The 5th TSME International Conference on Mechanical Engineering
17-19th December 2014, The Empress, Chiang Mai

TSF-113

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

Chotiwut Prasopsuk[1],Witoon Chingtuaythong[2], and PongjetPromvonge[2,*]

[1] Department of Mechanical Technology, Faculty of Industrial Technology,
ThepsatriRajabhat University, 321 Naraimaharat Road, Talaychubsorn, Lopburi, Thailand, 15000.
[2] Department of Mechanical Engineering, Faculty of Engineering,
King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, 10520.
*Corresponding Author: kppongje@kmitl.ac.th

Abstract

This paper 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 compare the thermal enhancement factor with smooth tube and insert the V-ribs.

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 heat transfer augmentation is a method to 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). An appropriate twisted tape modification is a challenge task as a proper design of twisted tape is a main key for heat transfer enhancement at a reasonable friction loss Promvonge [5] presents experimental study of the influence of conical-nozzle turbulator inserts on heat transfer and friction characteristics in a circular tube. The turbulators were placed in the test tube with two different types diverging and converging-nozzle arrangement with various pitch ratios, PR=2.0, 4.0, and 7.0. Promvonge [6] also investigated the effects of wires with square cross section forming a coil used as a turbulator on the heat transfer and turbulent flow friction characteristics and compared the experimental results with the results obtained from circular cross sectioned wire. Promvonge [7] again reported the employ of wire coil in conjunction with twisted tape for heat transfer augmentation in a tube. Bharadwaj et al. [8] examined the heat transfer and pressure drop in a spirally grooved tube with twisted tapes for laminar to turbulent regions.

A part from the above, there are other turbulator devices, such as baffles, ribs and fins that have been applied in heat exchanger tubes. However, in these groups, there are very few compared to twisted-tapes and wire coils. Therefore, the main aim of the present work is to investigate the influence of the V-baffled tape on heat transfer and flow friction in the tube heat exchangers. The V-baffled tape is a newly enhanced device invented and proposed for thermal performance improvement in a tube by a combination of the twisted-tape and the wire-coil merits.

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 hot-wire anemometer to measure flow velocities across the tube section. Manometer fluid was used in an inclined manometer with specific gravity of 0.826 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 Vari 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.

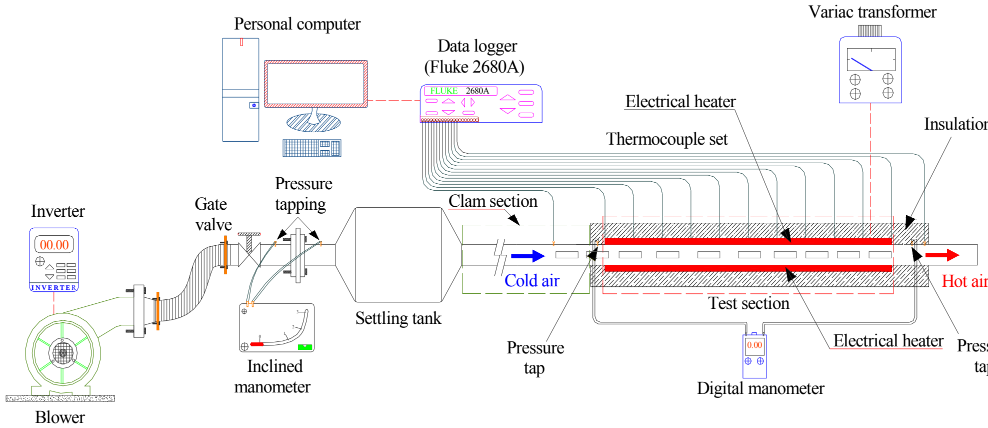

Figure 1. Schematic diagram of experimental apparatus.

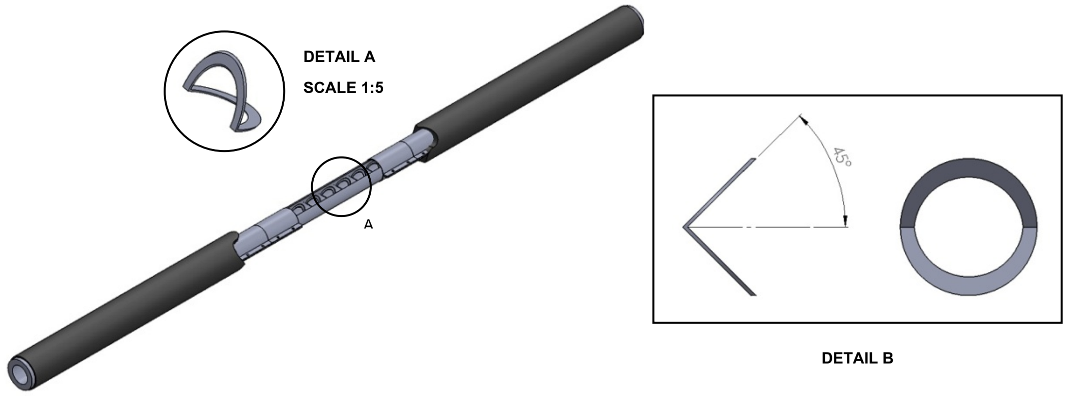

Figure 2. Test section with inclined baffles.

The detail of inclined baffles inserted into the heat exchanger square-duct is depicted in Figure 2. The tested duct made of 3 mm thick aluminum plates has a height of 45 mm (H) and a length of 1000 mm (L) while the inclined baffles have the blockage ratios (BR = e/H = 0.1, 0.15, 0.2) and 0.3 mm thickness with the attack angles (α) of 30°

3.Data Reduction

The average heat transfer coefficients are evaluated from the measured temperatures and heat inputs, with heat added uniformly to fluid (Q_{air}) and the temperature difference of surface and fluid ($\tilde{T}_s - T_b$), average heat transfer coefficient will be evaluated by:

$$Q_{air} = Q_{conv} = \dot{m}C_p(T_o - T_i)$$

$$h = Q_{conv} / \left(A\left(\tilde{T}_s - T_b\right)\right) \quad (1)$$

in which,

$$T_b = (T_o + T_i)/2 \text{ and } \tilde{T}_s = \sum T_s/28 \quad (2)$$

The term A is the convective heat transfer area of the heated wall whereas $\tilde{T}_s$ is the average surface temperature. Then, average Nusselt number based on the duct hydraulic diameter is written as:

$$Nu = hD_h/k \quad (3)$$

The friction factor is evaluated by:

$$f = 2\Delta P/\left((L/D_h)\rho U^2\right) \quad (4)$$

where ΔP is the pressure drop across the test section and U is the mean air velocity in the duct. The thermal enhancement factor (TEF) defined as the ratio of h of an augmented surface to that of a smooth surface, h_0, at a constant pumping power, Ref. [9], is written as

$$TEF = h/h_0\big|_{pp} = Nu/Nu_0\big|_{pp} = (Nu/Nu_0)(f/f_0)^{-1/3}$$

(5)

4. Result and Discussion

Heat Transfer

The effect of various baffles parameters on heat transfer is presented in the form of Nusselt number ratio, Nu/Nu_0, defined as a ratio of the augmented Nu to Nu_0 of smooth duct. Figure 3, displays the variation of Nu/Nu_0 with Re. It can be observed in the figure that the baffles provide a considerable Nu/Nu_0 increase with reducing PR, The Nu/Nu_0 shows a slightly decrease with the rise of Re. The baffles at BR=0.2 provides the maximum heat transfer rate because of highly interrupting the flow and promoting higher levels of vortex strength. The baffles with BR= 0.2, 0.15 and 0.1 yields the Nu/Nu0 of 1.91-2.51, 1.85-2.42, 1.73-2.27 times respectively.

Pressure Loss

The friction factor ratio, f/f_0, plotted against the Re is depicted in Figure 4, respectively. In the figure, it is visible that the f/f_0 tends to increase with the increment of Re. The baffles at BR=0.2 provides the highest f/f_0 because of higher flow blockage and larger surface area. The baffles with BR=0.2, 0.15 and 0.1 yields the f/f_0 of 4.31-5.40, 3.54-4.42, 2.81-3.52 times respectively.

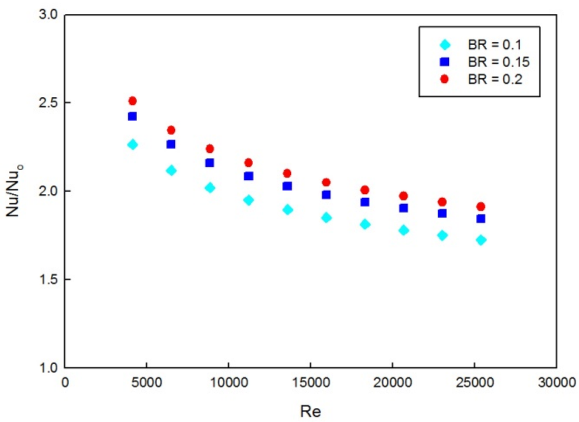

Figure 3. Variation of Nu/Nu_0

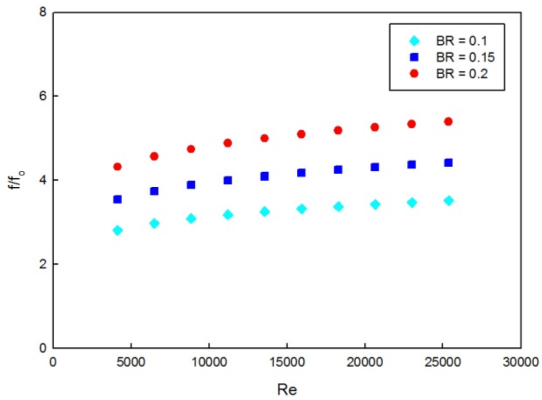

Figure 4. Variation of f/f_0

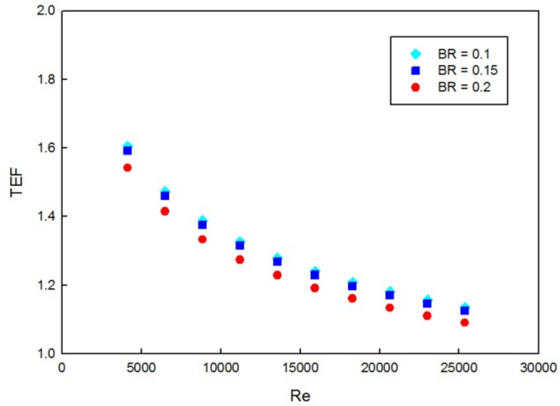

Figure 5. Variation of TEF with Re.

Thermal Enhancement factor (TEF)

Figure 5. shows the variation of the TEF with Re. For all, the data of Nu/Nu_0 and f/f_0 are compared at similar pumping power conditions. In the figure, the TEF tends to decrease with the rise of Re. It is seen that the baffles with BR=1.5 provides the TEF higher than the one with BR=0.1 for all cases at a similar attack angle. The optimum parameter of the present work are as BR=0.1 because at this point yields high value of Nu/Nu_0 while shows the lowest of f/f_0 value thus, provides the highest TEF of about 1.61 at the lowest Re.

5. Conclusion

An experimental study has been carried out to examine airflow friction and heat transfer characteristics in a uniform heat-fluxed square-duct fitted with baffles turbulators for the turbulent regime, Re from 4000-25,000. The use of baffles can induce vortex flows throughout the tested duct and provides better flow mixing than the smooth duct. The baffles turbulators yield a considerable increase in pressure drop and heat transfer over the smooth duct. The heat transfer rate and the flow friction increase with the increment of α and with decreasing the BR. The baffles at BR= 0.1 gives the highest heat transfer rate and pressure loss. Respectively, the Nu/Nu_0 and f/f_0 values for the baffles are found to be about 1.73-2.27 and 2.81-3.52 times over the smooth duct for all cases while the best operating regime is found at BR=0.1 which yields the maximum TEF of 1.61 at the lowest Re.

6. References

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