ISSN 2395-1621

Heat transfer performance and analysis of pipe heat exchanger fitted with different insert- A Review

#1 Mr. Hemant P.Gawade, #2 Prof. (Dr). Rajendra K.Patil
[1]hemantgawade123@gmail.com
[2]rkpvpit@gmail.com
#1Student: Mechanical Engineering Department Padmabhooshan Vasantdada Patil Institute of Technology, Bavdhan, Pune-21(India)
#2Professor: Mechanical Engineering Department Padmabhooshan Vasantdada Patil Institute of Technology, Bavdhan, Pune-21(India)

ABSTRACT

In this study heat transfer performance of pipe fitted with different insert studied with different research papers is explained. Screw tapes have been extensively studied to their advantages of steady performance, simple configuration and ease of installation. Now, the attention on how to optimize the thermal performance of tube fitted with helical screw tape inserts has been increased. To achieve a good heat transfer performance as well as low friction factor, we proposed pipe heat exchanger fitted with screw tape insert in present work.

Keywords—screw tape; thermal performance; friction factor.

ARTICLE INFO

Article History

Received : 18th April, 2015

Received in revised form :

24th April, 2015

Accepted : 26th April, 2015

Published online :

30th April, 2015

I. INTRODUCTION

Heat exchangers are mostly used devices in many areas of the industries. Hence, the using of high performance heat exchangers is very important for saving energy. [1] Thermal performance of heat transfer devices can be improved by heat transfer enhancement techniques. The turbulent generator with different geometrical configurations have been used as one of the passive heat transfer enhancement techniques and are the most widely used tubes in several heat transfer applications, for example, heat recovery processes, air conditioning and refrigeration systems, chemical reactors, food and dairy processes.[1] Heat transfer augmentation using various types of swirl flow generators like twisted tapes, helical screw tapes have been widely reported in literatures. It has been reported that such devices induce turbulence and superimposed vortex motion (swirl flow) causing a thinner boundary layer and consequently resulting in higher heat transfer coefficients.[2] Twisted-tape inserts are, therefore, used to mix the gross flow effectively in laminar flow to reduce the thermal resistance in the core flow through the channel. Integral axial ribs are also tabulators.[3] Twisted tape swirl turbulator is one of the commonly used passive types for heat transfer augmentation due to their advantages of steady performance, simple configurations and ease of installation.[4]

S. Sures et.al.[1]investigated comparison of thermal characteristics of Al_2O_3/water and CuO/water nanofluids in transition flow through a straight circular duct fitted with helical screw tape inserts was made in this study. The helical screw tape inserts with twist ratios Y = 1.78, 2.44 and 3 were used in the experimental study using 0.1% volume concentration Al_2O_3/water and CuO/water nanofluid. The average enhancements in Nusselt number for water with twist ratios of 1.78, 2.44 and 3 were 156.24%, 122.16% and 89.22% respectively when compared to plain tube. The average increase in Nusselt number corresponding to the twist ratios of 1.78, 2.44 and 3 were 166.84%, 128.67% and 89.22% respectively for Al_2O_3/water nanofluid. In the case of CuO/water nanofluid, the enhancements in Nusselt number were 179.82%, 144.29% and 105.63% for twist ratios 1.78,2.44 and 3 respectively. Thermal performance analysis based on the constant pumping power criteria shows that helical screw tape inserts give better thermal performance when used with CuO/water nanofluid than with Al_2O_3/water nanofluids.

Subhankar Saha, Sujoy Kumar Saha[2]tested the experimental friction factor and Nusselt number data for laminar flow through a circular duct having integral helical rib roughness and fitted with way strip inserts.The heat transfer test section was electrically heated and uniform wall heat flux boundary condition was imposed. Friction factor and Nusselt number correlations have been developed by log-linear regression analysis. The performance of the present fin geometry has been evaluated. The major findings of this experimental investigation are that the wavy strip inserts in combination with integral helical rib roughness perform better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain range of parameters.

Sujoy Kumar Saha,et al[3] investigated the experimental friction factor and Nusselt number data for laminar flow through a circular duct having integral axial rib roughness and fitted with center-cleared twisted-tape. Predictive friction factor and Nusselt number correlations have also been presented. The thermohydraulic performance has been evaluated. The major findings of this experimental investigation are that with and without center-cleared twisted tapes in combination with integral axial rib roughness perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain amount of twisted-tape center-clearance.

Halit Bas et. al [4] presented Flow friction and heat transfer behaviour in a twisted tape swirl generator inserted tube are investigated experimentally. The twisted tapes are inserted separately from the tube wall. The effects of twist ratios (y/D = 2, 2.5, 3, 3.5 and 4) and clearance ratios (c/D =0.0178 and 0.0357) are discussed in the range of Reynolds number from 5132 to 24,989, and the typical one (c/D = 0) is also tested for comparison. Uniform heat flux is applied to the external surface of the tube wall. The air is selected as a working fluid. The obtained experimental results from the plain tube are validated by using well known equations given in literature. The using of twisted tapes supplies considerable increase on heat transfer and pressure drop when compared with those from the plain tube. The Nusselt number increases with the decrease of clearance ratio (c/D) and twist ratio (y/D), also increase of Reynolds number. For all investigated cases, heat transfer enhancement (ξ) tends to decrease with the increase of Reynolds number and to be nearly uniform for Reynolds number over 15,000 and y/D lower than 3.0. The highest heat transfer enhancement is achieved as 1.756 for c/D = 0.0178 and y/D = 2 at Reynolds number of 5183. Consequently, the experimental results present that the best operating regime of all investigated twisted tape swirl generator inserts is detected at low Reynolds number, leading to more compact heat exchanger. The empirical correlations based on the experimental results of the present study are also given for prediction the heat transfer (*Nu*), friction factor (*f*) and heat transfer enhancement (ξ).

M.M.K. Bhuiya et.al [5] presented the heat transfer performance and friction factor characteristics in a circular tube fitted with twisted wire brush inserts were investigated experimentally. The twisted wire brush inserts were fabricated with four different twisted wire densities of 100, 150, 200, and 250 wires per centimeter by winding a 1 mm diameter of the copper wire over a 5 mm diameter of two twisted iron core- rods. Heat transfer and friction factor data in tubes were examined for Reynolds number ranging from 7,200 to 50,200. The results indicated that the presence of twisted wire brush inserts led to a large effect on the enhancement of heat transfer with corresponding increase in friction factor over the plain tube. The Nusselt number and friction factor of using the twisted wire brush inserts were found to be increased up to 2.15 and 2.0 times, respectively, than those over the plain tube values. Furthermore, the heat transfer performance was evaluated to assess the real benefits of using those type of inserts and the performance was achieved 1.85 times higher compared to the plain tube based on the constant blower power. Finally, correlations were developed based on the data generated from this work to predict the heat transfer, friction factor, and thermal performance factor for turbulent flow through a circular tube fitted with the twisted wire brush inserts in terms of wire density (y), Reynolds number (Re), and Prandtl number (Pr).

Subhankar Saha et.al[6] conducted experiment for friction factor and Nusselt number data for laminar flow of viscous oil through a circular duct having integral helical rib roughness and fitted with helical screw-tape insert. Predictive friction factor and Nusselt number correlations have also been presented. The thermohydraulic performance has been evaluated. The major findings of this experimental investigation are that the helical screw-tape inserts in combination with integral helical rib roughness perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain value of fin parameter.

P. Sivashanmugam et al [7] investigated Experimental investigation on heat transfer and friction factor characteristics of circular tube fitted with right-left helical screw inserts of equal length, and unequal length of different twist ratio have been presented. The experimental data obtained were compared with those obtained from plain tube published data. The heat transfer coefficient enhancement for right-left helical screw inserts is higher than that for straight helical twist for a given twist ratio. The effect of right-left helical twist length on heat transfer and friction factor was presented. The empirical relation for Nusselt number, friction relating Reynolds number, twist ratio and right-left distance were formed and found to fit the experimental data within

10% and 20% for Nusselt number and friction factor, respectively. Performance evaluation analysis has been made and the maximum performance ratio of 2.85 and 2.97, respectively were obtained for 300 R and 300 L, and 400 R and 200 L type inserts.

Paisarn Naphon et. al [8] presented study the heat transfer characteristics and the pressure drop of the horizontal concentric tube with twisted wires brush inserts are investigated. The inner diameters of the inner and outer tubes are 15.78 and 25.40 mm, respectively. The twisted wire brushes are fabricated by winding a 0.2 mm diameter of the copper wires over a 2 mm diameter of two twisted iron core- rod with three different twisted wires densities of 100, 200,

300 wires per centimetre. The plain tube with full-length twisted wires brush and regularly spaced twisted wires brush with 30 cm spacer length inserts are tested. Cold and hot water are used as working fluids in shell side and tube-side, respectively. The test runs are performed at the hot water Reynolds number ranging between 6000 and 20000. The inlet cold and hot water temperatures are 15, 20 °C, and between 40 and 50 °C, respectively. Effect of twisted wires density, inlet fluid temperature, and relevant parameters on heat transfer characteristics and pressure drop are considered. Twisted wire brushes insert have a large effect on the enhancement of heat transfer, however, the pressure drops also increase

II. EXPERIMENTATION

The pressure drop across the test section is measured using a differential pressure transducer mounted across the test section which is able to read up to 1 cm of water. S. Sures et.al. [1] Investigated a differential u-tube manometer is also fitted across the test section to validate the pressured drop shown by the pressure transducer. The fluid after passing through the heated test section flows through a riser section and then through the cooling unit which is an air cooled heat exchanger and finally it is collected in the reservoir. A peristaltic pump is used to circulate the fluid through the circuit. The pump discharge is varied by adjusting the speed of rotation.[1] in experimental set up of Subhankar Saha et. al. [2] The measurements were taken in a 19 mm ID and 2 m long circular stainless steel duct in which there was integral helical ribs. Heat transfer test section was electrically heated by nichrome heater. Uniform wall heat flux boundary condition was imposed. Nichrome heater wire had porcelain bead insulation on it. There was no direct contact of the nichrome heater wire with the duct wall. First, there was fiber glass tape insulation (electrical but not thermal) on the duct wall. Then the porcelain-bead covered nichrome heater wire was wrapped on the duct wall. Two consecutive turns of the heater wire touched each other in each duct. The thermal conductivity of the duct wall material was high enough and the duct wall thickness was sufficient to ensure uniform wall heat flux boundary condition. Asbestos rope and glass wool insulated the heat transfer test section after the heater wire. Finally the test section was covered with jute bag for further thermal insulation.[2] In the experimental investigation of Sujoy Kumar Saha et. al. [3] The pressure drop measurements were taken in a 13 mm ID and 2 m long circular acrylic duct. Heat transfer tests were carried out in a stainless steel duct having same dimension as that of pressure drop tests. Heat transfer test section was electrically heated by nichrome heater wire giving uniform wall heat flux boundary condition. Nichrome heater wire was having porcelain bead insulation on it. There was no direct contact of the Nichrome heater wire with the duct wall. First, there was fiber glass tape insulation (electrical but not thermal) on the duct wall. Then the porcelain-bead covered nichrome heater wire was wrapped on the duct wall. Two consecutive turns of the heater wire touched each other in each duct. The thermal conductivity of the duct wall material was high enough and the duct wall thickness was sufficient to ensure uniform wall heat flux. Asbestos rope and glass wool insulated the heat transfer test section after the heater wire. Finally the test section was covered with jute bag for further thermal insulation.[3] The experimental investigation of Halit Bas et al [4] includes a blower, a bell-mouth for air entering to the tube uniformly, a flow meter to measure the volumetric flow rate, a calming tube (6000 mm) for developing flow hydro dynamically and the heat transfer test tube (3100 mm) with a twisted tape insert. The SS304 seamless steel test and calming tube has 56 mm inner diameter (D1), 60 mm outer diameter (D2), and 2 mm thickness (t). The twisted tapes tested in experiments, which five different twist ratios (y/D =2.0, 2.5, 3.0, 3.5 and 4.0) and two different clearance ratios (c/D = 0.0178 and 0.0357) are considered in this experimental study, are fabricated from steel. The schematic figure of the test tube with twisted tape insert is given in Fig.1.

Fig1: Schematic view of the twisted tape inserted tube

Separated from the tube inner surface with teflon rings.[4]

The teflon attachments are manufactured according to the twisted tape thickness and clearance ratios in order to fix the twisted tapes separated from the tube wall and attached onto the twisted tapes to prevent contact of inserts with the tube inner surface. While in experiment conducted by M.M.K. Bhuiya et al. [5] consist of an inlet section, a test section, an air supply system (electric blower) and a heating arrangement. The tube shaped inlet section, 533 mm long, was made as integral part of the test section to avoid any flow disturbances upstream of the test section and to get fully developed flow in the test section as well. The inlet section shape of the experimental setup was made as per suggestions of Owner and Pankhurst [26] to avoid separation and stratification of the flow. Geometry of the test section fitted with the twisted wire brush insert over a 5 mm diameter two twisted iron core-rods and geometric parameters of the wire brush insert are shown in Fig. 2(a) and (b), respectively. The plain tube (test section) was made of brass having 70 mm inside diameter, 90 mm outside diameter, and 1500 mm in length. The twisted wire brush inserts were fabricated by winding 1 mm diameter of the copper wire over a 5 mm diameter of two twisted iron core- rods. The four different twisted wire densities of 100, 150, 200, and 250 wires were considered per centimeter by winding the copper wire over a two twisted iron core-rods. Nichrome wire (resistance 1.2 O/m) was used as an electric heater to heat the test section at constant heat flux condition. Nichrome wire was spirally wounded uniformly around the tube. The terminals of the Nichrome wire heating coil were connected to the variac transformer. The electrical output power was controlled by a variac transformer to obtain a constant heat flux condition throughout the entire test section. The outer surface of the test section was well insulated to minimize heat leak to the surroundings. In the experimental investigation of Sujoy Kumar Saha et al [6] the pressure drop measurements were taken in a 13 mm ID and 2 m long circular acrylic duct in which there was integral helical ribs. Heat transfer tests were carried out in a stainless steel duct having same dimension as that of pressure drop tests. Heat transfer test section was electrically heated by nichrome heater wire giving uniform wall heat flux boundary condition. Nichrome heater wire was having porcelain bead insulation on it. There was no direct contact of the Nichrome heater wire with the duct wall. First, there was fiber glass tape insulation (electrical but not thermal) on the duct wall. Then the porcelain-bead covered Nichrome heater wire was wrapped on the duct wall. Two consecutive turns of the heater wire seated side by side touching each other in each duct. The thermal conductivity of the duct wall material was high enough and the duct wall thickness was sufficient to ensure uniform wall heat flux. Asbestos rope and glass wool insulated the heat transfer test section after the heater wire. Finally the test section was covered with jute bag for further thermal insulation. The experiment set up of paper of P. Sivashanmugam et al [7] is same as earlier paper [4] except that after plain tube run right- left helical twist of equal and unequal length cited above were inserted and experiments were performed. In the experiment analysis of Paisarn Naphon et al [8] the test section and the connections of the piping system are designed such that parts can be changed or repaired easily. In addition to the loop component, a full set of instruments for measuring and control of temperature and flow rate of all fluids are installed at all important points in the circuit. The close-loops of hot and cold water consist of the 0.5 m3 storage tanks, electric heaters controlled by adjusting the voltage, and a cooling coil immerged inside a storage tank. R22 is used as the refrigerant for chilling the water. The hot water is adjusted to the desired level and controlled by temperature controller. After the temperature of the cold and hot water are adjusted to achieve the desired level, the water of each loop is pumped out of the storage tanks, and is passed through a filter, flow meter, test section, and returned to the storage tanks.

III. RESULT AND DISCUSSION

Result were discussed on the basis of heat transfer performance different types of insert S. Suresh et al[1] conclude that CuO/water nanofluid gives better enhancement in heat transfer than Al2O3/water nanofluid. Therefore helical screw tape inserts give better thermal performance when used with CuO/water nanofluid than with Al2O3/water nanofluid. The major findings of this experimental investigation of Subhankar Saha et al [2]are that the centre-cleared wavy strip inserts in combination with integral helical rib roughness perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain amount of wavy strip centre-clearance. This research findings is useful in designing tubes for heat exchangers. The major findings of this experimental investigation of Sujoy Kumar Saha et al [3] are that the with and without center-cleared twisted tapes in combination with integral axial ribs perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain amount of twisted- tape center-clearance. This research finding is useful in designing tubes carrying solar thermal mass of viscous oil in parabolic trough solar collector used in environmentally sound and increasingly cost effective solar thermal electric power plants. Experimental results of Halit Bas et al [4] show that using twisted tape separately from the tube wall instead of attached type can also supply enhancement on heat transfer. Also, this provides less contamination when compared with the attached one. The study of M.M.K. Bhuiya [5] revealed that the twisted wire brush inserts provided significant enhancement of heat transfer with the corresponding increase in friction factor. It was found that the Nusselt number, friction factor, and thermal performance factor increased with the increase of twisted wire densities. The major findings of this experimental investigation of Sujoy Kumar Saha et al [6] are that the helical screw-tape inserts in combination with integral helical rib roughness perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain value of fin parameter. This research finding is useful in designing tubes carrying solar thermal mass of viscous oil in parabolic trough solar collector used in environmentally sound and increasingly cost-effective solar thermal electric power plants. The experimental study of P. Sivashanmugam et al [7] says that the heat transfer coefficient enhancement for right left helical screw inserts is higher than that for straight helical twist for a given twist ratio. The effect of right-left length on heat transfer and friction factor were presented and found that heat transfer enhancement for 300 R and 300 L twist set is higher than that for 400 R and 200 L for all twist ratio. The empirical correlation for Nusselt number, and friction factor relating Reynolds number, twist ratio and right-left twist distance were formed and found to fit the experimental data within 10% and

20% for Nusselt number and friction factor, respectively. Paisarn Naphon [8] concludes that effect of twisted wires density, inlet fluid temperature, and relevant parameters on heat transfer characteristics and friction factor are considered. The swirl flow is generated as fluid flowing through the plain tube with twisted wires brush insert. Due to the presence of swirl flow, the convective heat transfer obtained from the plain tube with twisted wires brush insert is higher than that with the plain tube without twisted wires brush insert. Twisted wire brushes inserts have a significant effect on the enhancement of heat transfer; however, the pressure drops also increase too.

IV. Future Scope

Very less Researchers are working on heat transfer in tube in tube heat exchanger with helical screw tape insert. There is no recent work heat transfer coefficient and pressure drop in pipe in pipe heat exchanger using different materials of helical screw tape insert.

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