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CFD and experimental studies on heat transfer enhancement in an air cooler equipped with different tube inserts ☆

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ABSTRACT

This paper reports the experimental and Computational Fluid Dynamics (CFD) modeling studies on heat transfer, friction factor and thermal performance of an air cooled heat exchanger equipped with three types of tube insert including butterfly, classic and jagged twisted tape. In the studied range of Reynolds number the maximum thermal performance factor was obtained by the butterfly insert with an inclined angle of 90°. The results have also revealed that the difference between the heat transfer rates obtained from employing the classic and jagged inserts reduces by decreasing the twist ratio. The CFD predicted results were used to explain the observed results in terms of turbulence intensity. In addition, good agreements between the predicted and measured Nu number as well as friction factor values were obtained.

1. Introduction

It has been commonly known that the performance of heat exchangers especially for single-phase flows can be improved through many enhancement techniques. In general, heat transfer enhancement (HTE) techniques can be divided into two categories: (1) active techniques which need external power source and (2) passive techniques which do not need external power source. Some examples of passive HTE methods include: insertion of porous [1–4], twisted stripes and tapes [5–9], wire coil and helical wire coil inserts [10,11] as well as mounting of turbulent decaying swirl flow devices [12–14]. Despite the high pressure drop caused by insert in embedded tubes, the use of tube insert in heat exchangers has received a lot of attention during the last two decades [9,15]. The increase in turbulence intensity and swirling flow may be the main reasons for HTE induced by tube inserts. An experimental investigation was carried out on heat transfer and friction factor characteristics in a round tube equipped with propeller type swirl generators by Eiamsa-ard et al. [16]. The effects of the blade angle, pitch ratio and number of blades on Nusselt number, pressure loss and enhancement efficiency were also studied. In another work, Eiamsa-ard et al. [17] examined the heat transfer enhancement inside tubes using louvered strip tube inserts. Their experiments were carried out with louvered strip inserts with forward or backward arrangements accompanied by various inclined angles. The effect of conical ring turbulator arrangement on the heat transfer rate and friction factor was presented by Promvonge [18]. Their investigation showed that the conical-ring with diverging conical-ring array provided superior thermal performance factor compared to those with the converging conical ring and converging–diverging conical-ring arrays. Kongkaitpaiboon et al. [19] investigated the heat transfer and friction factor characteristics of a circular tube fitted with perforated conical-rings. Chang et al. [20,21] studied the heat transfer enhancement in a tube fitted with the serrated twisted tapes and broken twisted tapes. Saha [22] studied the heat transfer and pressure loss behaviors in rectangular and square ducts with combined internal axial corrugations and twisted-tapes with and without oblique teeth.

Due to advances in computer hardware and software and consequent increase in calculation speed, the Computational Fluid Dynamics (CFD) modeling technique was developed as a powerful and effective tool for better understanding of the complex hydrodynamics in many industrial processes. Bredell et al. [23] investigated the performance of fan in a forced draft air-cooled steam condenser. A CFD model was developed by Erek et al. [24] to verify the influences of fin geometry changes on heat transfer and pressure drop behavior of plate fin and tube heat exchanger. Zhang et al. [25] examined the heat transfer characteristics of a helically baffled heat exchanger combined with a finned tube experimentally and using CFD modeling.

Eiamsa-ard et al. [26] have carried out a numerical study on a tube equipped with loose-fit twisted tapes. They used four turbulence models and their results showed that prediction results of the SST k–ω turbulence model have better agreement with measurement results compared with other models. The increase of heat transfer rate caused by metallic porous tube inserts was investigated by Pavel and

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