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Heat transfer improvement in a double pipe heat exchanger by means of perforated turbulators

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ABSTRACT

Forced convective turbulent hydrothermal analysis in a double pipe heat exchanger is presented experimentally. Perforated turbulators have been utilized in annulus region. Hot water makes the cold air in outer tube warmer. Various amounts of pitch ratio, open area ratio and Reynolds number are considered. Correlations for Nusselt number, thermal performance and Darcy friction factor are examined. NSGA *II* is utilized to optimize the design. Physical phenomena are shown by means of FVM. Results reveal that thermal performance enhances with augment of open area ratio. Temperature gradient reduces with augment of pitch ratio. The maximum value of thermal performance obtained at $\eta = 1.59$ which is occurred for $Re = 6000,\ \lambda = 0.07,\ PR = 1.06$.

1. Introduction

Water to air heat exchanger can be selected as important type of heat exchangers. It can be utilized for residential heating and dehumidification. Swirl flow devices are one of the common ways for heat transfer improvement which becomes popular due to low price. Performance of desiccant coated heat exchanger was investigated by Ge et al. [1]. They showed that the ambient air temperature has no sensible impact on supply air. Multi-objective genetic algorithm has been used for plate-fin heat exchanges by Wen et al. [2]. Jaisankar et al. [3] have been used helical twist tape in solar heaters. Their results indicated that this device generates secondary flow. Yang and Liu [4] utilized plate baffles in their shell and tube heat exchanger. They presented path lines to show the benefits of their method. Syed et al. [5] used longitudinal fins in heat exchanger. They concluded that the shape of the fin has sensible role in decreasing weight of heat exchanger. Promvonge et al. [6] presented the influence of vortex generators on hydrothermal behavior. They proved that this technique can augment heat transfer. The benefits of permeable micro channel have been presented by Dehghan et al. [7]. They proved that this way is more effective in slip flow conditions.

Advantages of helical baffled heat exchangers were presented by Chen et al. [8]. Influence of conical inserts on heat transfer improvement was examined by Promvonge and Eiamsa-ard [9]. Targui and Kahalerras [10] studied the effect of oscillating flow on rate of heat transfer. They indicated that heat transfer improve by using oscillating flow. Sheikholeslami et al. [11] studied about swirl flow devices effect on fluid flow and heat transfer. Kumar et al. [12] presented the chevron angle influence on Nusselt number. They proved that nanofluid has higher exergy efficiency. Borquist et al. [13] applied LBM to simulate a micro-channel. They proved that the copper MHE is good choice for transferring low-temperature waste energy. Barakat et al. [14] investigated earth to air heat exchanger. They showed that the thermal efficiency of gas turbine enhances by 4.8%. Sheikholeslami et al. [15] investigated the impacts of helical turbulators on heat transfer performance. They concluded that thermal performance augments with rise of open area ratio. Dong et al. [16] studied the efficiency of helical baffle shell-and-tube heat exchanger. They indicated that thermal performance of cothHXf is much better than those of the segHX. In recent decade, passive methods have been applied by several researchers [17–26].

The main goal of this article is to study the heat transfer improvement and pressure loss in a water to air heat exchanger equipped with perforated turbolentor. Pressure drop and thermal treatment for various amounts of pitch ratio, open area ratio and

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Nomenclature

D	diameter of outer pipe
d	diameter of inner pipe
f	Darcy factor
L	length of the test section
ℓ	length of the tube
h	convective heat transfer coefficient
Nu	Nusselt number
PR	pitch ratio (=P/D_o)
P	pressure
Pr	Prandtl number
Re_a	Reynolds number of air flow
T	temperature
U	overall heat transfer
V_i	each independent parameter

Greek symbols

λ	open area ratio $(= Nd_s^2/((D_o + 2h)^2 - D_o^2))$
μ	viscosity
η	thermal performance
α	thermal diffusivity
ρ	density

Subscripts

a	air
s	smooth pipe
out	outlet
in	inlet
o	outer
i	inner
w	water

Reynolds number are studied. NSGA *II* and Numerical method have been utilized to obtain optimize design and physical phenomena, respectively.

2. Set up

Details of set up are shown in Fig. 1. All diameters and lengths are depicted in this figure. Water in the inner tube has been warmed by heaters exist in upper tank (tank B). The inner and outer tubes are made from copper and Plexiglas, respectively. Arrange of thermocouples is shown in Fig. 1(c). Pressure loss is measured by digital ST-8920 differential pressure. In order to transfer air to test section a blower has been utilized and its rate is controlled by an inverter. Counter flow arrangement has been considered. Tables 1 and 2 illustrate the properties of water and air. In order to improve rate of heat transfer, perforated circular rings has been insert in air side of test section (Fig. 2).

In order to calculate uncertainty analysis, Schultz and Cole method [27] has been utilized:

$$U_R = \left[\sum_{i=1}^{n}\left(\frac{\partial R}{\partial V_i}U_{V_i}\right)^2\right]^{1/2} \tag{1}$$

where U_{V_i} and U_R are error of each parameter and total error, respectively. Uncertainties of the experimental parameters are shown in Table 3. For all cases, the maximum absolute uncertainty was less than 6%.

3. Data reduction

In order to find Darcy factor and Nusselt number the following procedure can be considered.

$Q_a^\bullet$ and $Q_w^\bullet$ are heat transferred to the air and heat transferred from water, respectively.

(a)

Fig. 1. (a and b) Schematic diagram of the experimental setup; (c) test section and thermocouples.