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Research Paper

Experimental study of the ultrasonic effect on heat transfer inside a horizontal mini-tube in the laminar region

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HIGHLIGHTS

- Heat transfer enhancement by ultrasonic head was observed in the laminar region.
- Two ultrasonic heads were observed to give a better heat transfer enhancement.
- More significant heat transfer enhancement was shown in the entrance region.

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ABSTRACT

Ultrasound has been widely used in the drying, welding, cleaning, chemical, and heat transfer processes. Moreover, in recent years there has been an increased interest in the application of ultrasound for heat transfer enhancement in the field of heat transfer. However, only a few papers have investigated the effect of ultrasound on heat transfer inside the horizontal tube. Therefore, the objective of this experimental study is to investigate the influence of ultrasound on the heat transfer inside the horizontal tube in the laminar region. In this study, a stainless steel test tube with a diameter of 4 mm was used as the test section under the uniform wall heat flux boundary condition. The entrance and fully developed regions heat transfer coefficients were analyzed. The Reynolds number for the experiments ranged from 600 to 3000. A series of experiments with the different numbers of ultrasonic heads and the different locations of the heads placed on the tube were conducted. The results showed that a substantial enhancement in heat transfer by ultrasound was observed in the laminar region. Based on the combinations of different numbers and positions of ultrasonic heads, two ultrasonic heads were observed to give a better heat transfer enhancement in the entrance and fully developed regions.

1. Introduction

Heat transfer enhancement is an important topic in the area of thermal engineering. For the tube flow, the heat transfer can be enhanced by the passive or active methods [1]. Passive methods consist of roughing the tube inner surface, inserting the swirl-flow devices into the tube, and adding the solid-particles into the fluid. Traditional active methods are the application of mechanical aids, vibration, and electrostatic fields on the tube. Tam and his coworkers [2] applied the passive method, i.e. the micro-fins, to increase the heat transfer inside the macro-tube of 14.8 mm diameter. Although the increase of heat transfer was obvious in the upper transition and turbulent regions, that method was not applicable for the mini- or even the micro-tubes because it was difficult to fabricate the small fins on the inner surface of the mini- or micro-tubes. Therefore, an alternative heat transfer enhancement method is required for the smaller diameter tubes.

In the last decades, ultrasound has been gradually used in the chemical processes, cleaning, and thermal systems. Regarding to the heat transfer enhancement by ultrasound, Legay et al. [3] reviewed some ultrasonic papers in the studies of boiling heat transfer, convective heat transfer, and heat exchanger. However, only a few papers were related to the tube flow heat transfer with ultrasound. Monnot et al. [4] applied ultrasound to a tank filled with water and measured the heat transfer coefficient in the coil tube immersed into the tank. The maximum enhancement ratio of the heat transfer coefficient was 2.04. It was indicated that

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