Heat Transfer Characteristics using inserts in Tubes: A Review

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Abstract— Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Experiments were carried out for plain tube with/without wavy twisted tape insert at constant wall heat flux and different mass flow rates. The objective of this Project work is to analyses the heat transfer coefficient by using conical inserts and helical inserts with different arrangement in tubes. 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.

Key words: Heat Transfer Enhancement, Passive Method, Wire Coil, Circular Tubes

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. To improve the performance of heat exchanging devices for reducing material cost and surface area and decreasing the difference for heat transfer thereby for reducing external irreversibility, lot of techniques have been used. Among different passive means to increase heat transfer coefficient various types of inserts are promising.

Heat transfer augmentation technique refer to different methods used to increase these techniques. In general, the enhancement techniques can be divided into two main groups: active and passive techniques. The active techniques require external forces, e.g. electric field, acoustic, and surface vibration. The passive techniques require special surface geometries such as roughness surface, treated surface and extended surface or fluid.

Among many techniques (both passive and active) investigated for augmentation of heat transfer rates inside circular tubes, a wide range of inserts have been utilized, particularly when turbulent flow is considered. A lot of methods are applied to increase thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tube.

II. DIFFERENT METHODS OF HEAT TRANSFER ENHANCEMENT

A. Active Techniques:

This method involves some external power input for the enhancement of heat transfer and has not shown much potential owing to complexity in design. Furthermore, external power is not easy to provide in several applications. Some examples of active methods are induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc.

B. Passive Techniques:

These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behaviour (except for extended surfaces) which also leads to increase in the pressure drop. Passive heat transfer augmentation methods as stated earlier does not need any external power input. The passive methods are based on the same principle. use of this technique causes disturb 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 use.

1. Inserts 2. Extended Surface 3. Surface Modifications 4. Use of Additives

1) 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:

- Twisted tape and wire coils
- Ribs, Baffles, plates

2) Extended Surface:

In the study of heat transfer, a extended surfaces that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers.

III. LITERATURE SURVEY

A. Bodius Salam Et Al:

[1] 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.

B. Bharadwaj Et Al:

[2] 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. 1: 75-Start Grooved Tube](image)

**C. Alberto Garcia Et Al:**

[3] Experimentally studied on three wire coils of different pitch inserted in 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 number below 200, wire coils do not enhance heat transfer for Reynolds number 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 increase in the fully laminar region lie between 5% and 40%.

**D. Ahmet Tandiroglu:**

[4] Studied 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 $H/D=1, 2, 3$ and the baffle orientation angle $\beta=450, 900$ and $1800$. Air was used as working fluid in the range of Reynolds number 3000 to 20,000. It was varied different geometrical parameter such as baffle spacing $H$ and the baffle orientation angle $\beta$.

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. 2: 900 Half Circle Baffled Tubes](image)

**E. Naga Sarade S et al:**

[5] 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 inserts 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 Reynolds number increases higher heat transfer rates were observed. The increase in pressure drops by increasing ratio of porous material.

**IV. METHODOLOGY**

![Fig. 3: View of Experimental Set Up](image)

The tube with smooth tube and conical and helical inserted tube is used in the experimental set up. The tube material used is copper. The length of tube used is 1m and tube diameter is 22.22mm with 1mm thickness. In this experimental water is used as a working fluid. The heated test section is 1000 mm long. For wall temperature measurement, five thermocouples are used at different place of heating surface. Manometer is used to measure the pressure drop within the tested tube. The mass flow rate of water is controlled with the help of valve.
V. DESIGN PARAMETERS

A. Conical Insert:
Aluminium material ribs are used for experimental purpose due to easily availability and can be easily bend in required shape and angle as well as it as light in weight. For experimentation purpose five conical spring inserts are manufacture at same length and same diameter. 4 conical spring inserts are taken at experimentation at different arrangements and their performance is compared.

- Maximum diameter (D) = 22.22 mm
- Diameter of wire (d) = 3 mm
- Material = Aluminium
- Length of spring = 100 mm

B. Helical Spring Insert:
Aluminium material ribs are used for experimental purpose due to easily availability and can be easily bend in required shape and angle as well as it as light in weight. For experimentation purpose five helical spring inserts are manufacture at same length and same diameter. 4 helical spring inserts are taken at experiment purpose and their performance is compared.

- Wire diameter (d) = 3 mm
- Mean diameter (D) = 22.22 mm
- Pitch (p) = 10 mm
- Length of spring = 100 mm
- Material = Aluminium

VI. GRAPHS

The experimentation was carried out with the smooth tube without and with using conical spring inserts and helical spring inserts in Passive heat transfer enhancement methods. Heat transfer coefficient and friction factors are calculated for all cases. Parameters were plotted for Reynolds no. and mass flow rate. Following graphs are plotted to compare the performance of different inserts used in tube.

![Graph 1: Heat Transfer Coefficient Vs Reynolds Number](image1)

It is observed that the heat transfer coefficient increases with increase in Reynolds number. As Reynolds number increases, the water flow will cause more turbulence, so due to which the heat transfer rate will increase. It is observed that the tube without using any insert gives less heat transfer coefficient than with the use conical spring inserts and helical spring inserts.

![Graph 2: Friction Factor Vs Reynolds Number](image2)

It is observed that as Reynolds increases there is decrease in friction factor is observed. This is because friction factor is inversely proportional to the velocity. So as velocity increases (i.e., Reynolds number increases) friction factor will decrease.

VII. 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 because 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 friction factor. Friction factor reduces as the Reynolds number increases. This is because with increase in Reynolds number velocity increases and as friction factor is inversely proportional to velocity it decreases. This friction factor found to be maximum in conical convergent-divergent spring inserts followed by conical convergent spring inserts and to the helical spring inserts and least friction factor is obtained in smooth tube.

REFERENCES


