Heat Transfer Characteristics using Inserts in Tubes: A Review

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Abstrac—**Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer augmentation techniques are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. this paper contains literature survey which provides enhancement techniques in heat transfer using inserts.**

Keywords: Heat transfer enhancement, passive method, wire coil, twisted tape

I. INTRODUCTION

Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer augmentation techniques refer to different methods used to increase these techniques and broadly divided in two groups, passive and active. Active techniques involve some external power input for the enhancement of heat transfer.

Passive heat transfer augmentation method does not use any external power input. The passive methods are based on the principle, one of the way to enhance heat transfer rate, is to increase the effective surface area and residence time of the heat transfer fluid. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system. Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer rate.

II. DIFFERENT METHODS OF HEAT TRANSFER ENHANCEMENT

Active method: This method involves some external power input for the enhancement of heat transfer; some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc.

Passive method: Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system. Following Methods are generally used,

1. Inserts
2. Extended surface
3. Surface modifications
4. Use of additives.

Inserts:

Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer.
Different types of inserts are:

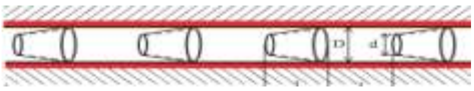
1. Twisted tape and wire coils
2. Ribs, Baffles, plates

III. REVIEW OF WORK CARRIED OUT

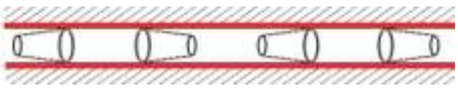
Alberto Garcia et al., [1] experimental studied on three wire coils of different pitch inserted in a smooth tube in laminar and transition regimes. Heat transfer experiments had been performed in the flow ranges: Re=10–2500; Pr = 200–700.It concluded that at Reynolds numbers below 200, wire coils do not enhance heat transfer. For Reynolds numbers between 200 and 1000 wire coils increase heat transfer. At Reynolds number around 1000, wire inserts increase the heat transfer coefficient up to eight times with respect to the smooth tube. The friction factor increases in the fully laminar region lie between 5% and 40%.

P. Promvonge [2] investigated the effects of the conical ring turbulator inserts on the heat transfer rate and friction factor on several conical rings used as turbulators were mounted over the test tube. Conical rings with three different diameter ratios of the ring to tube diameter (d/D = 0.5, 0.6, 0.7) were introduced in the tests, and for each ratio, the rings were placed with three different arrangements (converging conical ring, referred to as CR array, diverging conical ring, DR array and converging–diverging conical ring, CDR array). It was used as cold air at ambient condition for Reynolds numbers in a range of 6000–26,000. It was concluded that conical ring inserts to a higher heat transfer rate than that of the plain surface tube, and the DR array yields a better heat transfer than the others. The enhancement efficiency increases with decreasing Reynolds number and diameter ratio. The effects of using the conical ring causes a substantial increase in friction factor.

(a)DR array



(b)CR array



(c)CDR array

Fig 1: Test tube fitted with various conical ring arrays.

Bodius Salam et al., [3] had experimentally investigated heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut twisted tape insert. A stainless steel rectangular-cut twisted tape insert of 5.25 twist ratio was inserted into the smooth tube and the Reynolds numbers were varied in the range 10000-19000. They concluded that the Nusselt number increased with the increase of Reynolds number. An average of 68% enhancement of heat flux was observed for tube with rectangular-cut twisted tape insert than that of smooth tube. The experimental Friction factors with inserts were found to be 39% to 80% higher than Friction factor for smooth tube values. Heat transfer enhancement efficiencies were found to be in the range of 1.9 to 2.3 and increased with the increase of Reynolds number.

Fig 2: Twisted tape inserts.

P. Sivashanmugam, S. Suresh [4] had studied experimental investigation of heat transfer of water for laminar flow in circular tube fitted with full-length helical screw element of different twist ratio, increasing and decreasing order of twist ratio and it was compared with plain tube. They concluded that the heat transfer coefficient increases with the twist ratio and friction factor also increases with the twist ratio. There was no much change in the magnitude of heat transfer coefficient with decreasing twist ratio and with increasing twist ratio.

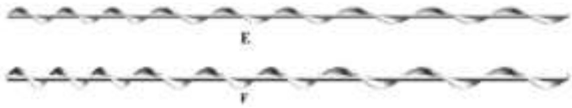


Fig 3: Helical screw inserts of increasing twist ratio.

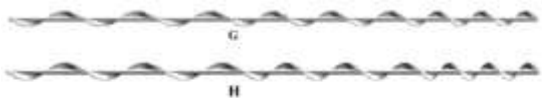


Fig 4: Helical screw inserts decreasing twist ratio.

P. Bharadwaj et al., [5] their aim was to 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. They had been considered Laminar to fully turbulent ranges of Reynolds numbers. 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 augmented by inserting twisted tapes having twist ratios Y =10.15, 7.95 and 3.4. They concluded that smooth tube shows that the spirally grooved tube without twisted tape yields maximum heat transfer enhancement in the laminar range than the turbulent range. Spirally grooved tube with twisted tape shows maximum enhancement 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 highest at in laminar, transitional and turbulent ranges of Reynolds numbers.

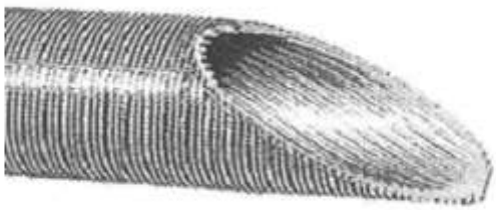


Fig 5: 75-start grooved tube.

Haydar Eren et al., [6] experimentally studied the heat transfer Characteristics of circular coil-spring turbulators. These results were parametrized by Reynolds numbers in the range of 2500 < Re < 1200, outer diameters of the springs (Ds=7.2 mm, 9.5 mm, 12mm, and 13 mm), numbers of the springs and the incline angles of the springs (Ø=0 deg, 7 deg, and 10 deg). They concluded that increasing spring number, spring diameter, and incline angle result increases on heat transfer, comparatively 1.5–2.5 times of the results of a smooth empty tube. Friction factor increases 40–80 times for a smooth tube. For the smallest incline angle of the springs Ø =0 deg heat transfer and friction factor have the lowest values, while for Ø =10 deg the heat transfer and friction factor have the highest values. If consider the design parameter, the incline angle has the dominant effect on heat transfer and friction loss while spring number has the weakest effect.

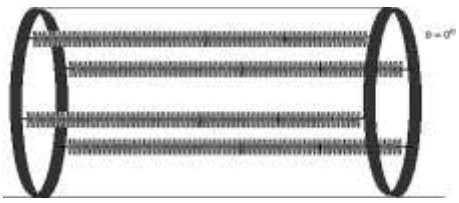


Fig 6: Dimensions of the springs

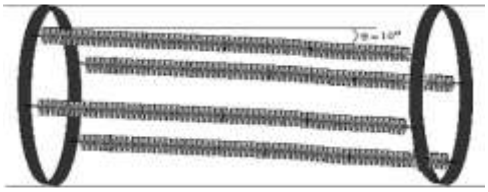


Fig 7: Incline angle of the springs

Naga Sarade S et al., [7] experimentally investigated of the augmentation of turbulent flow heat transfer in a horizontal tube by means of mesh inserts with air as the working fluid and it was compared with plain tube. Sixteen types of mesh inserts with screen diameter of 22mm, 18mm, 14mm and 10mm for varying distance between the screens in porosity range of 99.73 to 99.98 were considered for experimentation. The Reynolds number was varied from 7000 to 14000. They concluded that enhancement of heat transfer by using mesh insert s when compared to plain tube at same mass flow rate was more by factor of 2 times. As the mesh diameter decreases turbulence created in the tube decreases causing an increase in surface temperature. As Reynold's number increases higher heat transfer rates were observed. The increase in pressure drops by increasing ratio of porous material.

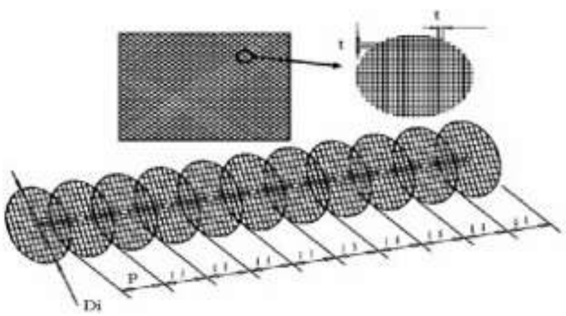


Fig 8: Mesh inserts

Ahmet Tandiroglu [8] aimed at studying the effect of the flow geometry parameters on transient forced convection heat transfer for turbulent flow in circular tube with baffle inserts. The characteristic parameter of the tubes was different range of pitch to inlet diameter ratio H/D=1, 2, 3and the baffle orientation angle β=45^0, 90^0 and 180^0. Air was used as working fluid in the range of Reynold's number 3000 to 20,000. It was varied different geometrical parameter such as baffle spacing H and the baffle orientation angel β. It was conclude that the tubes with baffle inserts give higher heat transfer rate than smooth tube. The time averaged Nusselt number increases with increasing Reynolds number. The rate of pressure drop increases with increasing Reynolds number for transient flow conditions but decreases with increasing Reynolds number for the steady state flow conditions. The rate of average pressure drop in the baffle inserted tubes for transient flow conditions was higher than that of steady state flow conditions.

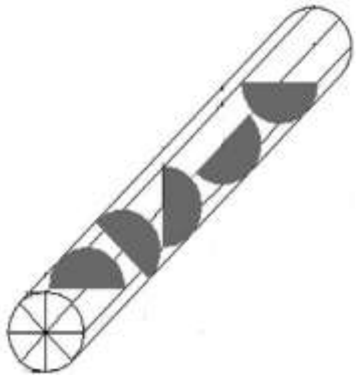


Fig 9: 45^0 half circle baffled tubes.

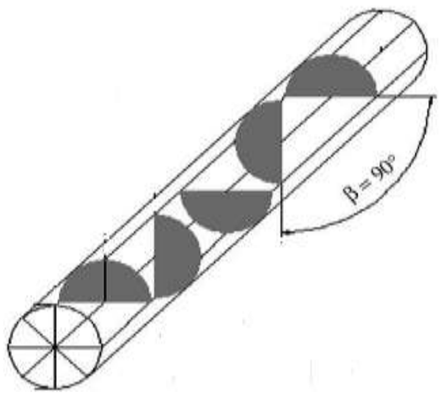


Fig 10: 90^0 half circle baffled tubes.

Watcharin Noothong et at.,[9] had experimentally investigated the enhancement of the heat transfer and friction factor characteristics of heat exchanger in the concentric double tube Plexiglas materialed heat exchanger. Cold water as annulus and hot air as inner fluid used as working fluid. 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 and 7 were inserted. They concluded that the efficiency and Nusselt number increases with decreasing the twist ratio and friction factor increases with decreasing the twist ratio. It can be observed that the swirl flow helps decrease the boundary layer thickness of the hot air flow and increase residence time of hot air in the inner tube. Secondary fluid motion was generated by the tape twist and the resulting twist mixing improves the convection heat transfer.

S.S.Joshi and V.M.Kriplani [10] experimentally studied of heat transfer in concentric tube heat exchanger with inner twisted tape and annular insert in the double pipe heat exchanger, different types of twisted tapes with different twist ratios were used. Effect of inserts on effectiveness of heat exchanger was analyzed for different Reynolds Numbers. Annular protrusions were used to augment the heat transfer by creating turbulence in the fluid flow. They conclude that 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 as well as effectiveness of heat exchanger was more. As the number of turns reduce heat transfer rates reduces. Increase in friction factor as the number of turn increases.

Fig 11: Full length tape in tube

Fig 12: Tape with attached baffle

CONCLUSION:

From this review, various ways of enhancing the heat transfer rate by generating the swirl flow by active or passive method can be observed by using various types of inserts. In a twisted type insets, heat transfer rate increases a plain tube used sbecause twisted type tube insert increase the turbulence of the flow. Also in a twisted type insets the pressure drop increases. In conical ring inserts, heat transfer rate is higher than that of the plain surface tube and increases the frication factor. In a wire inserts, the friction factor increases in the fully laminar region and increase the heat transfer coefficient with respect to the smooth tube. In mesh insert, increases in pressure drop by increasing ratio of porous material and enhancement of heat transfer rate when compared to plain tube. In a baffle insert, the rate of pressure drop increases with increasing Reynolds number for transient flow conditions.

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