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EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER BY FORCED CONVECTON WITH AND WITHOUT TWISTED STRIPS – A STUDY

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ABSTRACT

Heat transfer can be improved with the help of some direct or indirect approach of improvement of heat transfer rate in a heat exchanger as it plays a essential role in several mechanical equipments where heat generation happen. Whenever there are some external techniques used to enhance the heat exchange, the simple natural heat exchanger is converted into augmented forced heat exchanger. The intention to present this paper is to study the effect of twisted strip on heat transfer rate by forced convection which is useful in design and analysis of heat exchangers.

Key Words: Forced convection, twisted strip, heat transfer coefficient, heat transfer rate, heat transfer enhancement

1. INTRODUCTION

Based on the nature of heat exchange process heat can be exchanged by three ways out of which direct contact or open heat exchanger and regenerator have their limited uses but third one which has wide range of other classification is recuperator.

At present, the technology of the twisted Strips inserts is widely used in various industries. Insertion of twisted Strips in a tube provides a simple indirect technique for enhancing the convective heat transfer by introducing swirl into the bulk flow and by disrupting the boundary layer at the tube surface due to repeated change in surface geometry. The system has followed type of flow arrangements and geometric dimension with twisted Strips. The intention to present this paper is to study how the heat transfer can be enhanced by forced convection when we use

- Strip without a twist.
- Strip with a single twist.
- Strip with double twists.

1.1 TWISTED STRIPS:

In general a twisted Strips is a metallic strip having twist from its central axis whose design depends only on three main factors which are material of strip, pitch of the twist and the twist ratio which is define by the ratio of the pitch length to the inside diameter of the tube, but this is a technique which is used in some old era. Now the new generation modified twisted are the replacement of the plane twisted Strips. Some of the new generation twisted Strips are the Strips with attached baffles, slotted Strips or Strips with holes etc.

The simple heat exchanger equation for the convective heat transfer between a pipe and a fluid is Newton's Law of Cooling:

$$q'' = h\,(T_o - T_\infty)$$

The symbols q'', h, T_o, and T_∞ represent the heat wall heat flux, the heat transfer coefficient, the temperature of the flat plate and the temperature of the fluid respectively.

The basic concept of using twisted Strips is to convert laminar flow to turbulent flow which increases the rate of heat transfer termed as tabulator. There are lots of techniques which overcome the laminar flow to get turbulence in a pipe flow but the few of them can manage mass flow rate which is also the main factor in heat exchanger. For the free convection circumstances three main dimensionless numbers are:

Nu no. Nu = hl_c/k

Grashof number Gr = $g\beta L_c^3 \rho 2 \Delta t/\mu 2$

Prandtl number Pr = $\mu c_p/k$

2. LITERATURE REVIEW

A tube inserted with a twisted-tape performs better than a plain tube, and a twisted-tape with a tight twist ratio provides an improved heat transfer rate at a cost of increase in pressure drop for low Prandtl number fluids. This is because the thickness of the thermal boundary layer is small for a low Prandtl number fluid and a tighter twist ratio disturbs the entire thermal boundary layer as discussed by different authors.

Ahamed, J.U. and Bhuiya et. al [1] Heat transfer performance of porous twisted tape insert in a circular tube was experimentally investigated. Tube wall temperatures and pressure drops along the axial distance of the test section at steady state condition were measured for different flows having Reynolds number ranging from 1.4 x 104 to 5.2 x 104 for both the plain and the tube with porous twisted tape insert. Heat transfer coefficient, friction factor, and pumping power were calculated from the measured data. Heat transfer and fluid flow characteristics of the porous twisted tape inserted tube were explained from the measured and calculated values. Performance of the porous twisted tape inserted tube was also evaluated. The results showed for porous twisted tape inserted tube, the average heat transfer coefficient was 2.60 times higher, the heat flux was 1.55 times higher, the friction factor was 2.25 times higher and the pumping power was 2.0 times higher than those of plain tube values for similar flow conditions.

N . C. Kanojiya et. al [2] Heat transfer augmentation techniques are 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 heating and cooling in evaporators, air-conditioning equipment, thermal power plants, space vehicle, automobile etc. This paper contains literature survey of enhancement techniques in heat transfer using inserts with and without using nanofluid.

R.J.Yadav and A.S.Padalkar et. al [3] CFD investigation was carried out to study the heat transfer enhancement characteristics of air flow inside a circular tube with a partially decaying and partly swirl flow. Four combinations of tube with twisted-tape inserts, the half-length upstream twisted-tape condition (HLUTT), the half-length downstream twisted-tape condition (HLDTT), the full-length twisted tape (FLTT), and the plain tube (PT) with three different twist parameters (λ = 0.14, 0.27, and 0.38) have been investigated. 3D numerical simulation was performed for an analysis of heat transfer enhancement and fluid flow for turbulent regime. The results of CFD investigations of heat transfer and friction characteristics are presented for the FLTT, HLUTT, and the HLDTT in comparison with the PT case.

Prof. Naresh B. Dhamane, Prof. Mathew V. Karvinkoppa, Prof. Murtuza S. Dholkhwala et. al [4]

This paper presents an experimental study of heat transfer and friction characteristics in turbulent flow generated by a helical strip inserts with regularly spaced cut passages, placed inside a circular pipe across the test section. The experiments were conducted for water flow rates in the range of Re 5000 to Re 30000. For the experiment three different types of helical strips with helix angles of 30◦, 45◦ and 60◦ were used. Experimental results show that, the use of a helical strip inserted inside a circular tube results into an enhancement of heat transfer rate as they cause the turbulence in the flow with swirling moment. The local heat transfer coefficients were found to be increasing to very high values along the downstream of the helical strip, and then decreasing with the distance (x/L). The increase of heat transfer was found to be dependent on the Reynolds number in typical case. The effect of the number of the helical channels, and helix angle, on heat transfer was minute. It is found that using the helical tape can help to increase the heat transfer rate up to 20% depending on Re at constant pumping power. Enhancement efficiency decreases with increasing Reynolds number.

L. Syam Sundar and K.V. Sharma et.al. [5] The thermophysical properties like thermal conductivity and viscosity of Al2O3 nanofluid is determined through experiments at different volume concentrations and temperatures and validated. Convective heat transfer coefficient and friction factor data at various volume concentrations for flow in a plain tube and with twisted tape insert is determined experimentally for Al2O3 nanofluid. Experiments are conducted in the Reynolds number range of 10,000–22,000 with tapes of different twist ratios in the range of 0 < H/D < 83. The heat transfer coefficient and friction factor of 0.5% volume concentration of Al2O3 nanofluid with twist ratio of five is 33.51% and 1.096 times respectively higher compared to flow of water in a tube. A generalized regression equation is developed for the estimation of Nusselt number and friction factor valid for both water and nanofluid in plain tube and with inserts under turbulent flow conditions.
Kurhade Anant Sidhappa et. al [6] works in the condition of force convection by using twisted tape insert of width 16 mm thicknesses 1.2mm, length 0.5m and twist ratio 5.5, 6.5, 8.5 with circular holes of diameter 6mm and conclude that for Re No. range 2000 to 12000, the Nusselt number for twisted tape insert with twist ratio 8.5,6.5 and 5.5 was found to be 23.99%, 25.64% and 29.32% respectively also the Friction factor is increased approximately by 0.20%, 0.2673 % and 0.4545 % with twist ratio 8.5, 6.5 and 5.5 respectively.

Avinash Savekar et. al [7] Give a Analysis of Heat Transfer in Pipe with Twisted Tape Inserts to understand the effect of change in pitch of twisted tape on the flow physics, results of Re no.800 and twist ratio 2, 3, 4 and 5 are considered and conclude the variation of twist ratio and Re No. on heat transfer and flow characteristics using twisted tape inserts and also the heat transfer increases with decrease in twist ratio and increase in Reynolds number.

G.Nagarajan et. al [8] found in double pipe heat Exchanger of diameter 0.015 m and length of 2.5 m with variable twisted type insert in ANSYS fluent that a trend of increase in heat transfer with the provision of insert on the heat exchanger. The heat transfer was found to increase as the Re No. was varied over the range. The result shows that effect of insert on the enhancement of heat transfer depends on both the pattern of insert and Re No.of the flow.

N.A.Uzagare et. al [9] after analyzing heat transfer augmentation using V-Jagged twisted tape gives The heat transfer enhancement, thermal performance and friction factor characteristics of V jagged twisted tape turbulator inserted tube will be investigated experimentally.

D.S. Nakate et. al [10] Performed for heat exchanger by inserting twisted tape turbulators with baffle For same twist ratio, Baffled reduced width twisted tape with holes & Baffled reduced width twisted tape shows higher heat transfer coefficient & friction factor increase because of higher degree of turbulence created also gives higher heat transfer coefficient than the reduced width twisted tapes.

Snehal S. Pachegaonkar et. al [11] gives the result for the performance analysis of double pipe heat exchanger of inner pipe inner diameter 16.5mm, outer diameter 21.5mm and outer pipe inner diameter 42mm, outer diameter 48.5mm with Annular M.S. Twisted Tape Insert of Width 10mm, pitch 67mm,107mm, twist ratio 6.7, 10.7 , tape thickness 1.4mm length of 1.5m. For plain double pipe heat exchanger result shows linear tendency, since the Nu No. is directly proportional to Reynolds number. The results for heat exchanger with twisted tape has parabolic tendency From the results obtained it is concluded that the best performance with twisted tape inserted into annulus of double pipe heat exchanger is obtained at twist angle 450 due to more swirl and turbulence induced by tape insert.

Shubham Jadhav et. al [12] Augmentation techniques refer to different methods used to increase rate of heat transfer without increasing size and without affecting overall performance. These techniques used in Heat Exchangers. Some of the applications of heat exchanger are in process industry, thermal power plants, air conditioning equipment's, radiator for space vehicles, automobiles etc. So, for various application heat exchangers are designed ,which needs exact analysis of heat transfer rate and pressure drop estimations. For compactness and optimize cost, augmentation techniques are used. Augmentation techniques are broadly classified in 3 types viz. Active, Passive and compound techniques. Passive techniques using different inserts are widely used nowadays because of low cost and simplicity, so here brief discussion is on heat augmentation using different inserts. Whenever inserts are used for heat argumentation, along with increase in heat transfer rate, the pressure drop (pumping loss) and friction

factor also increase. So, need of optimization between benefits of increased heat transfer rate and higher cost involved due to increased pumping and frictional loss. Mainly, in this present seminar, effect on heat transfer characteristics by using twisted tapes have been studied and compare with plane tube. Also effect of different twist ratios have been seen.

Chirag Maradiya et. al [13] Heat transfer devices have been used for conversion and recovery of heat in many industrial and domestic applications. Over five decades, there has been concerted effort to develop design of heat exchanger that can result in reduction in energy requirement as well as material and other cost saving. Heat transfer enhancement techniques generally reduce the thermal resistance either by increasing the effective heat transfer surface area or by generating turbulence. Sometimes these changes are accompanied by an increase in the required pumping power which results in higher cost. The effectiveness of a heat transfer enhancement technique is evaluated by the Thermal Performance Factor which is a ratio of the change in the heat transfer rate to change in friction factor. Various types of inserts are used in many heat transfer enhancement devices. Geometrical parameters of the insert namely the width, length, twist ratio, twist direction, etc affect the heat transfer. For example counter double twisted tape insert has TPF of more than 2 and combined twisted tape insert with wire coil can give a better performance in both laminar and turbulent flow compared to twisted tape and wire coil alone. In many cases, roughness gives better performance than the twisted tape as seen in case of flow with large Prandtl Number. The artificial roughness can be developed by employing a corrugated surface which improves the heat transfer characteristics by breaking and destabilizing the thermal boundary layer. This paper provides a comprehensive review of passive heat transfer devices and their relative merits for wide variety of industrial applications.

S. Naga Sarada et. al [14] Heat transfer augmentation refers to the process of increasing the heat transfer coefficient which leads to the improvement in the performance of the system. The twisted tape insert is a device used for increasing the heat transfer rate in the heat exchanger system due to its advantages of easy fabrication, operation as well as low maintenance. Some of the applications of heat exchangers are in process industries, thermal power plant, air conditioning equipment, refrigerators, radars for space vehicles, automobiles etc. Previously, most of the researchers focused on different types of inserts such as coil wire insert, mesh inserts, brush inserts, twisted tape insert, wire coils etc. with different geometries, slots, holes, ribs, fins, dimples and cuts. This review paper mainly focuses on the twisted tape insert with different cuts like semi-circular cut, v-cut, delta-winglet cut, rectangular cut, peripherally cut, serrated cut, elliptic cut, quadrant cuts and the effects of these cuts on heat transfer enhancement, pressure drop, friction factor and thermal performance factor characteristics in heat exchanger tubes.

H.V. Chavan et.al [15] Tubular heat exchanger is a device that enables exchange of heat between two fluids which are at different temperatures and separated by a solid wall occurs in many engineering applications. The one way to enhance the performance of Tubular heat exchanger is to improve tube side heat transfer rate. Twisted tape insert is one of the passive heat transfer enhancement techniques, which are extensively used in various heat transfer applications such as, air conditioning and refrigeration systems, heat recovery processes, food and dairy processes, chemical process plants. A small scale experimental setup was done to enhance the heat transfer rate of tubular heat exchanger. The heat enhancement of Heat Exchanger is done using twisted tape inserts with various twist ratios (TR=3.78, 3.89, 4.22). The effects of two dimensionless parameters namely Nusselt Number & Friction factor on the effectiveness of Tubular Heat Exchanger are studied. The turbulent flow was created by inserting the twisted tape inserts into the test pipe creating high rate of turbulence in pipe, which results in increasing heat transfer enhancement and pressure drop. The twisted tape twisting. The length and width of insert was 1000 mm and 45 mm respectively. The outside diameter & inside diameter of test pipe is 50 mm & 48 mm respectively. The length of test section is 1000 mm. The Reynolds number is varied from 5000 to 25000. The results of varying twisted tape inserts with different twisted ratio have been compared with the values for the smooth tube. It showed that the highest heat transfer rate was achieved for the twisted tape with twist ratio 3.78.

Pradip Pathade et. al [16] Many industrial facilities face problem of effective heat transfer due to the performance issues of heat exchangers. Optimizing changes in flow regime and redesigning heat exchangers for best possible heat exchange for maximizing profits. Twisted tube type shell and tube heat exchanger (TTSTHE) combats nearly all performance drawbacks in conventional heat exchangers. 'Twisted Tube Technology' is the new technology in the era of heat transfer equipment.The concept of swirl flow moment of fluid creates turbulence enhancing thermal-hydraulic performance of TTSTHE. The TTSTHE increases the overall efficiency of heat transfer. The advantage of twisted type shell and

tube heat exchanger over conventional heat exchanger are Studied in this paper on the basis of economics, performance and material of construction including reactive metals for improved performance, no vibration, and no dead spots etcetera. The retrofit situation is increased capacity, lower installed cost, lower shell side pressure drop and low fouling over shell and tube heat exchanger. The literature also supports the application of twisted type shell and tube heat exchanger in large scale and small scale industries. The challenges faced are mostly in operating and maintaining this type heat exchangers. However, engineering and design standards are crucial for design and construction consideration of heat exchanger needs to be looked into.

EXPERIMENTAL SET-UP DETAILS:

S.N.	Material	Dimensions
1	Copper strip (Flat)	450 x 25 x 5 mm
2	Copper strip (Single twist)	450 x 25 x 5 mm
3	Pitch for each strip	150mm
4	Copper strip (Double twist)	450 x 25 x 5 mm
5	Thermocouples	J-Type
6	Dimmer stat	240V 5A
7	Voltmeter	0-230V
8	Ammeter	0-5A
9	U Tube Manometer	
10	Orifice	
11	Blower	

Table1: Details of experimental set-up

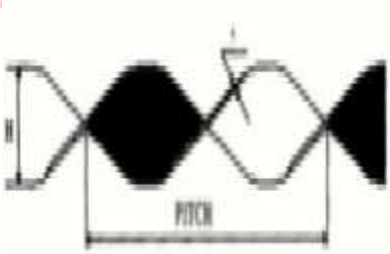

Figure1: Typical twisted strip

CONCLUSION:

Heat exchangers are becoming more and more vital in 21st century as the use of technology and machinery is increasing day by day. Since it plays such a vital role, improving heat transfer rate in machinery is needed. Using twisted strips to enhance the heat transfer is an indirect method to improve the efficiency of heat exchanger. With more and more technological advancement there is a high scope in this field for the improvement of heat transfer and pressure drop. This can be achieved with obtaining different range of Nu no. & Pr no.. The actual results with enhanced heat transfer can be obtained with experimental outcomes. When compared to the previous research made into the subject with natural convection it can be suggested that the heat transfer rate is greater in double twisted strip than a strip with single or no twist. One can always enhance the heat exchange by changing the dimensions of the strip used in heat exchanger.

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