

A Review On Modern Techniques Of Heat Transfer Enhancement In Circular Tube

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Abstract

In the recent years, high expenditure of energy and material accessibility has resulted in increased efforts, aimed at producing more capable heat exchange devices. Heat exchangers are widely used in several industries, such as thermal power plants, air conditioning equipment, chemical processing plants, refrigerators, radiators for space vehicles as well as automobiles etc. The design of heat exchanger needs a consideration of different modes of heat transfer, pressure drop, sizing, long period performance evaluation as well as financial aspect. The present paper is a review of research work of modern techniques in heat transfer enhancement. Many researchers have used various techniques to enhance heat transfer. Worldwide energy utilize is projected to increase by almost 1.6 times, from 4.03×10^{20} J in 1999 to 6.4×10^{20} J in 2020. Hence, if the effectiveness of energy usage could enhance by 10 per cent, by means of various heat transfer enhancement techniques, this will result in 6.4×10^{19} J of benefit in terms of energy utilization to the society. In present paper importance is given on different techniques of heat transfer enhancement, developed in recent times.

Keywords: heat transfer, enhancement, heat exchanger, etc

Introduction

Conventional resources of energy are depleting at an alarming rate, which makes future sustainable growth of energy extremely complicated. As a result, significant importance has been placed on the development of various augmented heat transfer surfaces and devices. The study of improved heat transfer performance is referred to as heat transfer enrichment, augmentation or intensification. In general, this means an increase in heat transfer coefficient. Energy and materials-saving considerations, as well as financial incentives, have led to efforts to produce more capable heat exchange devices. General thermal-hydraulic goals are to decrease the size of a heat exchanger needed for a specified heat duty, to advance the capacity of an existing heat exchanger, to reduce the approach temperature difference for the process streams, or to reduce the pumping power.

Applications of Heat Transfer Enhancement

All the industries in the world are under financial pressure to increase the energy efficiency of their processing plants to compete in today's global market. Hence, these industries must spend in inventive thermal technologies that would considerably reduce unit energy utilization in order to reduce overall cost. Important applications of heat transfer enhancement are listed below:

1. Automotive Industries
2. Heating, Ventilating, Refrigeration and air conditioning
3. Process Industries
4. Power sector
5. Industrial Heat Recovery
6. Aerospace and others.

Literature Review

Veeresh Fuskele et al. [1] performed the experimental work on heat transfer enhancement in double pipe heat exchanger using a new type of insert called twisted wire mesh. With introduction of insert in a path of flow of liquid, high degree of turbulence is created which results into increase heat transfer rate as well as pressure drop. The author determine the heat transfer coefficient and friction factor for two different twisted wire mesh type insert having twist ratio $y=5$ & $y=7$ as shown in fig.1. In order to validate experiment result, standard correlation of heat transfer were used. The results obtained from experimentation for twisted wire mesh having different twist ratio have compared with result of smooth plain tube. It is found that, for twisted mesh type insert friction factor increased to 4.0 to 4.3 times and heat transfer coefficient increased from 1.69 to 2.09 times as compare to smooth tube value. In addition, Researcher also investigated the effect of new wire mesh type of insert on heat transfer enhancement efficiency. The results obtained leads to conclusion that with insertion of insert, heat transfer rate increase with reasonable pressure drop.

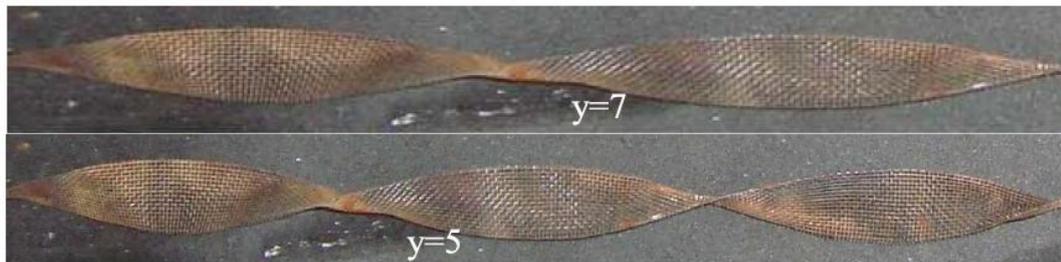


Fig.1:- twisted wire mesh type insert having twist ratio $y=5$ & $y=7$ [1]

Shrirao et al. [2] performed investigation of the mean Nusselt number, friction factor and thermal augmentation factor characteristics in a circular tube with different types of internal threads of 120 mm pitch under uniform wall heat flux boundary conditions. In the performance, with air as the test fluid, measured data are taken at Reynolds number in range of 7,000 to 14,000. The performance was carried out on circular tube with three different types of inner threads viz. acme, buttress and knuckle threads of constant pitch. Results shows Fig.1 shows test tube with inner threads. Mean Nusselt numbers for test tubes with inner threads such as buttress, acme and knuckle threads are 1.46, 1.30 and 1.19 times better than that for the plain tube. The thermal augmentation factors are in a range between, 1.12 - 1.04, 1.1 - 1.03 and 1.08 - 1.02 respectively for the test tubes with buttress, acme and knuckle threads. Fig.3 shows the variation of enrichment ratio with Reynolds Number.

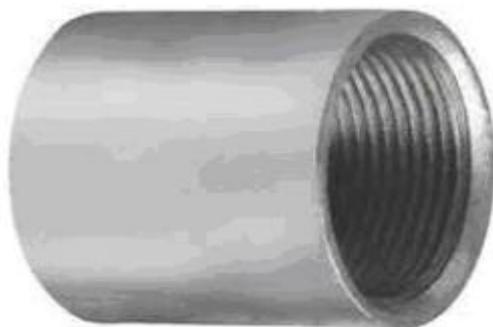


Fig.2:- test tube with inner threads [2]

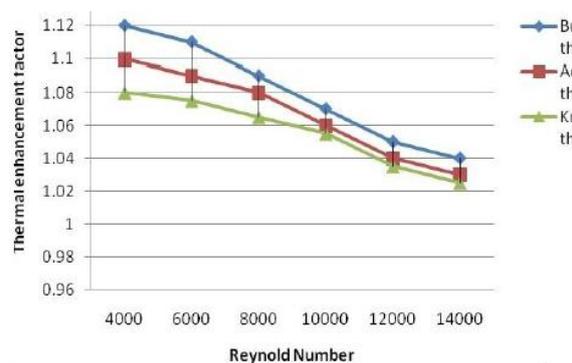


Fig.3 variation of enrichment ratio with Re No.[2]

N. A. Lokhande et al. [3] performed experimental investigation in order to study the effect of conical spring inserts in circular tube on heat transfer enhancement and friction factor. The heat transfer in tube with conical spring inserts is found to be more as compared to smooth tube. The increase in heat transfer coefficients of water is 54.63% higher for conical spring inserts. The increase in heat transfer occurs because more turbulence is generated within the tube by using different shaped of inserts as compared to without using inserts. As the Reynolds number increase the friction factor will be reduced. With increase of Reynolds number, velocity is also increases and the friction factor is inversely proportional to

the velocity and hence it decreases. In smooth tube less friction factor is obtained as compared to conical spring inserts. In conical spring, when number of inserts is used more than 4, more friction factor is obtained in tube which gives more heat transfer coefficient. Percentage increase in average values of heat transfer coefficient of inserts as compared to smooth tube without using any inserts is given in fig 5.

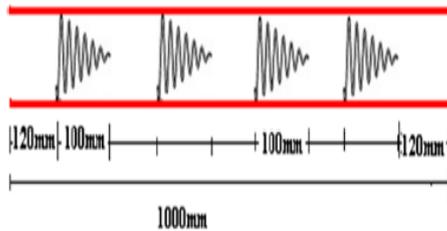


Fig.4:- conical convergent spring inserts in tube [3]

Sr. no	Arrangement	Avg. heat transfer coefficient	Increase % of heat transfer coefficient
1	Without using any inserts	2876.35	-----
2	Conical spring inserts	6340.05	54.63

Fig.5 Comparison of heat transfer enhancement [3]

Li Zhang et al. [4] performed the experimentation in order to advance heat transfer performance of shell side of double-pipe heat exchanger with helical protrusion on its inner tube, some vortex generators (VGs) were installed along the centreline of the helical channel. With air as the operational fluid and steam as the heating medium, Heat transfer performance and pressure drop attribute of the enhanced heat exchangers were investigated by author. Winglet-type VGs (delta or rectangular winglet pair) and Wing-type VGs (delta or rectangular wing) were used to combine with helical fins. Nusselt number and the friction factor can be well related by power-law correlations in the Reynolds number range studied. In order to estimate the thermal performance of the shell side enhanced over the shell side without enhancement, Comparisons were made under three constraints: (1) identical pressure drop, IPD (2) identical mass flow rate, IMF; and (3) identical pumping power, IPP. The outcomes show the shell side improved by the compound heat transfer enhancement has better performance than the shell side only enhanced by helical fins at shorter helical pitch under this three assumptions.

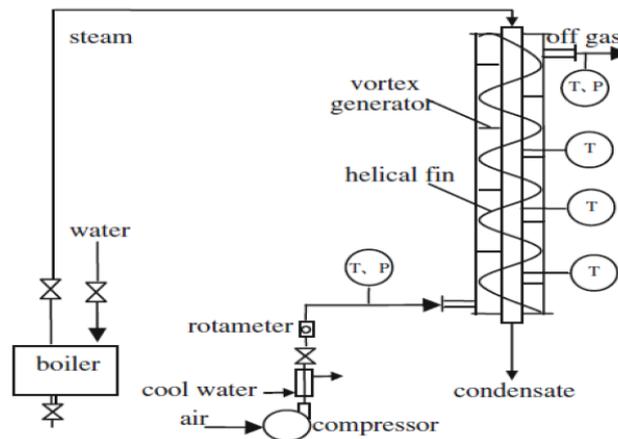


Fig.6 Schematic diagram of the experimental system for helical fin [4]

Sarada et al. [5] has done experimental study of the escalation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. In order to reduce extreme pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, compact width twisted tapes of widths ranging from 10 mm to 22 mm, which are lesser than the tube inside diameter of 27.5 mm are used. Performance was 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, 22, 18, 14 and 10 mm) correspondingly. The Reynolds number varied from 6000 to 13500. Both pressure drop and heat transfer coefficient are calculated and the outcome is compared with those of plain tube. It was found that the augmentation of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for 26mm width

and 33 to 39% for reduced 22 mm width inserts. highest friction factor grow was about 18% for 26 mm and only 17.3% for 22 mm width inserts compared to plain tube Fig.7 shows photo varying width twisted tape.



Fig.7 varying width twisted tape [5]

Jadoaa et al. [6] studied the result of drilling of the cut conical ring turbulator (with constant ring to tube diameter ratio) and space ratio on rate of heat transfer, friction factor, and augmentation efficiency under ranging of Reynolds number from 5000 to 23500. In addition, correlation for Nusselt number, friction factor and performance estimate criteria to assess the real benefits in using the drilled-conical ring turbulator of the enhanced tube are determined. Fig.8 shows Geometry of Drilled Conical-Ring turbulator. The outcome show that the process of drilling of the conical ring within tube gives elevated rates of heat transfer more than that in the conical ring without drilling. Fig.9 shows Variation of Enhancement Efficiency with Reynolds Number. Based on the experiment data of the tube fitted with drilled conical ring, Nusselt number, friction factor and enhancement efficiency correlations are derived in the following forms, respectively, $Nu=1.725 \times Re^{0.891} \times (d/D)^{-1.012} \times (s/D)^{0.011}$, $Cf = 18Re^{-0.11} \times (d/D)^{-1.11} \times (s/D)^{-0.121}$, $\mu = 9.987 \times Re^{-0.112} \times (d/D)^{-0.0121}$

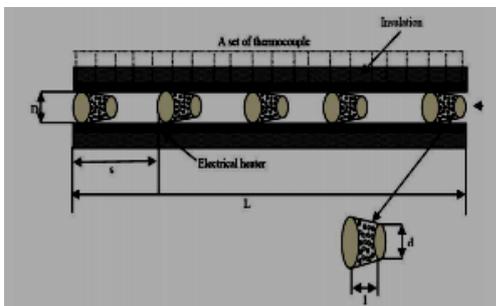


Fig.8 Drilled Conical-Ring Turbulator [6]

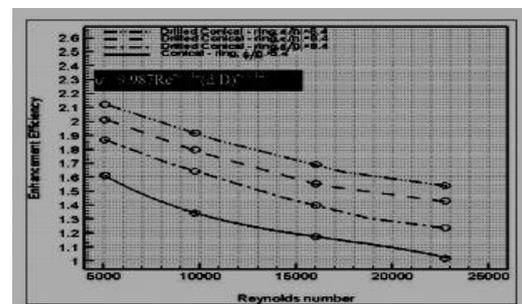


Fig.9 Variation of Enhancement Efficiency with Re No. [6]

Haydar Eren et al. [7] experimentally carried out the heat transfer Characteristics of circular coil-spring turbulator. These results were parameterized by Reynolds numbers in the ranges from 2500 to 1200, outer diameters of the springs ($D_s=7.2$ mm, 9.5 mm, 12mm, and 13 mm), numbers of the springs and the springs inclination ($\theta=0$ deg, 7 deg, and 10 deg). Author observed that as compare to results of a smooth empty tube increasing spring number, spring diameter, and springs inclination result increases on heat transfer whereas Friction factor increases 40–80 times for a smooth tube. For the least incline angle of the springs $\theta=0$ deg heat transfer and friction factor have the least values, while for $\theta=10$ deg the heat transfer and friction factor have the maximum values. If incline angle consider as design parameter, it has the dominant effect on heat transfer and friction loss while spring number has the weakest effect.

Sarada, et al. [8] performed numerical and experimental investigations of the enhancement of turbulent flow heat transfer in a horizontal circular tube by means of mesh inserts with air as the working fluid. Experimentation were carried out by sixteen types of mesh inserts with screen diameters of 22 mm, 18 mm, 14 mm and 10 mm for variable distance between the screens of 50 mm, 100 mm, 150 mm and 200 mm in the porosity range of 99.73 to 99.98 . The horizontal tube was subjected to uniform and constant heat flux for which Reynolds number varied from 7,000 to 14,000. Fig.10 shows Porous Medium manufactured from Copper Screens. The highest Nusselt number obtained at least pitch (2.5 mm) of

bigger mesh diameter (26mm) using CFD analysis is 2.15 times that of plain tube. The maximum increase in Nusselt number and pressure drop approximately 1.86 and 1.23 times was obtained through experimental examination than plain tube for $R_p = 0.8$ with the distance between screens equal to 50 mm. Fig.11 shows variation of Nusselt number with Reynolds number.

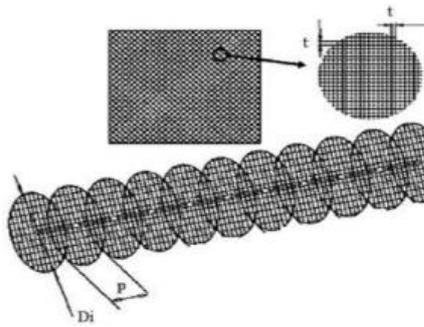


Fig.10 Porous Medium Copper Screens [8]

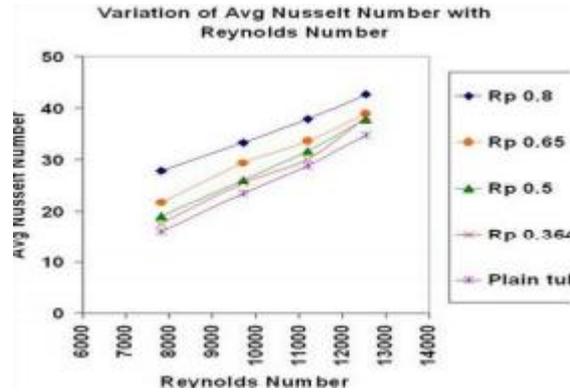


Fig.11 Variation of Nusselt number with Reynolds Number [8]

Sarada, et al. [9] examined the heat transfer augmentation by square leaf inserts. Overall augmentation ratio is observed highest for BW insert. The maximum overall improvement ratios for 300 BW, 600BW and 900 BW, 300 FW, 600 FW inserts are 1.30, 1.32, 1.34, 1.02 and 0.79 respectively. Although Nusselt number increases with respect to plain tube is less for 600 BW insert compared to that of 900 insert, as the obstacle to air flow is less in this case, it might have caused the increase of overall augmentation ratio. Fig.12 shows Louvered Square Leaf Inserts 300 BW, 600 BW and 900, 300 FW, 600. Nusselt number increased by a maximum of 128.39, 121, 81.31, 30.03 and 32.72 % in the presence of 900, 600 forward, 600 backward, 300 forward, 300 backward square leaf inserts respectively whereas Friction factor increased by a maximum of 441.31, 369.17, 143.43, 116.48 and 80.39% in the presence of 900, 600 forward, 600 backward, 300 forward, 300 backward square leaf inserts respectively. Fig.13 shows variation of enhancement ratio with Reynolds number.



Fig.12 Louvered Square Leaf Inserts [9]

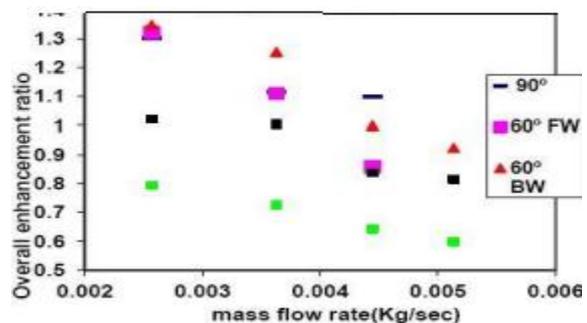


Fig.13 variation of enhancement ratio with Re no. [9]

P. Bharadwaj et al. [10] investigate experimentally determined pressure drop and heat transfer characteristics of flow of water for Laminar to fully turbulent ranges in a 75-start spirally grooved tube with twisted tape insert. For experimentation author considered flow ranges from Laminar to turbulent region. The grooves were clockwise with respect to the direction of flow and compared to smooth tube, the heat transfer enhancement due to spiral grooves is further increased by inserting twisted tapes having twist ratios $Y = 10.15, 7.95$ and 3.4 . Researcher concluded that smooth

tube shows that the spirally grooved tube without twisted tape yields maximum heat transfer enrichment in the laminar range than the turbulent range. Spirally grooved tube with twisted tape shows maximum improvement in the laminar range than the turbulent range. Among the three twist ratios ($Y = 10.15, 7.95$ and 3.4) tested, heat transfer performance of clockwise twisted tape with $Y = 7.95$ is found to be the maximum at in laminar, transitional and turbulent ranges of Reynolds numbers.

Smith Eiamsa et al. [11] studied influence of helical tapes insert in a tube on heat transfer enhancement experimentally. The maximum Nusselt number may be increased by 160% for the full-length helical tape with centered-rod, 150% for the full length helical tape without rod and 145% for the regularly-spaced helical tape, $s = 0.5$, in comparison with the plain tube.

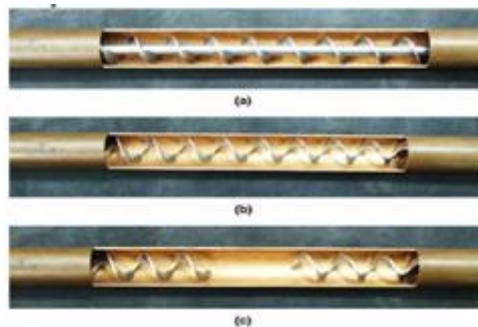


Fig.14 various configuration of helical insert [11]

Wand and Suden et al. [12] discussed the comparison of wire coil inserts and twisted tape in their work. It was observed and noted that to disturb the central core flow the twisted tapes are the solution but if peripheral annular flow is to be mixed with core flow the wire coil inserts perform better. In context with heat transfer rate they have concluded that twisted tape perform better than the wire coil inserts. In process industries the fluids used have high density because of high viscosity and dirt and thus they need high pumping power. In such cases the pumping power is the important element and is drive to put constraints on selection of passive device. When pumping power is an issue pressure drop adds limitation on type of insert, as twisted tape cause more pressure drop than wire coil inserts. To analyze such involvement of pressure drop in the heat transfer enhancement many of researchers have introduced a term 'Overall enhancement efficiency' to predict the performance of an insert. It counts positive effect of heat transfer improvement and negative effect of pressure drop rise.

P. Naphon, P. Sriromrull et al. [13] performed experimentation on micro fin tubes with coiled wire inserts. The heat transfer characteristics and the pressure drop of the horizontal double pipes with and without coiled wire insert were tested. The inner and outer diameters of the micro-fin tube were 8.92 and 9.52 mm, respectively. The coiled wire was made-up by bending a 1-mm-diameter iron wire into the coil wire with coil diameter of 7.80 mm. Cold and hot water were used as running fluids in shell side and tube side, respectively. The test runs were carried out at the cold and hot water mass flow rates ranging between 0.01 and 0.07 kg/s and between 0.04 and 0.08 kg/s, respectively. The inlet cold and hot water temperatures were between 15 and 20 °C and between 40 and 45 °C, respectively. The results obtained from the micro-fin tube with coiled wire insert were compared with those obtained from the smooth and micro fin tubes. Author concluded that the coiled wire insert had a considerable effect on the enhancement of heat transfer. However, the friction

factor of the tube with the coiled wire insert also increases. Author also stated that wire coil effectiveness is in inverse proportion with Reynolds Number.

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