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A Review on Application of Double Ribbed Twisted Tapes in Heat Transfer Enhancement of Tubular Heat Exchanger

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Abstract- Nowadays, heat exchangers with twisted-tape inserts have widely been applied for enhancing the convective heat transfer in various industries such as thermal power plants, chemical processing plants, air conditioning equipment, refrigerators, petrochemical, biomedical and food processing plants. In general, twisted tape insert introduces swirl into the bulk flow which consequently disrupts a thermal boundary layer on the tube surface. Recently, the use of twisted tape with cuts and holes becomes popular due to their thermal performance improvement in comparison with other types of twisted tape and several studies have been carried out on these types of modified twisted tape. This work aims to propose a numerical model for heat transfer intensification in a heat exchanger tube equipped with novel V-cut twisted tape.

Keywords: Plane tube, plane tube with twisted tape, V- cut twisted tape, Nusselt number, Reynolds number, Performance factor, pressure drop, Friction factor.

I. INTRODUCTION

Nowadays, heat exchangers with twisted-tape inserts have widely been applied for enhancing the convective heat transfer in various industries such as thermal power plants, chemical processing plants, air conditioning equipment, refrigerators, petrochemical, biomedical and food processing plants. In general, twisted tape insert introduces swirl into the bulk flow which consequently disrupts a thermal boundary layer on the tube surface.

The thermal performance of heat exchangers can be increased by heat transfer enhancement methods. Tape insert is one of the passive heat transfer enhancement method and used in most heat transfer application, for example, air conditioning and refrigeration systems food processes. Enhancing the thermal performance of heat exchange affects directly on energy, material and cost savings. Consequently, improving the heat exchange can significantly improve the thermal efficiency in applications involving heat transfer

Processes as well as the economics of their design and operation [1]. DPHEs are primarily adapted to high temperature and high-pressure applications due to their small diameters. They are cheap, but the space they occupy is relatively high compared to the other types. To achieve the desired heat transfer rate in the given design and length of the heat exchanger at an economic pumping power, numerous techniques have been provided. These improvement techniques were classified as active and passive techniques [2, 3].

In recent days the twisted-tape inserts have been widely applied for enhancing the convective heat transfer in various industries, due to their effectiveness, low cost and easy set up. Because it also creates the swirl flow which improves the fluid mixing and mix the bulk flow well. It is relatively low cost and low pressure drop with less fouling problems.In general, using different ways to increase the surface area for heat transfer has contributed significantly in increasing the thermal performance of heat exchangers when compared with its counterparts without the surface optimization, but there is a downside in which the increase in pressure drop for the surface optimization and thus for maintaining the flow requires the use of recycling fluid pumps in a larger capacity than normal situation.

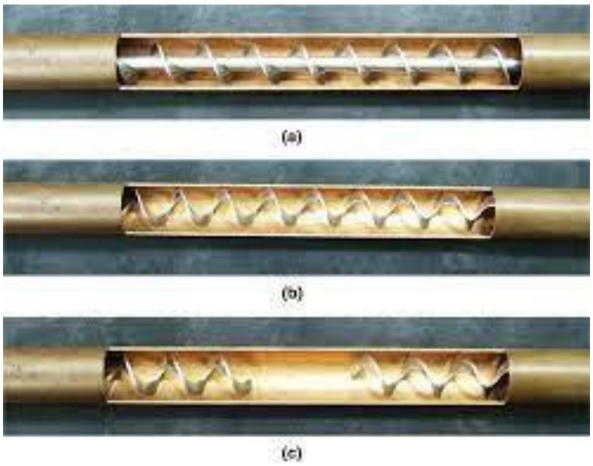

Fig 1. Double pipe heat exchanger with helical tape inserts.

II. HEAT TRANSFER MODE

The science of heat transfer is concerned with the generation, use, exchange, and conversion of heat and thermal energy between physical systems. Heat transfer is the discipline of thermal engineering that concerns the calculation of rate at which heat flows within the medium, across the interface or from one surface to another.

There are different modes of heat transfer which includes:
- Heat transfer through conduction
- Heat transfer through convection
- Heat transfer through radiation

III. HEAT TRANSFER AUGMENTATION

Heat transfer enhancement techniques generally reduce the thermal resistance either by increasing the effective heat transfer surface area or by generating turbulence in the fluid flowing inside the device.
Rough surfaces or extended surfaces are used for the purpose of increasing the effective surface area whereas inserts, winglets, turbulators etc. are used for generating the turbulence. These changes are usually accompanied by an increase in pumping power which can results in higher cost.

The effectiveness of a heat transfer enhancement technique can be evaluated by the Thermal Performance Factor (TPF) which represents the ratio of the relative effect of change in heat transfer rate to change in friction factor.

In general, some kind of inserts is placed in the flow passage to augment the heat transfer rate, and this reduces the hydraulic diameter of the flow passage. Heat transfer enhancement in a tube flow by inserts such as twisted tapes, wire coils, ribs and dimples is mainly due to flow blockage, partitioning of the flow and secondary flow. Flow blockage increases the pressure drop and leads to increased viscous effects because of a reduced free flow area. Blockage also increases the flow velocity and in some situations leads to a significant secondary flow.

Secondary flow further provides a better thermal contact between the surface and the fluid because secondary flow creates swirl and the resulting mixing of fluid improves the temperature gradient, which ultimately leads to a high heat transfer coefficient twisted tape generates a spiral flow along the tube length. A wire coil insert in a tube flow consists of a helical coiled spring which functions as a non-integral roughness.

IV. LITERATURE REVIEW

Azher et al. (2018) studied forced convection heat transfer through a horizontal pipe built-in with/without twisted tape-inserts is numerically studied under a uniform heat flux condition. Water is used as a working fluid.

Sivakumar et al. (2018) investigate the friction factor characteristics and heat transfer characteristics of a concentric tube with triangular cut twisted tape (TCTT) insert with twist ratio Y is 5.4 and depth of triangular cut was 1.2 cm were studied for laminar flow.
Mahipal et al. (2018) deals with the use of swirl flow devices with different combinations as passive heat transfer augmentation technique. In this article, the two different swirl flow devices used are namely twisted tape (TT) and wire coil (WC) turbulator. The present work deals with the counter flow type condition of heat exchanger. Effect of different length combination of these two different turbulator twisted tape and wire coil on the heat transfer, friction factor and pressure drop for Reynolds number ranges from

2000-10000, has studied in double pipe heat exchanger (single pass).

Agrawal et al. (2018) Heat transfer enhancement technique refers to different methods used to increase rate of heat transfer without affecting much overall performance of the system. These techniques are used in heat exchangers; some of the application of heat exchangers is in process industries, thermal power plant, air conditioning equipment, refrigerator, radar for space vehicles, automobiles etc. In the past decades several studies on passive techniques of heat transfer enhancement have been reported.

Bhattacharyya et al. (2017) Numerical investigation of heat transfer characteristics in a tube fitted with inserted twisted tape swirl generator is performed. The twisted tapes are separately inserted from the tube wall. The configuration parameters include the, entrance angle (α) and pitch (H).Investigations have been done in the range of α = 180o, 160o and 140o with Reynolds number varying between 100 to 20,000.

Maradiya et al. (2017) 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.

Mahdi et al. (2016) reported the use of variant twisted tapes fitted in a double pipe heat exchanger to improve the fluid mixing that leads to higher heat transfer rate with respect to that of the plain-twisted tape. Heat transfer, flow friction and thermal enhancement factor characteristics in a double pipe heat exchanger fitted with plain and variant twisted tapes using water as working fluid are investigated experimentally.

Jedsadaratanachai et al. (2014) presents a numerical analysis of laminar fully developed periodic flow and heat transfer in a constant temperature-surfaced circular tube with single twisted tape inserted. The twisted tape is introduced and inserted in the middle of the tested tube. The effects of twisted ratios (y/W = 1, 2, 3, 4, 5and 6) are presented for Reynolds number (Re) values ranging from Re = 100 to 2000. The SIMPLE algorithm and periodic condition are used in the current study.

Pawan et al. (2013) investigate the level of heat transfer enhancement that can be achieved by forced convection in which water is flow inside horizontal pipe. The use of semi-circular cut inserts generate turbulence and superimposed vortex motion (swirl flow) causing a thinner boundary layer and consequently resulting in higher heat transfer coefficient with relatively low flow resistance. The study is focused on Reynolds number in turbulent flow. In the proposed work the influence of semi-circular cut twisted tape on pressure drop, Nusselt number (Nu) and friction factor (f) are experimentally determined.

V. CONCLUSION

From the present review, it can be concluded that the heat transfer enhancement occurs in all cases due to reduction in the flow cross section area, an increase in turbulence intensity and an increase in tangential flow established by various types of inserts. Geometrical parameters of inserts like width, length, twist ratio, etc. affect the heat transfer enhancement considerably.

Twist direction is also an important parameter in case of multiple twisted tapes since the counter-swirl performs better than the co-swirl. The role of inserts in increasing the turbulence intensity is more significant in laminar regime than in turbulent regime. Therefore to enhance the heat transfer in turbulent flow, wire coil inserts are used.

In recent years, second generation enhancement techniques that combine the twisted tape inserts and wire coil have been used to get better heat transfer performance in laminar as well as turbulent flows. Some researchers have also used regularly spaced and perforated twisted tape for the purpose of material saving; the results have shown that the perforation can lead to TPF of more than one. Since perforation results in less obstruction. The regularly spaced twisted tape does not generate turbulence in non twisted tape area. Therefore, it is better to use full-length twisted tape instead of regularly spaced twisted tape.

In large Prandtl number flow, roughness performs better than the twisted tape and the maximum heat transfer occurs due to roughness when the roughness height is three times the viscous sub-layer thickness. The artificially corrugated rough surface can be developed to significantly improve the heat transfer characteristics by breaking and destabilizing the thermal boundary layer on the surface. Passive techniques are widely used in various industries for their cost saving, low maintenance requirements and easy set up.

The TPF reduces with increase in Reynolds Number. Twisted tape does not perform well where air is used as a working fluid. It performs well where water and nano fluid are used as working fluid because of larger density of liquid. Therefore for air heating applications vortex generators, ribs or deflectors are more helpful in increasing the TPF. In case of liquids swirl producing devices are more helpful in increasing the TPF.

Exhaustive research has been done by many investigators on the use of twisted tape, artificial roughness or vortex generators to enhance the heat transfer characteristics in tube heat exchangers as discussed in this review; however the areas related to outer tube geometries like conical, parabolic, frustum, etc have not yet been explored and could be the focus of new research.

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