

Heat Transfer Augmentation in Tube Using Various Twisted Tape Inserts: A Review

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Abstract— several researches have done on heat transfer enhancement in tube by inserting various tapes in past few years. There is necessity for increasing the thermal performance of heat exchangers, thereby reducing size of heat exchanger and saving of material, effecting energy & cost led to development & use of heat transfer augmentation techniques. In heat transfer augmentation techniques, passive techniques are simple, cheap and easily can employed in heat exchanger as compared to active techniques. Heat transfer augmentation techniques are commonly applied in various areas such as thermal power station, process industries, refrigeration, air conditioning etc. The present paper is a review of heat transfer enhancement using tape inserts.

Key words: Heat exchanger, Heat transfer augmentation, Passive techniques, Tape inserts

I. INTRODUCTION

In the recent years, heat transfer technology be it in the form of conduction, convection or radiation has been widely applied to heat exchanger applications in refrigeration, automotive, process industries etc. such as in spacecraft engineering, aviation engineering, power engineering, chemical, petroleum refining and food stuff industries, refrigerating and cryogenic engineering etc. The overall dimensions and mass of the heat exchangers are increasing continuously with the unit power and volume of production. Alloyed steels and non-ferrous metals are being used in large amount for manufacturing heat exchanger.

It is an immediate problem to reduce the overall dimensional characteristics of heat exchangers. The urgency to increase the thermal performance of heat exchangers, because of this cost and material savings have led to development and use of many techniques termed as "Heat Transfer Enhancement techniques". By using heat transfer augmentation techniques, there will be increase in efficiency. Enhancement techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. These techniques are also referred to as "Heat Transfer Enhancement" or "Intensification". Improvement in heat transfer led to manufacture more efficient and smaller heat exchanger.

There are three different heat augmentation techniques namely passive, active and compound techniques. The present paper is study of heat transfer augmentation in a tube using tape inserts.

II. HEAT TRANSFER AUGMENTATION TECHNIQUES

Heat transfer augmentation techniques are divided into three types as

A. *Passive Techniques:*

B. *Active Techniques:*

C. *Compound Techniques:*

In Passive techniques, there is not required any external power but active techniques require external power.

1) *Passive Techniques:*

These generally use surface or geometric modifications to the flow channel by introducing inserts or additional devices. Any direct input of external power not required in passive techniques. Heat transfer augmentation is achieved by following passive techniques:

- (a) **Treated Surfaces:** this technique includes application of coating. This technique is used in condensing and boiling operation
- (b) **Extended Surfaces:** Extended surfaces are generally in the form of fins and nowadays fins are using in heat exchangers for heat transfer enhancement.
- (c) **Displaced Enhancement Devices:** Displaced enhancement devices are those inserts, which primarily used in confined forced convection. To increase energy transport at the heated surface by displacing the fluid from the surface of the duct with bulk fluid from the core flow, the various inserts are inserted into the flow channel
- (d) **Swirl Flow Devices:** Swirl flow devices are used to generate rotating flow. Some of the different types are Inlet Vortex Generators, Twisted Tape Inserts. They can be used for single phase flow and two-phase flows.
- (e) **Coiled Tubes:** Coiled tubes leads to more compact heat exchangers. Coiled tube generates secondary flows or vortices due to its curvature of coils. It promotes higher single phase heat transfer coefficients as well as improvement in most regimes of boiling.

2) *Active Techniques:*

Active techniques require external power to improve heat transfer rate. Design and use of these techniques are more complex and it has very limited applications. Heat Transfer Enhancement by this technique can be achieved by Mechanical Aids, Injection, Surface Vibration and Electrostatic Fields.

3) *Compound Techniques:*

Compound techniques are those techniques which involves simultaneous combination of above mentioned two or more techniques with purpose of improving thermo hydraulic performance of a heat exchanger.

III. LITERATURE REVIEW

Suvanjan Bhattacharyya, Subhankar Saha, et al. [1] presented heat transfer enhancement in a circular tube Laminar flow having integral transverse rib roughness. It fitted with centre-cleared twisted-tape. Centre clearance $c=0, 0.2, 0.4, 0.6$, Rib pitch $(P/e) = 2.0437, 5.6481$ and rib

height (e/D) = 0.07692, 0.1026. Predictive friction factor and Nusselt number co-relations are also presented. The thermo-hydraulic performance evaluated in this study by them and the main findings of their experimental investigations are that with and without centre cleared twisted tape in combination with integral axial rib.



Fig.1: Centre Cleared Twisted Tape

They worked within the Reynolds number range of 10-1000, got friction factor in the range of 0.017-1.2 and Nusselt no. in the range of 3-15. The friction factor and Nusselt number decreases with increase in the value of centre clearance initially however, but after $c=0.4$, no appreciable changes occur in the friction factor and Nusselt number. Experimental results shows that the combination of tapes with rib perform better than individual.

M.M.K. Bhuiya, M.S.U. Chowdhury, M. Saha, et al. [2] proposed heat transfer and friction factor characteristics through a tube fitted with perforated twisted tape inserts in turbulent flow. The experiments were conducted in a turbulent flow regime with Reynolds number ranging from 7200 to 49,800. Working fluid used as air in experiments under uniform wall heat flux boundary condition. They got the Nusselt no. values of range 20-100 and friction factor of range 0.017-0.15. From experiment, it has been found that the heat transfer enhancement occur by using perforated twisted tape inserts with corresponding increase in friction factor in comparison to that of the plain tube.

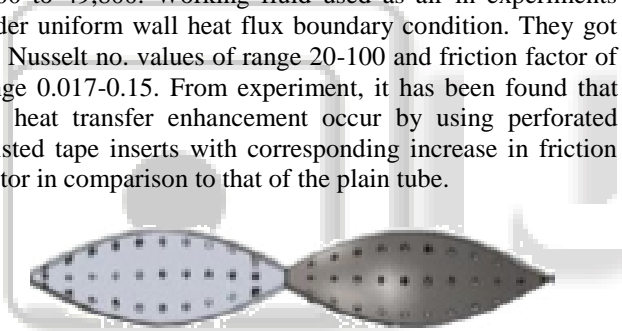


Fig. 2: Perforated Twisted Tape

S. Eiamsa-ard, Wongcharee, P. Eiamsa-ard Thianpong [3] experimented on heat transfer enhancement in a tube using delta-winglet twisted tape inserts. The experiments are conducted using the tapes with three different twist ratios ($y/w = 3, 4$ and 5) and three depth of wing cut ratios ($d/w = 0.11, 0.21, 0.32$) over a Reynolds number ranging from 3000 to 27,000 in a uniform wall heat flux tube. In this work delta-winglet tapes are used as vortex generators to increase turbulence intensities and produce secondary flows near the tube wall. They got Nusselt No. ranging from 20 to 200. They got the friction factor ranging from 0.05 to 0.25.



Fig. 3: Delta-Winglet Twisted Tape

The values of Nusselt number and friction factor in the twisted tape are noticeably higher than those in the plain tube and also in tube equipped with delta winglet twisted tape are higher than those in plain tube and also equipped with typical twisted tape. Experimental results show that

mean Nu number and mean friction factor in the tube using this tape increase with decreasing twisted ratio and increasing depth of wing cut ratio.

Sumana Biswas, Shuvra Saha, et al. [4] researched on enhancement of heat transfer using rectangular-cut twisted tape insert. An experiment was conducted for measuring tube-side heat transfer coefficient, heat transfer enhancement efficiency, friction factor of water for turbulent flow. For experiment copper tube of internal diameter 26.6 mm and outer diameter 30 mm and test length 900 mm was used. In copper tube a rectangular cut twisted tape insert was inserted having twist ratio 5.25 and the rectangular cut 8 mm depth and 14 mm width. Tapes were made of stainless steel. A uniform heat flux condition was created by wrapping nichrome wire around test section and fiber glass over the wire. The Reynolds no. was varied in the range of 10000-19000. The Nusselt numbers obtained in the range of 100-310, friction factors ranging from 0.06 to 0.12.



Fig. 4: Rectangular-Cut Twisted Tape

The swirl flow generated by twisted tape was responsible for thinning of thermal boundary layer and increasing the mixing between core and tube wall flow. Additional disturbances generated because of rectangular cut in the twisted tape which increase the tangential contact between secondary flow and the wall surface of the tube which made heat transfer coefficient higher through the flow. Also it is observed that heat fluxes increases with the increase of Reynolds number. By using this tape heat fluxes increased and it is more than those for smooth tube. Heat transfer enhancement takes place because of higher values of heat transfer coefficient, although temperature difference between wall and bulk fluid significantly decreased for the tube with insert. An average of 68% enhancement of heat flux was observed for tube with insert than that of smooth tube.

Sujoy Kumar Saha, Suvanjan Bhattacharyya et al. [5] worked on thermo-hydraulics of laminar flow of viscous oil through a circular tube having integral axial rib roughness and fitted with centre-cleared twisted-tape. This experimental investigation shows that integral axial rib roughness with centre-cleared twisted tapes and without centre-cleared twisted tapes perform significantly better than the individual. In presence of integral axial ribs swirl flow obtained and additional fluid mixing due to flow separation, reattachment and recirculation of the fluid unlike simple twisted tapes.



Fig. 5: Centre-Cleared Twisted-Tape

Also there is faster momentum and thermal energy diffusion and transport in both molecular and bulk flow levels causing additional pressure loss and faster heat transmission.

K. Wongcharee, S. Eiamsa-ard [6] worked on friction and heat transfer characteristics of laminar swirl flow. The tapes used for experiment are alternate clockwise and counter-clockwise twisted-tapes in round tubes. The thermo-hydraulic characteristics of the circular tubes equipped with alternate clockwise and counter-clockwise twisted-tapes for the Reynolds number ranging from 830 to 1990, are investigated. In the experiments, three different twist ratios ($l/W=3, 4$ and 5) were inserted individually into the uniform wall heat flux tubes where water was utilized as the working fluid.



Fig. 6: Alternate Clockwise and Counter-Clockwise Twisted-Tapes

The obtained results shows that, Nusselt number, friction factor and thermal performance factor associated with alternate clockwise and counter clockwise insert was greater as compared to simple twisted tape. They worked in the Nusselt number ranging from 800 to 2000. They got Nusselt number ranging from 10-55 and Friction factor in the range of 0.2-0.6. At similar condition, Nusselt number obtained by using alternate clockwise and counter clockwise twisted tape is significantly higher as compared with simple twisted tape. For the range studied Nusselt number increases with decreasing twist ratio.

A. G. Matani, Swapnil A. Dahake [7] has done experimental investigation on study of heat transfer enhancement in a tube using counter/co-swirl generation. In this experimental study, twisted tape and double twisted tape used for counter/co-swirl generation and wire coil with twisted tapes used for co-swirl generation.

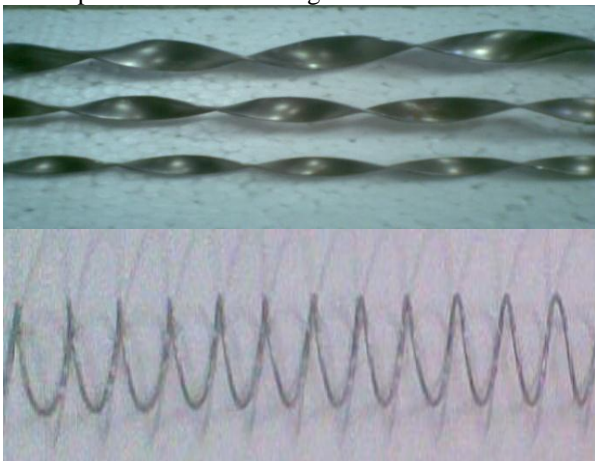


Fig. 7: Details of twisted tapes and wire coil

The experiment is conducted for Reynolds no. ranging from 5000 to 18000. Air used as working fluid in experiments and they got the Nusselt no. ranging from 45-117. The friction factor obtained from experiment by using both tapes and wire coil ranges from 0.15 to 0.55.

The following table gives the details about the results i.e. Nusselt number and friction factor obtained by various research scholars.

| Sr. no | Research scholar | Tape Used | Reynolds No. | Results | |
|--------|--|---|--------------|-----------------|---------|
| | | | | Friction Factor | Nu No. |
| 1 | Suvanjan Bhattacharyya, Subhankar Saha | Centre Cleared Twisted Tape | 10-1000 | 0.017-1.2 | 3-15 |
| 2 | M.M.K. Bhuiya, M.S.U. Chowdhury, M. Saha | Perforated Twisted Tape | 7200-49800 | 0.017-0.15 | 20-100 |
| 3 | S. Eiamsa-ard, Wongcharee, P. Eiamsa-ard Thianpong | Delta-Winglet Twisted Tape | 3000-27000 | 0.05-0.25 | 20-200 |
| 4 | Bodius Salam, Sumana Biswas, Shuvra Saha | Rectangular-Cut Twisted Tape | 10000-19000 | 0.06-0.12 | 100-310 |
| 5 | K. Wongcharee, S. Eiamsa-ard | Alternate Clockwise and Counter Clockwise Twisted-Tapes | 830-1990 | 0.2-0.6 | 10-55 |
| 6 | A.G. Matani, Swapnil A. Dahake | Twisted tapes with wire coil | 5000-18000 | 0.15-0.55 | 45-117 |

Table 1: Comparison of Results Obtained By Research Scholar

IV. CONCLUSION

This paper reviews the investigation carried out by various researches in order to enhance the heat transfer, friction factor and Nusselt number by the use of inserts of different shapes, sizes and orientation. Above work can be summarized as follows:

- (1) The enhancement devices of the modified twisted tape show a considerable improvement of Nusselt number and friction factor relative to the simple twisted tape, depending on twist ratios.
- (2) The Nusselt number is found to increase with decrease of the twist ratio and with increase in the Reynolds number.
- (3) The friction factor is found to increase with decrease of twist ratio.
- (4) Heat transfer in swirl flow is higher than non-swirling flow.
- (5) The considerable heat transfer improvement observed using different tapes inserts as compared to smooth tube acting alone.

V. FUTURE SCOPE

- (1) Heat transfer augmentation can be achieved by using tapes like triangular wavy tape (TWT) inserts. TWT is as shown below

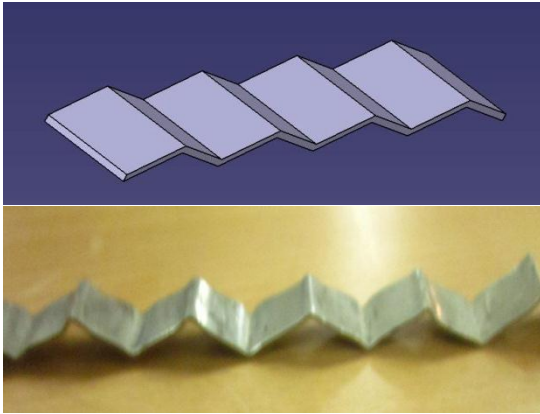


Fig. 8: Triangular wavy tape

- (2) Heat transfer enhancement can also be achieved by making hole on the surface of tape like holes on one slant parallel faces and holes on all slant faces.
- (3) The experiment should be conducted for increasing Nusselt no. by changing twist ratio.
- (4) The experiment should be conducted for increasing heat transfer by using fluid like nanofluids.

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