Advances and Applications in Mathematical Sciences
Volume 21, Issue 9, July 2022, Pages 5101-5108

HEAT TRANSFER AUGMENTATION IN A RECTANGULAR HEAT EXCHANGER THROUGH PASSIVE HEAT TRANSFER TECHNIQUES

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Abstract

Heat exchanger is vital in almost all the mechanical and process industries. Over the years many researchers are putting their efforts to enhance the performance of the heat exchangers particularly in terms of heat transfer rate, effectiveness and efficiency. This paper endeavors on passive heat augmentation techniques which are employed in heat exchangers. Thus to make the study more specific thermal performance of heat exchanger is studied by placing twisted tape inserts with different pitch to width ratio along with different geometrical cuts shapes. The

2020 Mathematics Subject Classification: 80Axx.
Keywords: Heat transfer, twisted tape, heat exchanger, Nusselt number, Reynolds number.
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Received January 23, 2022; Accepted May 18, 2022.

paper thus aims to analyze the results tested for the correlations between Nusselt number and Reynolds number. For the pitch/width (p/w) ratio of 3 with semi-circular cut, the increase in Nusselts number is highest of around 30% than for any other geometrical profile.

1. Introduction

Heat exchanger (HE) is the basic and key equipment in most of the mechanical as well as process industries. Heat transfer (HT) rate in HE is one of the important parameter while the designing it. Many researchers are working in the field of HT enhancement techniques in HEs. Basically these HT enhancement techniques are categorized in two groups, active and passive techniques. In active techniques, the performance of HE (i.e. heat transfer rate) is enhanced by providing additional energy to the system while in passive techniques, the thermal performance is enhanced by geometrical modifications like fins, rough surfaces, coated surfaces and by inserting inserts which are also called swirl flow devices. The inserts are of different types like wire coil inserts, twisted tapes (TTs) and their combination. All kind of inserts are very popular for enhancing the performance of HEs and the selection is mainly based on the design of HE. The purpose behind these swirl flow device insertion is to enhance the heat transfer rate by disturbing velocity boundary layer, by reducing the thickness of thermal boundary layer and allowing core fluid to mix with peripheral fluid. TT inserts are easy to manufacture and install, their cost is too less.

Moya-Rico et al. [1] investigated the thermal performance of double tube heat exchanger (HE) by inserting the TTs. About 320 test were carried out by varying heat transfer (HT) fluid mass flow rate and different TT configurations and found that there is a significant increase in HT rate with three free-spacing of TTs. The numerical investigation was carried out for HE equipped with double V-cut TT inserts having different depth to width ratios is conducted by Nakhchi and Esfahani [2] and observed that the HT rate is increased by 27.4% with TT having depth to width ratio of 1.8 compared to normal tapes. The same study was extended by Kumar et al. [3] using triangular perforated TTs and found that the thermal performance factor is enhanced by 1.49 over plane tape. The numerical investigation is performed by Hossein et al. [4] to predict the thermal performance of tube HE by inserting stationary and rotating TTs of varying length to pitch ratio (L/P) and the maximum thermal performance of tube HE is observed with stationary TT inserts having L/P ratio of 1:6. Vaisi et al. [5] conducted experimental analysis for the performance prediction of twin pipe HEs with plane and perforated TT inserts and observed that there is significant rise in the HT rate of heat exchanger with perforated tape inserts. Paneliya et al. [6] carried out experimental as well as numerical investigation for the performance prediction of tube HEs equipped with fixed and variable pitch TTs and found good agreement between experimental and numerical results. Dagdevir and Ozceyhan [7] experimentally investigated the HT performance of tube HE with dimpled, perforated and plain TT inserts and the maximum HT rates were observed for dimpled TT inserts. Saravanan and Jaisankar [8] carried out the experimental analysis to augment the HT characteristics of *V*-trough solar collector by employing *V* and Square cut TT inserts and the thermal performance is increased by 5.96% with *V*-cut TT inserts. Mokkapati and Li [9] numerically studied the effect of TT inserts in exhaust heat recovery systems. Promvonge [10] and Tamna et al. [11] experimentally studied the thermal performance of square heating/cooling duct HE by employing TT of different pitch to width ratio and found significant rise in HT rates. Many researchers experimentally and numerically investigated the effect of different geometrical cuts and varying pitch to width ratio of TT inserts on the thermal performance of HEs [12, 13, 14]. From the studies available in the literature, it was observed that the performance of the HE can be enhanced by TT inserts with different geometrical shapes and varying pitch to width ratios. In present study the heat transfer characteristics of rectangular HE is experimentally investigated by employing TT inserts of different pitch to width ratios without cuts and with triangular, rectangular and semi-circular cuts.

2. Experimentation

The experiments were conducted by employing forced convection and for that uniform flow of air is provided over the TT inserts by using a rectangular duct. At the beginning of experiment, all the strips are place in the line of air flow and the TT position and air flow velocity are measured with the help of anemometer. The heating coils are connected at the end of each TTs and a provision is provided at three different locations to fix the thermocouples. The reference junctions of all the thermocouples are placed in ice. The photographic view of experimental setup is presented in Figure 1.

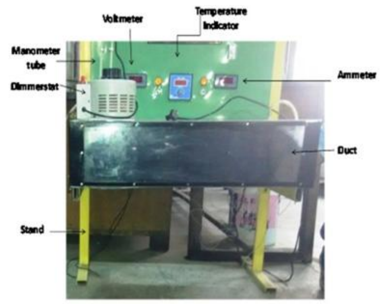

Figure 1. Experimental setup.

After checking all the connection of thermocouples and heating coils, the power supply is turned on and after some time when the steady state situation is achieved (i.e. the temperature of TTs does not vary with time), the thermocouple readings are recorded with the help of digital meter. The entire procedure were repeated for all configurations of TTs by varying the current input from 50 to 120 watt and the output data is recorded. All the configuration of TT employed are presented in Figure 2. Reynolds number for each reading is calculated, then overall heat transfer coefficient and Nusselt number is also calculated.

Different configurations of twisted tape used for experimentation

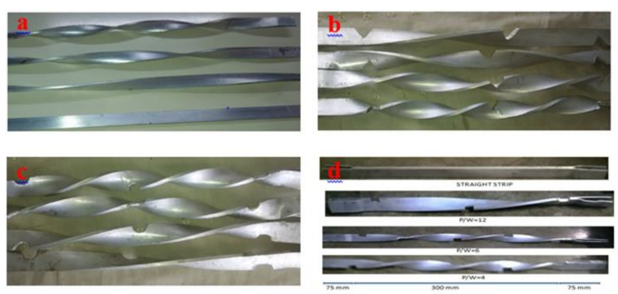

Figure 2. Model strips a) without cuts, b) with triangular cuts, c) with semi-circular cuts and d) with rectangular cuts.

3. Thermodynamic Analysis

Average temperature 'T' can be calculated as

$$T = \frac{T_1 + T_2 + T_3}{3} ({}^\circ C) \tag{1}$$

Temperature difference 'ΔT' can be calculated as

$$\Delta T = T - T_a ({}^\circ C) \tag{2}$$

Mean film temperature 'MFT' can be calculated as

$$MFT = \frac{(T + T_a)}{2} ({}^\circ C) \tag{3}$$

The heat transfer coefficient 'h' can be calculated as

$$h = \frac{Q}{A} \times \Delta T (w/m^2 K) \tag{4}$$

Nusselt number 'Nu' can be calculated as

$$Nu = h \times \frac{w}{k} \tag{5}$$

Reynolds number 'Re' is calculated as

$$R_e = \frac{\rho \times v \times l}{\mu} \tag{6}$$

4. Results and Discussion

In this section, the thermal performance of rectangular HE is experimentally investigated by employing TT inserts of different pitch to width ratios without cuts and with triangular, rectangular and semi-circular cuts. The experimental results were compared and discussed.

Effect of different geometrical cuts and p/w ratio on heat transfer coefficient 'h'

Figure 3 shows the effect of geometrical shapes with different pitch to width ratio. It can be observed that, for the same length of TT, the heat transfer coefficient value is maximum for the TT inserts with semi-circular cuts at p/w ratio of 3 compared to TT without cuts and with triangular and rectangular cuts and p/w ratio of 4, 6 and 12. This happen because the TT with semi-circular cuts and p/w ratio of 3 generates more turbulence in rectangular duct and hence the heat transfer rate is more compared to other configurations.

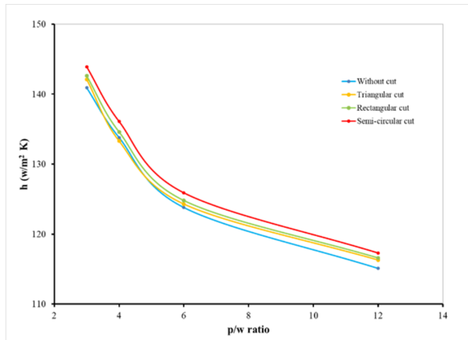

Figure 3. HT coefficient of different shapes with different pitch to width ratio.

Variation in heat transfer coefficient with heat input for TT with semi-circular cuts

From Figure 3, it is clear that the maximum heat is transferred with TT having semi-circular cuts and p/w ratio 3. Figure 4 shows the effect of variation in heat input on HT coefficient with different p/w ratio.

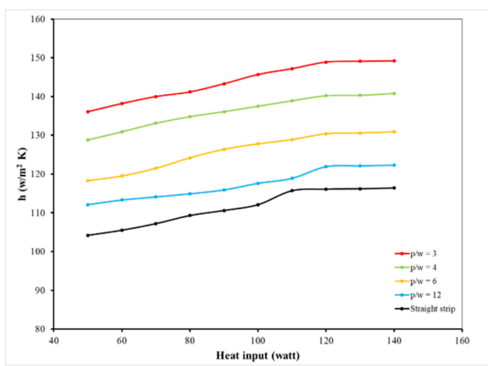

Figure 4. Effect of heat input on heat transfer coefficient with different p/w ratio.

5. Conclusion

The thermal performance of rectangular HE is carried out and observed that the HT get enhanced with increase in the number of twist or in other words p/w ratio decreases. It was observed that, there is a definite relationship between Nusselts number and that of HT coefficient. Nusselts number and HT coefficient increases for the same mass of flow rate of air and the same area of cut, but change in cut profile being lowest in triangular cut, slightly higher in rectangular cut and highest in semi-circular cut.

For the p/w ratio of 3, the increase in Nusselts number is highest of around 30% than for any other geometrical profile. There is sharp percentage increase in Nusselts number value and heat transfer coefficient below 6 while from 6-12 the value of both there parameters do not show very high percentage increase.

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