Heat and Fluid Flow Analysis over Different Tube Inserts in Concentric Tube Heat Exchanger: A Review

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Abstract— Concentric tube heat exchanger is an indirect contact type heat exchange as it consists of one pipe placed concentrically inside another one of larger pipe They are widely used in sensible heating and cooling of the process fluid where small heat transfer area are required. They may also be used for small amount of boiling or condensation on the process fluid side. Different type of tube inserts are very useful to increase the heat surface area, heat transfer performance, overall heat transfer coefficient, effectiveness of heat exchanger.

Key words: Heat Transfer, Plane & Twist Inserts, Overall Heat Transfer Coefficient, Effectiveness

I. INTRODUCTION

Heat exchanger is a device which transfers thermal energy from hot fluid to cold fluid with maximum rate and minimum investment and running cost. Typical heat exchangers experienced by us in our daily lives include condensers and evaporators used in air conditioning units and refrigerators. Boilers and condensers in thermal power plants are examples of large industrial heat exchangers. There are heat exchangers in our automobiles in the form of radiators and oil coolers.

II. concentric TUBE HEAT EXCHANGER

A typical concentric tube heat exchanger is shown in Figure 1. Essentially; it consists of one pipe placed inside another one of larger diameter pipe with appropriate end fittings on each pipe to guide the fluids from one section to the next. One fluid flow in inner pipe and another fluid flow in annulus between inner and outer pipe. Parallel and counter types of flow done in concentric tube heat exchanger. The inner pipe may have external longitudinal fins welded to it either internally or externally to increase the heat transfer area for the fluid with the lower heat transfer coefficient. Also apply the different typed of insert in inner tube to increase the heat transfer area and heat transfer rate.

III. LITERATURE REVIEW

Ta-Sung Huang, Pai-Hsiang Wang, Yu-Wei Chiu and Jiin-Yuh Jang [1]. Discussed for different kinds of tube inserts, including longitudinal strip inserts with/without holes and twisted-tape inserts with three different twist angles (α=15.3°, 24.4° and 34.3°). From the simulation results, It is found that the heat transfer coefficient and pressure drop of tube banks with strip inserts are 5~16% and 90~140% higher than those of tube banks without inserts. When strip inserts with holes are used, the heat transfer coefficient and pressure drop are 12~27% and 220~250% higher than those for tube banks without inserts. The heat transfer coefficient and pressure drop of tube banks with twisted tape inserts of α =15.3°, 24.4° and 34.3° are, respectively, 6~32% & 130~170%, 12~43% & 240~280%, and 25-61% & 290~330% higher than those of tube banks without inserts. The numerical results of heat transfer coefficient for strip inserts without/with holes and twisted-tape inserts agreed with the experimental data within 4.1%, 4.5% and 8.5%, respectively.

S. S. Joshi, V.M.Kriplani [2]. In this study the overall performance of suitably designed concentric tube heat exchanger is analyzed with passive heat transfer augmentation technique. In which different types of twisted tapes with different twist ratios are used. Find the effect of inserts on effectiveness of heat exchanger is analyzed for different Reynold Numbers. Simultaneously the friction factors for both inner and annular flow are analyzed. The heat transfer in the heat exchanger could be enhanced by using inserts and Tapes. Use of annular insert causes slight increase in heat transfer coefficient and effectiveness of heat exchanger. The Tape with more number of turns causes more turbulence which causes more heat transfer to occur. Hence the effectiveness of heat exchanger is more. As the number of turns reduce heat transfer rates reduces. As the number of turn’s increases, the heat transfer rate increases but increase in friction factor is observed.

Anil Singh Yadav[3].Influences of the half length twisted tape insertion on heat transfer and pressure drop characteristics in a U-bend double pipe heat exchanger have been studied experimentally. Show in Figure 2. The heat transfer coefficient is found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger.

V.N. Kapatkar, Dr. A. S. Padalkar and Sanjay Kasbe [4]. An experimental investigation of heat transfer and friction factor of a smooth tube fitted with full length twisted tape inserts for laminar flow have been studied under uniformwall heat flux condition. The tapes have twist ratios from 5.2 to 3.4. The isothermal friction factor for the flow with the twisted tape inserts are 340% to750 % higher as...
compared with those of smooth tube flow, in the given range of twist ratios.

Fig. 2: Flow Rate vs. Heat Transfer Coefficient.

Smith Eiamsa-ard, Chinaruk Thianpong and Pongjet Promvonge [5]. In the present study, a twisted-tape was inserted into the inner tube with various free spacing twisted-tapes: \( s = 2P, 3P, \) and \( 4P \), respectively. It is show that the free spacing twisted-tapes, \( s = 2P \) gives the heat transfer lower than full length twisted tape around 5-15% while it can be decreased the pressure drop around 90%.

Watcharin Noothong, Smith Eiamsa-ard and Pongjet Promvonge[6]. In the experiments, the swirling flow was introduced by using twisted tape placed inside the inner test tube of the heat exchanger with different twist ratios, \( y = 5.0 \) and 7.0. The maximum Nusselt numbers for using the enhancement devices with \( y = 5.0 \) and 7.0 are 188% and 159%, respectively, higher than that for the plain tube. In addition, the effects of the twisted tape on the heat transfer enhancement efficiency are also investigated.

P. Murugesan, K. Mayilsam, S. Suresh, P.S.S. Srinivasan [7] Experimental investigations of heat transfer and friction factor characteristics of circular tube fitted with full length twisted tape with trapezoidal -cut were studied for the Reynolds number range of 2000-12000 with trapezoidal -cut twisted tape for twist ratios 6.0 and 4.0. Result is heat transfer coefficient and friction factor increases with the decrease in twist ratio compared with plain tube. Trapezoidal -cut twisted tape for twist ratios 6.0 and 4.0 augment the heat transfer rate 27 and 41.8 % higher than the plain tube. Moreover, the performance ratio for trapezoidal- cut twisted tape is greater than one; therefore enhancement is competent in the point of energy savings.

Smith Eiamsa-ard, Chinaruk Thianpong and Pongjet Promvonge [8]In the experimental condition, a twisted-tape was inserted into the inner tube with various free spacing twisted-tapes: \( s = 2P, 3P, \) and \( 4P \), respectively. All of the experiments were carried out at the same inlet condition with the Reynolds number of the inner tube, \( Re=2300 \) to 7500.

From the experimental results the values of Nusselts number increase around 144% for the free spacing, \( s = 2P \), while used of twisted-tape insert into the inner tube leads to maximum Nusselt number around 157% over the plain tube for full length twisted-tape. Furthermore the Pressure drop of the regularly-spaced twisted tape could be reduced around 90-440% compared with the full length twisted-tape.

Warakorn Nerdnoi, Pritchaya Somravysin, Smith Eiamsa-ard [9]. The purpose of this study is to investigate heat transfer and pressure drop characteristics in a double pipe heat exchanger fitted with a helical-rod insert. The greatest improvement of heat transfer was found from helical-rod inserts where Nusselt numbers ranged from 150% to 160% comparison with the plain tube values at corresponding Reynolds numbers. It is shown that the pressure drop for the tube with the helical-rod insert is 6 to 9 times of those of the plain tube for the range of Reynolds numbers tested.

Smith Eiamsa-ard, Yuttana Ploychay, Somchai Sripattanapipat and Pongjet Promvong [10]. This paper provides heat transfer and friction factor data for single-phase flow in a double concentric tube heat exchanger fitted with a helical tape insert. In the double concentric tube heat exchanger, hot air was passed through the inner tube while the cold water was flowed through the annulus. The influences of the helical insert on heat transfer rate and friction factor were studied for counter flow. The result show that the increases in heat transfer and friction factor are strongly influence by swirling motion induced by the helical. As the Reynolds number increases, the swirling flow is stronger which in turn results in an increase in the heat transfer and friction factor while it decreases at low Reynolds number.

Smith Eiamsa-ard, Chinaruk Thianpong, Petpices Eiamsa-ard, Pongjet Promvonge [11]. The paper presents a comparative investigation of enhanced heat transfer and pressure loss by insertion of single twisted tape, full-length dual and regularly-spaced dual twisted tapes as swirl generators, in a round tube under axially uniform wall heat flux (UHF) conditions. The experiments are performed using single twisted tapes and full-length dual twisted tapes with three different twist ratios \( (y/w=3.0, 4.0 \) and 5.0) and also regularly-spaced dual twisted tapes with three different space ratios \( (s/D=0.75, 1.5 \) and 2.25). The following conclusions can be drawn.

1) The heat transfer rate for the dual twisted tapes is increased from 12% to 29% in comparison with the single one for \( y/w=3.0 \) to 5.0 by giving strongly dual swirling flows into the test tube. Depending on the flow conditions and twist ratio \( (y/w) \), the increases in heat transfer rate over the plain tube are about 146%, 135% and 128% for \( y/w=3.0, 4.0 \) and 5.0, respectively.

2) The use of the smaller space ratio \( (s/D=0.75) \) yields the highest heat transfer than the larger space ratio but lower than the full length tape \( (s/D=0.0) \). It is also found that at the small space ratio, \( s/D=0.75 \), there is a slight difference in heat transfer compared with the full-length tape \( (s/D=0.0) \).

3) The Nusselt numbers for the tube with dual twisted tape elements in tandem at \( s/D=0.0, 0.75, 1.5 \) and 2.25, are about 146%, 140%, 137% and 132% over the plain tube, respectively.

4) The friction factor from using the dual twisted tapes is found to increase up to 23% over the single twisted tape. The friction factor tends to decrease with the rise of Reynolds number and twist ratio values.

5) The smaller space ratio of the dual twisted tapes in tandem is more attractive in heat transfer application due to higher enhancement efficiency than the single one.
S. Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha, L. Shyam Sunder [12]. Enhancement of heat transfer using varying width twisted tape inserts with air as the working fluid. In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, reduced width twisted tapes of widths ranging from 10 mm to 22 mm. Experiments were carried out for plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. The twisted tapes are of three different twist ratios (3, 4 and 5) each with five different widths (26-full width, 22, 18, 14 and 10 mm) respectively. The Reynolds number varied from 6000 to 13500. Both heat transfer coefficient and pressure drop are calculated and the results are compared with those of plain tube. The following conclusions can be drawn:

1) The enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width and 33 to 39% for reduced width–22 mm inserts. This enhancement is mainly due to the centrifugal forces, resulting from the spiral motion of the fluid.

2) Reduction in tape width causes reduction in Nusselt numbers as well as friction factors. The maximum friction factor rise was about 18% for 26mm and only 17.3% for reduced width inserts compared to plain tube.

3) The overall enhancement ratio of the tubes with full width twisted tape inserts is 1.62 for full width – 26mm and 1.39 for reduced width–22 mm twisted tape insert. 61% material savings could be obtained for reduced width–22 mm and the performance is 1.32–1.39 times compared to plain tube.

HONG Mengna, DENG Xianhe, HUANG Kuo and LI Zhiwu [13]. Pressure drop and compound heat transfer characteristics of a converging-diverging tube with evenly spaced twisted-tapes (CD-T tube) have been investigated experimentally. The results show that the twisted-tape with twist ratio γ = 4.72 and rotation angle θ =180° has the best performance among the four types of twisted-tapes presented in this paper. At Reynolds number ranging from 3400 to 20000, when space ratio s = 48.6, the heat transfer efficiency index which increases as the Reynolds number increases, is 0.85–1.21 and 1.07–1.15 compared to that of a smooth circular tube and a CD tube without twisted-tape inserts respectively.

B. Silapakijwongkul, S. Eiamsa-arad and P. Promvonge [14]. In this work, effect of the tapes twisted in clockwise and counterclockwise arrangement (C-CC arrangement) on heat transfer and friction factor characteristics in a double pipe heat exchanger was investigated experimentally. The experiments were undertaken for the Reynolds number range of 2200 to 11500 and for several twisted-tape pitch ratios, PR = 0.4, 0.6 and 0.8. It can be concluded as follows:

1) It was observed that the twisted-tape inserts with clockwise and counter-clockwise (C-CC) caused turbulence/swirl flow into the tube and leaded to high heat transfer rate of 219% over the plain tube.

2) It can be seen that use of the twisted-tape with C-CC arrangement results in the increase in friction considerably around 5-10% above the original twisted tape.

REFERENCES


Paisarn Naphon [15]. The heat transfer characteristics and the pressure drop of the horizontal double pipe with coil-wire insert are investigated. The effect of the coil pitch and relevant parameters on heat transfer characteristics and pressure drop are considered. It can be seen that the heat transfer rate and heat transfer coefficient depend directly on the mass flow rates of hot and cold water. Effect of coil-wire insert on the enhancement of heat transfer tends to decrease as Reynolds number increases.

IV. CONCLUSION

Concentric tube heat exchangers are mainly use in food industries. For increase heat transfer rate, effectiveness and reduced size of Concentric tube heat exchanger with different tube insert increase the heat transfer surface area. From literature review it can be concluded that

1) Different kinds of tube inserts, including longitudinal strip inserts with/without holes and twisted-tape inserts with different twist angles, half length twisted tape, regularly spaced twisted tapes, trapezoidal cut twisted tape are used in concentric tube heat exchanger and find out the heat transfer area increased effectiveness of heat exchanger increased and size of heat exchanger is reduced.

2) Also optimize the single twisted tape, full length dual twisted tapes and regularly spaced dual twisted tapes when surface area increased the heat transfer increased compared to plain tube.

3) Investigate clockwise and counterclockwise twisted tape turbulators on heat transfer and observed that the twisted-tape inserts with clockwise and counter-clockwise (C-CC) caused turbulence/swirl flow into the tube and leaded to high heat transfer rate of over the plain tube.
Investigations of Heat Transfer and Pressure Drop Characteristics of Flow through Circular Tube Fitted with Regularly-spaced Twisted Tape. King Mongkut’s Institute of Technology Ladkrabang, Thailand


