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A Study of Heat Transfer Enhancement by using Triangular V-ribs in Round Tube

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Abstract

This is a review on the technique of heat transfer augmentation in circular tube with triangular V-ribs. Fundamental concepts for increasing the heat transfer enhancement using the V-ribs to generate vortex flow through a constant heat-fluxed in the round tube. The experiments were performed with conditions. The blockage ratio calculated from the rib height per tube diameter (BR = e/D) is 0.2, attack angle 45^{o} and different pitch ratio (PR=P/D) 0.5, 1.0, 1.5, 2.0 respectively. Present in terms of Reynolds number (Re) is in the range of 5,000-25,000. Present in term Nusselt Number and friction factor for comparison the thermal enhancement factor of tube with the triangular V-ribs and smooth tube. The triangular V-ribs at PR = 1.0 provides the highest heat transfer and friction factor.

Keywords: V-ribs, Nussult number, Friction factor, Thermal enhancement factor.

1. Introduction

Techniques for save energy in industrial there are a variety. One of technique is developed the heat exchanger performance. Therefore, the heat transfer enhancement techniques have been widely applied in heat exchanger systems, in order to improve the heat transfer coefficient [1-4]. The technique for increasing the thermal performance can be classified two methods there are active and passive methods. In active method heat transfer could improve by external power. In passive method heat transfer augmentation is enhance heat transfer without external power. The technique is inserted the twisted tape in a circular tube is one of the most effective approaches. The inserted twisted tape generates swirling flow and increases turbulence intensity which is major influencing factors for heat transfer enhancement In fact, using twisted tape increases both desirable heat transfer rate and undesirable friction loss (pressure drop). There are many types of vortex generators employed in the heat exchanger tubes such as circular/twisted-rings [7] and [8] and angle-finned tapes [9] and [10].

A part from the above, There are other turbulence devices, such as baffles, ribs and fins that have been applied in heat exchanger tubes. The main roles of ribs in heat exchangers are to increase the heat transfer area and the length of exchangers. So the main aim of the present work is to investigate the influence of the Triangular V-ribs on heat transfer and flow friction in the tube heat exchangers.

2. Experimental Set up and Procedure

A general schematic diagram of the experimental apparatus is shown in Fig. 1. In the apparatus setting below, the copper test tube having inner diameter (*D*) of 50 mm and thickness of 2 mm was 4000 mm long included the test section length (*L*) of 2000 mm. The test tube was heated by continually winding flexible electrical wires providing a uniform heat-flux boundary condition. The outer surface of the test tube was well insulated to reduce convective heat loss to surroundings. The inlet bulk air from a 1.5 kW blower was directed through the orifice flow-meter and passed to the heat transfer test section in the turbulent region, Reynolds number from 5000 to 25,000. The airflow rate was measured by the orifice flow-meter, built according to ASME standard [9] and calibrated by using a anemometer to measure flow velocities across the tube section. Manometer fluid was used in an digital manometer to ensure reasonably accurate measurement of pressure drop. The volumetric airflow rates from the blower were adjusted by varying the motor speed through an inverter. The electrical output power of electric heater was controlled by a Vary AC transformer. The inlet and outlet fluid temperatures in the tube were measured by K-type thermocouples while the surface temperatures (T_w) were measured by 56 thermocouples located along the test section. All of the temperatures getting from the system were consistently recorded using a data logger. The pressure drop across the test section was measured using a digital manometer

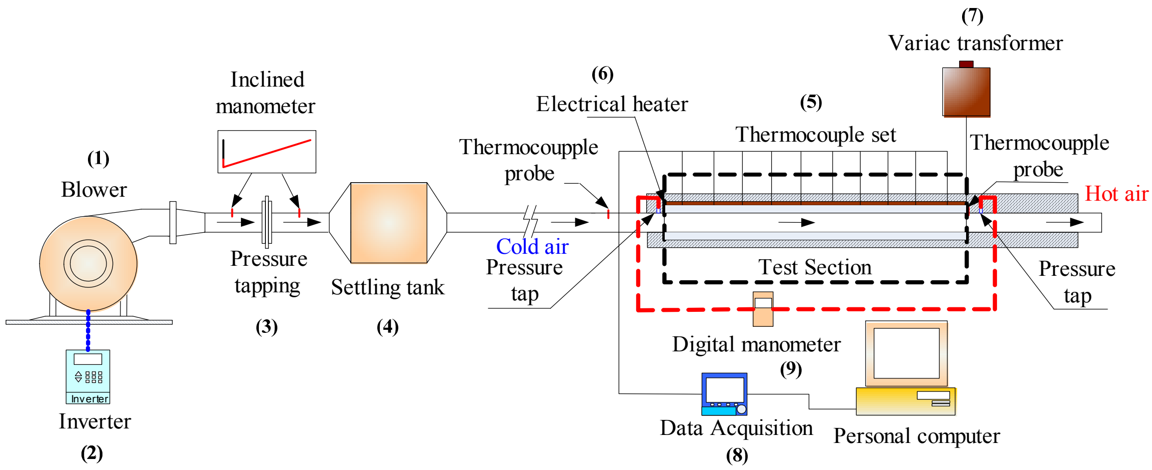


Figure 1. Schematic diagram of experimental apparatus.

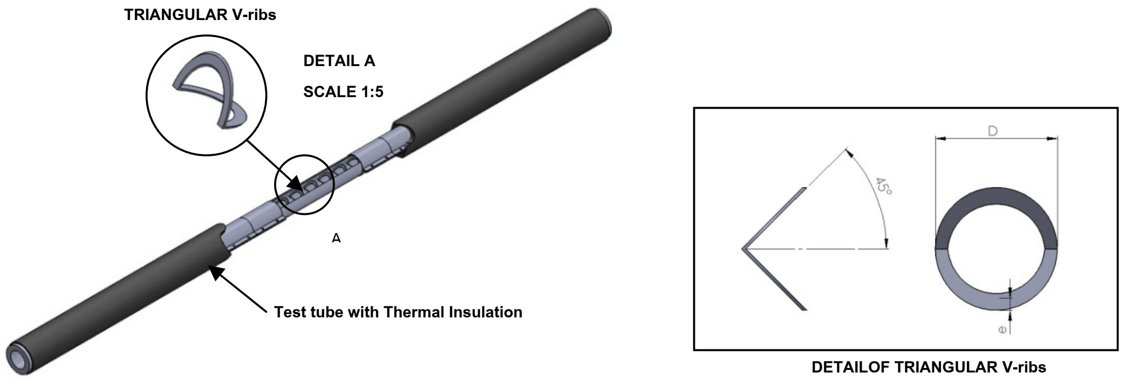


Figure 2. Test section with triangular V-ribs.

The detail of inclined baffles inserted into the heat exchanger round tube is depicted in Figure 2. The tested tube made of 3 mm thick aluminum plates has a height of 45 mm (H) and a length of 1000 mm (L) while the inclined

3. Data Reduction

The Reynolds number (*Re*) based on tube diameter is given by

$$Re = UD/\nu \tag{1}$$

The friction factor (*f*) computed by pressure drop across the test section length (*L*) is

$$f = \frac{2}{(L/D)}\frac{\Delta P}{\rho U^2} \tag{2}$$

Where ΔP is the pressure drop across the test section and U is the mean air velocity in the round tube

In the experiment, the steady state of the convective heat transfer rate is assumed to be equal to the heat loss from the test section. The average heat transfer coefficient (*h*) is estimated as

$$h = mC_{p,a}(T_o - T_i)/A(\tilde{T}_w - T_b) \tag{3}$$

The heat transfer is calculated from Nusselt number which can be obtained by

$$Nu = \frac{hD}{k} \tag{4}$$

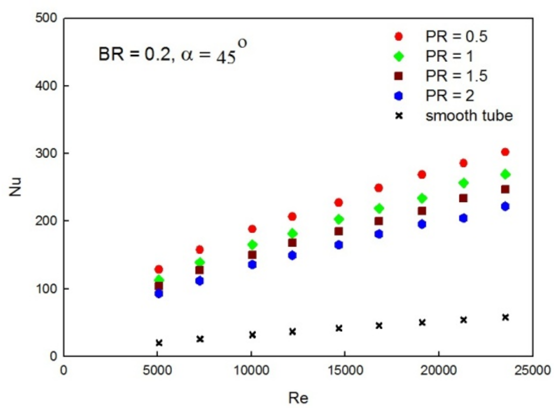
From equal pumping power and the relationship between friction and Reynolds number, the thermal enhancement factor (TEF) can be written by

$$TEF = \left.\frac{h_s}{h_p}\right|_{pp} = \left.\frac{Nu_s}{Nu_p}\right|_{pp} = \left(\frac{Nu_s}{Nu_p}\right)\left(\frac{f_s}{f_p}\right)^{-1/3} \tag{5}$$

Where h_p and h_s are the heat transfer(1) coefficients for the plain tube and the inserted tube.

4. Result and Discussion

4.1 Effect on heat transfer



(2)

(3)

Figure 3a. Variation of Nu with Re for tubes fitted with the 45° triangular V-ribs.

The relationship between Nusselt number (Nu) and Reynolds number (Re) of the tube fitted with the triangular V-ribs demonstrated in Fig. 3(a). In the figure, the Nu increases with the increment of Re but with the decrease in the pitch ratio. The heat transfer of the tube with the triangular V-ribs is found to be much better than that of the smooth tube, because the triangular V-ribs inserted into the tube can help to induce an interruption of velocity/thermal boundary layer development, to increase the fast fluid mixing between the central core and the near-wall flows and to cause the heat transfer enhancement by increasing turbulence intensity.

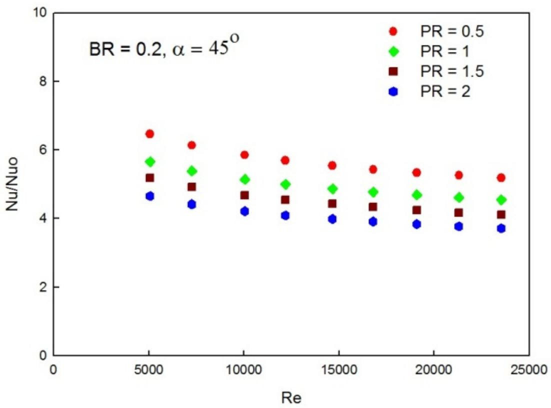


Figure 3b. Variation of Nu/Nu_0 with Re for tubes fitted with the 45° triangular V-ribs.

The Nusselt number ratio (Nu/Nu_0) defined as a ratio of augmented Nusselt number to Nusselt number of smooth tube plotted against the Re is displayed in Fig. 3(b). In the figure, the Nu/Nu_0 tends to slightly decrease with the rise of Re for all cases studied. Under the present experimental conditions, the increases in heat transfer for using the 45º the triangular V-ribs are about 4.3-6.2 times higher than the smooth tube. The Nu/Nu_0 is reduced with the increase in PR value.

4.2. Effect on friction factor

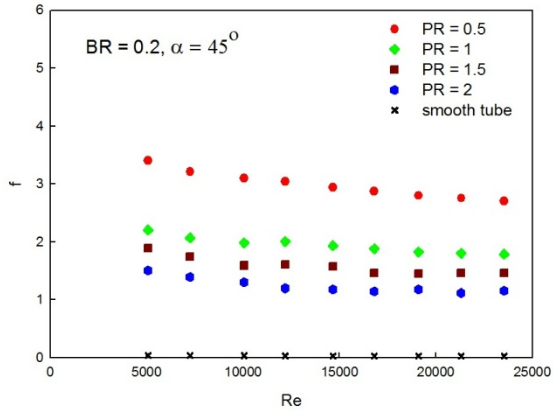


Figure 4(a). Variation of *f*. with Re for tubes fitted with the 45° triangular V-ribs

Figure 4(a) shows the variation of the friction factor (*f*) with Re values obtained from using the 45º triangular V-ribs inserts. It is observed that the *f* shows a decrease trend with the rise in the Re and the pitch ratio. The triangular V-ribs gives rise to the *f* values higher than the smooth tube alone. This can be attributed to the flow blockage, higher surface area and the act caused by the reverse flow.

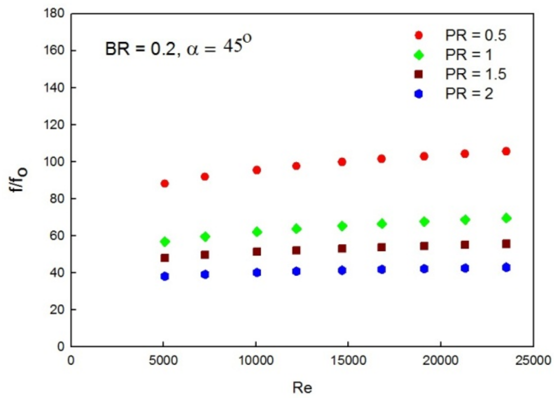


Figure 4(b). Variation of f/f_0 with Re for tubes fitted with the 45° triangular V-ribs

The variation of the friction factor ratio, f/f_0 with Re is presented in Fig. 4(b). It is seen that the f/f_0 tends to increase with the increment of

Re values. The triangular V-ribs provides the higher f/f_0 at about 40-100 times depending on Re and PR values.

4.3 Thermal Enhancement factor (TEF)

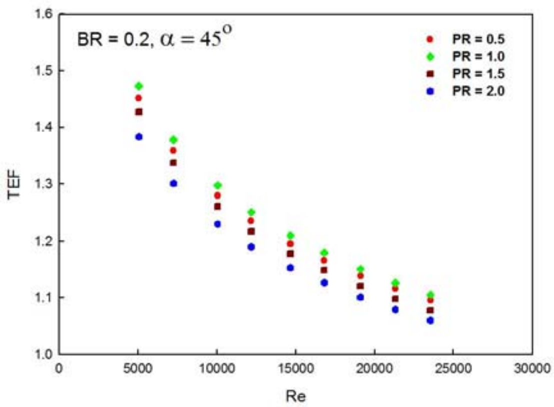


Fig. 5 Variation of TEF with Re for 45° triangular V-ribs

Figure 5 shows the variation of the thermal enhancement factor (TEF) with Re values. It can be seen in the figure that the TEF values generally are above unity, indicating that the use of the triangular V-ribs is advantageous over the smooth tube. The TEF tends to decrease with the increment of Re and PR values.

The maximum TEF values for each the 45° triangular V-ribs case are around 1.45, 1.50, 1.40 and 1.35 at PR=0.5, 1.0, 1.5 and 2.0, respectively

5. Conclusion

An experimental study has been conducted to examine an influence of the 45° triangular V-ribs inserted into a heating tube at several pitch ratios (PR= 0.5, 1.0, 1.5 and 2.0) on the Nu/Nu_0, f/f_0 and TEF characteristics. The following conclusions can be drawn in the present investigation.

The triangular V-ribs insert yields higher Nu/Nu_o rate up to 6.5, 5.8, 5.0 and 4.7 times above the plain tube, while gives f/f_0 up to 110, 70, 50 and 40 times at PR = 0.5, 1.0, 1.5 and 2.0, respectively.

The TEF is found to be higher than unity for all the 45° triangular V-ribs inserts. The maximum TEF for the 45° triangular V-ribs is found to be about 1.5 at PR = 1 and lower Re.

6. References

[1] Promvonge, P., Skullong, S., Kwankaomeng, S. and Thiangpong, C. (2012). Heat transfer in square duct fitted diagonally with angle-finned tape–Part 1: Experimental study, Int. Com-mun. Heat and Mass Transfer. 2012, pp. 617-624.

[2] Chandra, P.R., Alexander, C.R. and Han, J.C. (2003). Heat transfer and friction behaviour in rectangular channels with varying number of ribbed walls, Int. J. Heat Mass Transfer. vol.46, 2003, pp. 481–495.

[3] Han, J.C., Zhang, Y.M. and Lee, C.P. (1991). Augmented heat transfer in square channels with parallel, crossed and V-shaped angled ribs, ASME, Heat Transfer. Vol. 113, 1991, pp. 590–596.

[4] Chompookham, T., Thianpong, C., Kwankaomeng, S. and Promvonge, P. (2010). Heat transfer augmentation in a wedge-ribbed channel using winglet vortex generators, Int. Com-mun. in Heat and Mass Transfer. Vol. 37, 2010, pp. 163–169.

[5] V. Kongkaitpaiboon., K. Nanan. and S. Eiamsa-ard. (2010). Experimental investigation of convective heat transfer and pressure loss in a round tube fitted with circular-ring turbulators

Int. Com-mun. Heat Mass Transfer, Vol. 37, 2010, pp. 568–574.

[6] C. Thianpong., K. Yongsiri, K. Nanan. and S. Eiamsa-ard. (2012), Thermal performance evaluation of heat exchangers fitted with twisted-ring turbulators Int. Commun. Heat Mass Transfer, Vol.39, 2012, pp. 861–868.

[7] P.Promvonge.,S. Skullong., S.Kwankaomeng, and C. Thiangpong. (2012), Heat transfer in square duct fitted diagonally with angle-finned tape – part 1: experimental study Int. Com-mun. Heat Mass Transfer, Vol. 39(5), 2012, pp. 617–624.

[8] P. Promvonge.,S.Skullong., S.Kwankaomeng, and C. Thiangpong. (2012) Heat transfer in square duct fitted diagonally with angle-finned tape – part 2: numerical study Int. Com-mun. Heat Mass Transfer, Vol. 39(5), 2012, pp. 625–633.