaft to do work. They will output a lot of heat continuously at operating condition. To avoid the damage or deformation of the relevant parts by the poor thermal dissipation, one can induce the coolant into the internal channels of the rotating machine. The internal channels usually are 180-deg turned or multi-pass serpentine to increase the total heat-exchange surface area in an impacted volume, then enhancing the cooling performance. The internal cooling technology using the 180-deg turned or multi-pass serpentine channels are also applied widely in many industry applications, like as the heat exchanger, the electronic cooling, the heat absorber for solar energy or industry waste heat, the cooling for turbine blades, and so on.

The heat transfer in the 180-deg turned or multi-pass serpentine channel has received much attention. At early time, most of them focused on the smooth-wall channels [1–6]. Following studies were the ribbed-wall channels [7–18]. Zhang et al. [7] examined the heat transfer and friction in rectangular channels with ribbed or ribbed-grooved wall. They reported that the ribbed-grooved wall enhanced more heat transfer and turbulence intensity than the pure ribbed wall. Lin et al. [8] employed 3-dimensional numerical simulations to predict the fluid flow and heat transfer behaviors in the U-bend channels with smooth or inclined ribbed wall at stationary and rotating conditions. Their numerical results provided the details about the fluid flow field. Liou and his colleagues [9–11] used the transient liquid crystal method to measure the heat transfer coefficient in the U-bend channels with smooth or vertical ribbed wall at stationary and rotating conditions. They also utilized the Laser Doppler Velocimetry to measure the relevant velocity field, which provided sufficient fluid flow data to explain the local heat transfer characteristics. Han and his colleagues [12–16] performed a series of experimental and numerical tests to investigate the fluid flow and heat transfer behaviors in the U-bend channel with 45-deg ribbed wall at stationary and rotating conditions. Kim et al. [17,18] experimentally explored the heat transfer and pressure drop in a rotating two-pass duct with various transverse ribs. The angles between the rib axis and the main flow direction were 90° and 70°. They reported that a

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doi:10.1016/j.ijheatmasstransfer.2011.06.036