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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. 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.

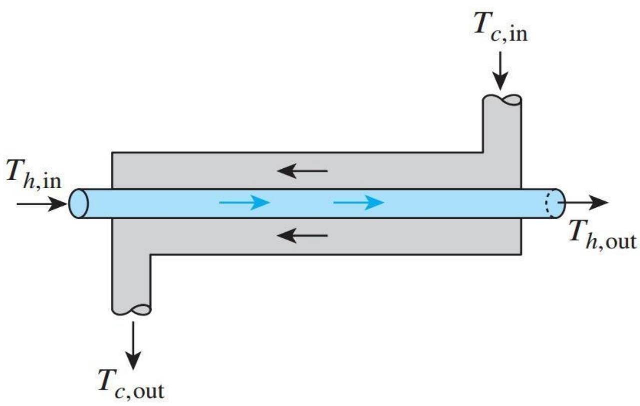

Fig 1. Double pipe heat exchanger.

II. 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 α = 180°, 160° and 140° 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 nano-particles, 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-nano fluid be three times.

III. RESEARCH METHODOLOGY

Recently, the use of TT with cuts and holes becomes popular due to their thermal performance improvement in comparison with other types of TT and several studies have been carried out on these types of modified TT. The main physical reasons for improved performance of these types of TT can be presented as: (1) Strong swirl flow induced by TT (2) The secondary vortex flow generated near the cuts and holes which improves the turbulent intensity of the fluid flow and (3) Better fluid mixing between the tube walls and the core region. The above literature review shows that the heat transfer enhancement by using modified TT.

Among the modified TT, the ones with cuts (V-cut, square-cut, etc.) show better heat transfer enhancement due to additional vortex flow through the cuts with improves the swirl flow and turbulent intensity of the fluid flow. However, the effects of different cut ratios on turbulent flow heat transfer and thermal performance intensification are limited explored. This has motivated the present study to perform numerical analysis for better understanding the flow structure and physical reasons for heat transfer enhancement through heat exchanger tubes equipped with Vcut TT.

Furthermore, while most of the previous studies have focused on cut ratios lesser than 1, It is necessary to explore the performance of the TT with larger cut ratios. This work aims to numerically investigate the effect of the double V-cut TT (0.6<b/c<1.25) on streamlines, turbulent intensity, velocity fields, heat transfer, friction, and the thermal performance factor of turbulent fluid flow through heat exchanger tubes. This numerical analysis could be helpful in designing of the advanced heat exchangers.

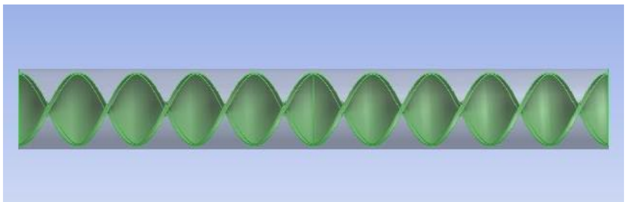

Fig 2. CAD model.

IV. BOUNDARY CONDITIONS

In the present investigation, the commercial CFD software FLUENT 6.3, which is based on the finite volume method, is used for the numerical computation, and the SIMPLE algorithm is used for finding a solution for the coupling between the pressure and velocity. The finite- element model is built and meshed using the software Gambit, and unstructured grids are used. The tetrahedral grid is used for meshing the models, and the grid in the region near the tube wall, which is highly refined, is considered as the boundary layer. Fig. 4.3 shows the meshing grid at z = 20 mm. The inlet and outlet conditions used in the calculation are periodic boundary conditions. The upstream temperature is 301.15 K, and the temperature of the tube wall is 343.15 K. No slip conditions are imposed on the tube wall and the surfaces of the twisted tape. The convergence criterion is that all the norms of the residuals for the continuity, momentum, and energy equations should be less than 10^{-6}

V. RESULTS AND DISCUSSION

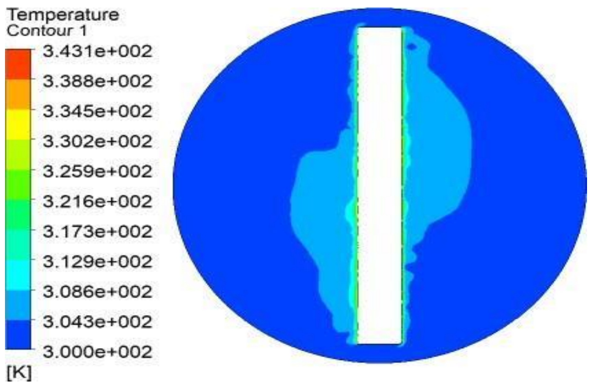

Fig 3. Temperature contour:

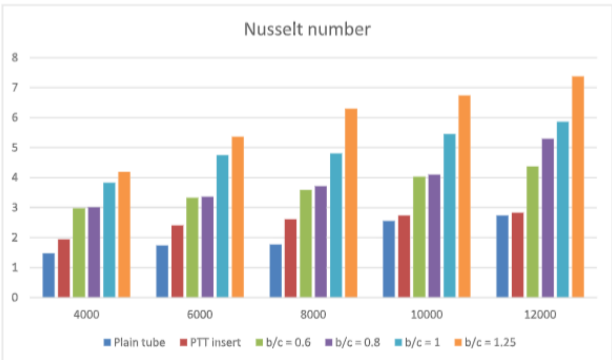

Fig 4. Nusselt number variation.

Figure 4 shows the variations of Nusselt number against Reynolds numbers for different double V-cut ratios. In this graph x axis shows the Reynolds number and y axis shows the Nusselt number. It can be seen, the Nusselt number increase when Reynolds number increase in plain tube and tube with PTT insert and cut ratio is increase when Reynolds number increase.

VI. CONCLUSION

The thermal performance of heat exchanger with twisted tape is numerically investigated at different Reynolds number, Nusselt number, pressure drop and friction factor, overall heat transfer ratio and thermal performance factor were evaluated using horizontal pipe with plain twisted tape (PTT)and V cut twisted tape (VTT) at different cut ratio (b/c) of 0.6, 0.8, 1 and 1.25).

As a result, the following conclusions are drawn:

- The use of twisted tape increases the heat transfer enhancement. The (V-cut) twisted tape presents a better heat transfer enhancement than that of the (P-TT) with all values of twisted ratio.
- The Nusselt number, pressure drop friction factor, overall enhancement ratio and thermal performance factor values for tubes with v-cut twisted tape (VTT) are greater than for plain tube and tubes with plain twisted tape (PTT). Given the strong vortex flow created by twisted tape, the rates of heat transfer are always higher for pipes using twisted tape. The Nusselt number is greater in V-cut twisted shapes (VTT); values increasing with increase in cut ratio. The thermal performance factor of VTT is better than PTT.

REFERENCES

[1] Azher M. Abed, Hasan Sh. Majdi, Zainab Hussein, Doaa Fadhil, Ammar Abdulkadhim (2018), Numerical Analysis Of Flow And Heat Transfer Enhancement In A Horizontal Pipe With P-TT And V-Cut Twisted Tape, Case Studies In Thermal Engineering,Vol 12,Pp 749–758.

[2] Pawan A. Sawarkar, Pramod R. Pachghare (2013), Experimental Analysis Of Augmentation In Heat Transfer Coefficient Using Twisted Tape With Semi- Circular Cut Insert, International Journal Of Science And Research, Volume 4 Issue 4,Pp 1174-1179.

[3] S. Liu, M. Sakr (2013), A Comprehensive Review On Passive Heat Transfer Enhancements In Pipe Exchangers, Renewable And Sustainable Energy Reviews, Vol 19, Pp 64–81.

[4] Mazen M. Abu-Khader (2012), Plate Heat Exchangers: Recent Advances, Renewable And Sustainable Energy Reviews, Vol 16, Pp 1883–1891

[5] M.A. Akhavan-Behabadi, Ravi Kumar, A. Mohammadpour, M. Jamali-Asthiani (2009), Effect Of Twisted Tape Insert On Heat Transfer And Pressure Drop In Horizontal Evaporators For The Flow Of R-134a, International Journal Of Refrigeration Vol 32, Pp 922-930.

[6] Halit Bas, Veysel Ozceyhan (2012), Heat Transfer Enhancement In A Tube With Twisted Tape

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Inserts Placed Separately From The Tube Wall, Experimental Thermal And Fluid Science, Vol 41, Pp 51–58.

[7] Suvanjan Bhattacharyyaa, Himadri Chattopadhyay, Ayan Halda r(2017), Design Of Twisted Tape Turbulator At Different Entrance Angle For Heat Transfer Enhancement In A Solar Heater, Beni-Suef University Journal Of Basic And Applied Sciences, Pp 1-24.

[8] Smith Eiamsa-Ard, Chinaruk Thianpong, Petpices Eiamsa-Ard, Pongjet Promvonge (2009), Convective Heat Transfer In A Circular Tube With Short-Length Twisted Tape Insert, International Communications In Heat And Mass Transfer, Vol 36, Pp 365–371.