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Friction and heat transfer characteristics of laminar swirl flow through the round tubes inserted with alternate clockwise and counter-clockwise twisted-tapes ☆

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ABSTRACT

The thermohydraulic characteristics of the circular tubes equipped with alternate clockwise and counter-clockwise twisted-tapes (TA) for the Reynolds number ranging from 830 to 1990, are reported. In the experiments, the twisted tapes with three different twist ratios (y/W = 3, 4 and 5) were inserted individually into the uniform wall heat flux tubes where water was utilized as the working fluid. The plain tube and the tube inserted with twisted tape (TT) were also tested, for comparison. The obtained results reveal that, Nusselt number, friction factor and thermal performance factor associated by TA are higher than those associated by TT. Among the tapes examined, the one with the smallest twist ratio of y/W = 3 is found to be the most efficient for heat transfer enhancement. For the range studied, the applications of both TT and TA for heat transfer enhancement are found to be promising since the thermal performance factors determined under the same pumping power are all above unity. In addition, the empirical correlations for Nusselt number, friction factor and thermal performance factor have also been developed. The consequential results obtained from the correlations are found to be in good agreement with the experimental results within ±8% variation for Nusselt number (Nu), ±8% for thermal performance factor (η) and ±5% for friction factor (f).

1. Introduction

Heat transfer enhancement techniques (HTE) are applied in many engineering applications for example heat exchanger, air condition, heat recovery process, chemical reactor and refrigeration system, to improve the heat transfer coefficient or thermal performance. The enhancement directly relates to the reductions of the size and cost of involving equipment. Heat transfer enhancement techniques are classified into two major groups, one is an active method which needs an external power source, another is a passive method which does not need any external power source. Among the techniques used in the passive method, the use of twisted tape in the enhanced tube as the swirl flow generator is apparently prominent, due to its low cost and high efficiency for improving heat transfer rate.

Heat transfer enhancement by insertion of twisted tape into a heat exchanger tube has been studied, extensively [1–20]. Manglik and Bergles [1,2] and Samar et al. [3] mentioned that the heat transfer improvement associated by a twisted tape can be caused by the following factors (1) the decrease of hydraulic diameter which leads to the increase in flow velocity (2) the increase of flow path length due to helical configuration of the twisted tape (3) the increase of shear stress at wall tube and improvement of fluid mixing by secondary flow and (4) the fin contribution if the tape insert is in good thermal contact with the wall of the tube.

Variants of twisted tapes have been evaluated. Rahimi et al. [4] performed the experimental and computational fluid dynamics (CFD) investigation on the friction factor, Nusselt number and thermal-hydraulic performance of the tube equipped with typical and three modified twisted tapes (perforated, notched, and jagged twisted tape). Among the modified twisted tapes, the jagged twisted tape offered the greatest Nusselt number, friction factor and thermal performance factor. Eiamsa-ard et al. [5] reported the heat transfer enhancement and pressure loss of the tube fitted by regularly-spaced dual twisted tapes with three different twist ratios (y/w = 3.0, 4.0 and 5.0) and three different space ratios (s/D = 0.75, 1.5 and 2.25). The experimental results revealed that the heat transfer rate decreased with increasing space ratio (s/D). Eiamsa-ard et al. [6] also found that twin counter twisted tapes (counter swirl tapes) provided higher heat transfer rates than the twin co-twisted tapes (co-swirl tape) and the single twisted tape by around 12.5–44.5% and 17.8–50%, respectively, due to the better fluid mixing between a core flow and a flow near the tube wall.

Jaisankar et al. [12] analyzed the heat transfer and friction factor characteristics of thermosyphon solar water heater equipped by the tapes with full length left–right twist, fitted with rod and spacer at the trailing edge. It was pointed out that the tape with full length left–right

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