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A Review on Heat Transfer Enhancement in Tubular Heat Exchanger with Twisted Tape

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Abstract- Thermal power stations, chemical processing plants, air conditioning equipment, freezers, petrochemical, biomedical, and food processing facilities are only some of the many current uses for heat exchangers with twisted-tape inserts, which promote convective heat transmission. As the twisted tape insert adds swirl to the bulk flow, it causes the thermal boundary layer on the tube's surface to separate. The thermal performance of heat exchangers can be enhanced by the application of heat transfer improvement methods. Tape inserts are a common passive heat transfer augmentation method used in many settings. These include air conditioning and refrigeration systems as well as the food processing sector.

Keywords- Heat Transfer Enhancement, Tubular Heat Exchanger, Twisted Tape.

I. INTRODUCTION

Improving the thermal performance of a heat exchange might lead to immediate savings in energy, materials, and finances. Therefore, improving heat exchange efficiency can have a significant influence on thermal efficiency and cost-effectiveness in systems that use heat transfer processes in their design and operation [1].

The most common applications for DPHEs are in high-temperature and high-pressure environments because of their small size. They're cheap, but compared to the alternatives, they take up a lot of room. It is possible to achieve the desired heat transfer rate within the limits of the heat exchanger's design and length with a minimum amount of pumping power by employing one of many strategies.

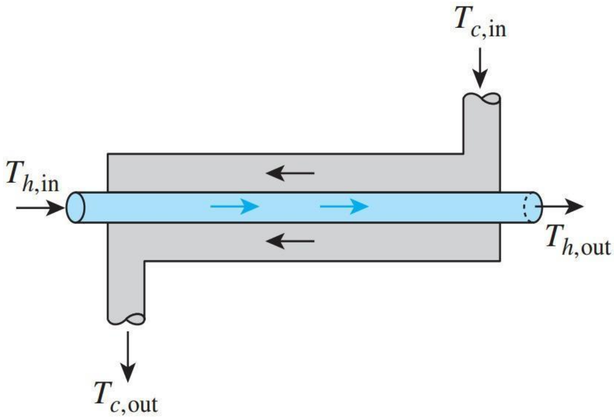

Fig 1. Double pipe heat exchanger.

Active and passive augmentation techniques were distinguished [2, 3]. Because of their effectiveness, low cost, and ease of installation, twisted-tape inserts have been increasingly popular in recent years to promote convective heat transmission. Because it creates a whirling motion that improves fluid mixing and guarantees a steady, uniform bulk flows. The pressure drop is negligible, the cost is low, and there are hardly any fouling difficulties.

The thermal performance of heat exchangers has been greatly improved by optimizing heat transfer surfaces in a variety of ways, but this improvement has come at a cost: higher pressure drops associated with these optimizations necessitate more powerful recycling fluid pumps to maintain flow.

II. HEAT TRANSFER MODE

Heat transfer is the study of how heat is generated, distributed, transformed, and utilized in a variety of physical contexts. Heat transfer is a branch of thermal engineering concerned with the study of the rate when heat flows through a material, over an interface, or from one surface to another.

There are several ways heat may be transferred, including:

- Heat transfer through conduction
- Heat transfer through convection
- Heat transfer through radiation

1. Convection:

Convection is a process that requires moving plenty of liquid around. Whenever a density difference is produced because of a temperature gradient, this process is known as natural convection or free convection. Consider the situation of an isothermal plate, in which both the plate's temperature and its surrounding temperature are kept constant. As the fluid near the wall warms and rises due to buoyancy, cooler fluid moves in closer to the wall to replace it. A revolving current is created as a result of the density difference.

A boundary layer of varied velocities, temperatures, and densities marks the transition from the plate to the free stream. As one travels farther into space, one's velocity first climbs to a peak, and then drops to zero. This is because the density difference decreases with distance from the plate at a faster rate than the influence of viscosity. Heat transfer enhancement has seen widespread use in the last several decades.

When a heat exchanger's heat duty per unit size has to be enhanced or when the size and cost of the equipment needs to be minimized, heat transfer enhancement is required. The goal is served by both active and passive enhancements. Active augmentation, in which more energy is added (often in the form of an electromagnetic field) to induce a specific change in the flow, constitutes a less common technique. Alterations to the heat transfer surface or the addition of a device that modifies the flow field are examples of passive enhancements.

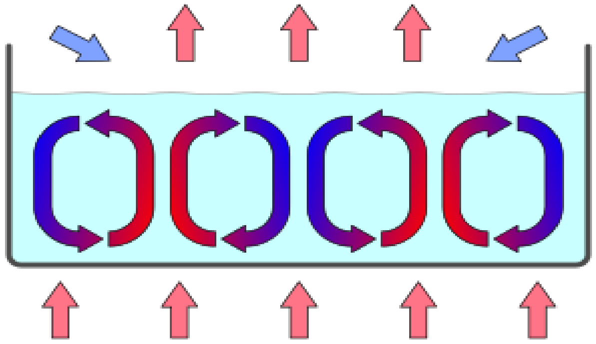

Fig 2. Convection.

III. HEAT EXCHANGER

A heat exchanger is a tool for maximizing the transmission of heat between two mediums, whether they are separated by an impassable barrier or in direct contact with one another. They are used in many fields, from the processing of natural gas to the cooling and heating of buildings to the production of electricity.

A heat exchanger is a mechanical device that transfers heat between two different systems or materials in order to preserve a desired temperature gradient. The purpose of a heat exchanger is to allow one fluid to transfer heat to another fluid while remaining physically separated from both. Heat exchangers come in a broad range of sizes and forms, but they all use some type of thermally conductive technology to physically separate the fluids.

IV. HEAT TRANSFER AUGMENTATION

Heat transfer enhancement techniques thermal resistance is often lowered by expanding the device's effective heat transfer surface area or by creating turbulence in the fluid's internal flow, or both. Inserts, winglets, turbulators, etc. are employed to generate turbulence, whereas rough surfaces or extended surfaces are utilized to increase the effective surface area. These alterations often need more expensive pumping equipment. The Thermal Performance Factor (TPF) quantifies the efficiency of a heat transfer improvement method by comparing the effect of its modification to that of the friction factor.

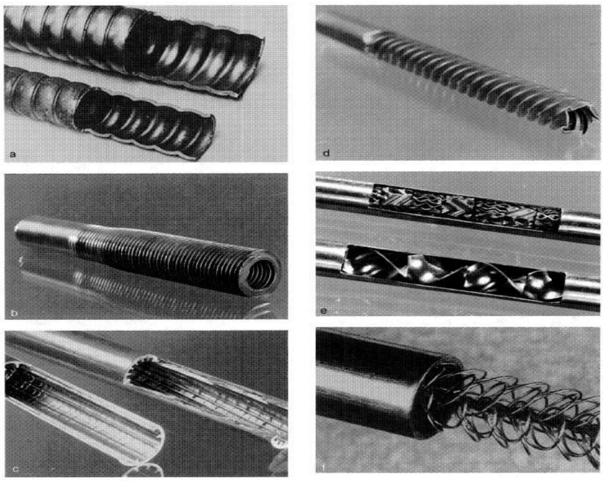

Fig 3. Heat Transfer Augmentation.

The hydraulic diameter of the flow route is often decreased when inserts are used to increase the heat transfer rate. Blocking the flow, dividing the flow, and secondary flow are the primary mechanisms by which inserts like twisted tapes, wire coils, ribs, and dimples improve heat transmission in a tube flow. Because of the decrease in free flow area, the pressure drops and the viscous effects of an obstruction both rise. When a flow is blocked, the speed of the flow rises and, in certain cases, a substantial secondary flow develops.

Furthermore, secondary flow offers greater thermal contact between the surface and the fluid as a consequence of the swirl and mixing of the fluid that is produced. This in turn results in a high heat transfer coefficient. A spiraling current is created along the tube's length when the tape is twisted. The non-integral roughness of a wire coil insert in a tube flow is provided by a helical coiled spring.

V. RELATED WORK

Azher et al. (2018) The effect of these variables on the local and average Nusselt Number and thermal performances was studied and compared to those of a simple pipe operating under the same conditions. The results demonstrate that for each Reynolds number, the average Nusselt number and friction factor increase with increasing twisted ratio. As Re and tape twist ratio were both increased, thermal performance factors trended upward. As can be seen, the mean thermal performance factor for the (V-cut) twisted-tape and the (P-TT) twisted-tape with TR=4 was greater (4.45 and 4.19, respectively) than that for TR=6. Finally, this research can provide some helpful insights for choosing application-specific, shell-and-tube heat exchanger geometrical parameters for a twisted tape insert.

Sivakumar et al. (2018) demonstrate that both the Reynolds number and the presence of TCTT inserts improve the induced heat transfer rate. There was a wide variety of Reynolds numbers used, from 5710 to 18366. Tubes with triangular-cut twisted tape inserts had Nusselt numbers that were 1.1 to 1.3 times higher than those of plain twisted tape tubes at Reynolds number analogues. Compared to ordinary twisted inserts, the friction factor and heat transfer rate were both improved with the TCTT arrangement.

Mahipal et al. (2018) In this analysis, water used as working fluid in both side inner side and annulus side also. Inserts has inserted in the inner pipe, which increases the heat transfer coefficient and Nusselt number compare to the plain tube. The friction factor is also increased compare to the plain tube. Simulations have carried out using software and the results obtained from the simulation has validated by comparing with the standard results published by the other journals research paper.

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 are 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. This paper reviews mainly on twisted tape heat transfer enhancement and its design modification towards the heat transfer enhancement and saving pumping power.

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 $\alpha = 180^o$, 160^o and 140^o with Reynolds number varying between 100 to 20,000. In this paper, transition - SST model which can predict the transition of flow regime from laminar through intermittent to turbulent has been utilized for numerical simulations. The computational results are in good agreement with experimental data. The results show that higher entrance angle yields a higher heat transfer value. The using of single twist twisted tape supplies considerable increase on heat transfer and pressure drop when compared with the conventional twisted tapes. A large data set has been generated for heat transfer and thermal-hydraulic performance which is useful for the design of solar thermal heaters and heat exchangers.

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.

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. affects 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.

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. Tests are performed for laminar flow ranges. The experimental data for a plain tube and plain-twisted tapes are validated using the standard correlations available in the literature. Two different variant twisted tapes which include V cut-twisted tape and Horizontal wing cut-twisted tape with twist ratios of $y = 2.0$, 4.4 and 6.0 are used. In addition, the variation of heat transfer coefficient of copper–nanofluids with different of Reynold's number and volume concentration of nanoparticles in plain tube without twisted tape. Based on these studies, the major conclusion has been arrived the Nusselt number, friction factor and thermal enhancement factor of variant twisted tapes are higher than that of plain twisted tape for the twist ratios of 2.0, 4.4 and 6.0 respectively so among the variant twisted tapes used in the present work, the horizontal wing cut-twisted tape give better performance due to the effect of increased turbulence which improves the fluid mixing near the wall of the test tube.

By increasing volume concentration of nanoparticles, thermal conductivity increases while the thermal boundary layer thickness decreases. The Maximum thermal enhancement factor for P-TT, V-TT and HW-TT are 3.903, 4.269 and 4.488 respectively and enhancement plain twisted tape is better than CuO-nanofluid be three times.

VI. CONCLUSION

Heat transfer augmentation techniques offer significant benefits in terms of improved system efficiency, reduced energy consumption, and enhanced performance. By employing methods such as turbulent flow, surface modifications, fluid additives, and optimized heat exchanger designs, industries can optimize heat transfer rates and achieve substantial cost savings.

As technology continues to advance, further research and development in this field will lead to even more innovative and efficient heat transfer augmentation techniques.

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