Proceedings of the 15th International Heat Transfer Conference, IHTC-15
August 10-15, 2014, Kyoto, Japan

IHTC15-8732

THE EFFECT OF INNER SURFACE ROUGHNESS AND HEATING ON FRICTION FACTOR IN HORIZONTAL MINI-TUBES

Lap Mou Tam[1,2], Hou Kuan Tam[1*], Afshin J. Ghajar[3], Wa San Ng[1,2], Choi Keng Wu[1,2]

[1] Department of Electromechanical Engineering, Faculty of Science and Technology, University of Macau, Av. Padre Tomás Pereira, Taipa, Macau, China.
[2] Institute for the Development and Quality, Macau.
[3] School of Mechanical and Aerospace Engineering, Oklahoma State University, Stillwater, Oklahoma, USA

ABSTRACT

According to the recent literature survey, it was concluded that the friction factor in mini- and micro-tubes could be predicted accurately by using macro-scale theory. However, certain issues should be further investigated. They are: (a) the effect of inner surface roughness and (b) the effect of mini- and micro-tube diameters on the start and end of the transition region. Moreover, only a few studies investigated the effect of heating on friction factor in mini- and micro-tubes, especially, in the transition region. Therefore, an experimental setup was built in this study to measure the pressure drop for the horizontal mini- and micro-tubes under the isothermal and uniform wall heat flux boundary conditions. Distilled water was used as the test fluid. Seven stainless steel mini-tubes (2000μm to 508μm in inner diameters) with various surface roughness values (1.94μm to 5.30μm) were used as the test section.

The experimental results clearly showed the effect of heating and roughness on friction factors in the laminar, transition, and turbulent regions. For the friction factors under isothermal condition, the mini-tubes had a narrower transition range due to the roughness when compared to the macro-tubes. For the friction factor under heating condition, the laminar data and the start of transition were different from the isothermal case. Under heating condition, the narrower transition range due to the roughness was also observed in the mini-tubes. However, the effect of heating was not seen on the end of transition and in the turbulent region.

KEY WORDS: Nano/Micro scale measurement and simulation, Convection, Friction factor, Inner surface roughness, Mini-tube

1. INTRODUCTION

Due to rapid advancement in fabrication techniques, the miniaturization of devices and components is ever increasing in many applications. Whether it is in the application of miniature heat exchangers, fuel cells, pumps, compressors, turbines, sensors, or artificial blood vessels, a sound understanding of fluid flow in mini- and micro-scale channels and tubes is required. Indeed, within this last decade, countless researchers have been investigating the phenomenon of fluid flow in mini-, micro-, and even nano-channels. One major area of research in the phenomenon of fluid flow in mini- and micro-channels is the friction factor. However, amidst all the investigations in mini- and micro-channel flow, there seem to be a lack in the study of the flow in the transition region. One obvious question is the location of the transition region with respect to the hydraulic diameter of the channel and the roughness of the channel. To successfully understand friction factor and the location of the transition region, a systematic experimental investigation on various roughness values of mini- and micro-tubes is necessary. However, the science behind these advanced technologies seems to be controversial, especially fuelled by the experimental results of the fluid flow and heat transfer at

*Corresponding Author: hktam@umac.mo