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CFD Analysis of Tubular Heat Exchanger with Ribbed Twisted Tapes for Heat Exchanger Enhancement

M.Tech. Scholar Vinita Kapse, Prof. Sharvan Vishwakarma
Department of Mechanical Engineering,
TIEIT, Bhopal

***Abstract*- A heat exchanger is really a system that transfers heat between two or more fluids. The fluids can also be single-phase or two-phase, so they can be isolated or in close contact, depending on the form of exchanger. In this study, two twisted ribbons are inserted into another heat exchanger tube and heat transfer is studied. The aim of both the ongoing project is to figure out how fast heat transfers in a circular tube with entangled ribbons. The Reynolds (Re) number as well as the geometry of tube is the parameters of concern. For the first case, diameter of tube is taken 50.8 mm and length 1000 mm. For the second case the diameter is increased and length is kept constant, diameter is constant and length is increased for third case, and for fourth cases both length and diameter is increased. It is found that with the increase in both length and diameter of tubes, the heat transfer is increasing, pressure drop is decreasing by 56%, Nusselt number (Nu) is decreasing by 72% and the thermal enhancement factor is increasing by 12%. It can be concluded that the increase in diameter results in decrease in heat transfer while increase in length is preferable for increase in heat transfer rate. Hence, among the selected four designs, the fourth case with diameter=80mm, and length=3000 mm is the most preferable one.**

***Keywords*- Heat exchanger, single-phase, Nusselt number (Nu), Reynolds (Re), thermal enhancement factor, pressure drop.**

I. INTRODUCTION

A heat exchanger is really a system that transfers heat between two or more fluids. The fluids can also be single-phase or two-phase, so they can be isolated or in close contact, depending on the form of exchanger. While many of the ideas used in their construction are the same, devices containing power sources, including such nuclear fuel pins or burning stoves, really aren't usually called heat exchangers. In heat exchangers, There seem to be no external relations involving heat and function in most cases. Heating or cooling a fluid stream including evaporating or condensing fluid streams with one and sometimes more components are common applications. Other goals could be to recover or refuse heat, or to sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or monitor a process fluid.

Shell and tube heat exchangers or condenser (cooler) tubes have a high degree of heat energy transfer, making them among the most important, and not the most important, elements of the device. The ability of even a heat exchanger to maximize heat transfer determines its efficiency. Scale formation of scale significantly decreases the ability of both the heat exchangers and condenser tubes which pass heat, affecting the cooler's overall efficiency. To address this problem despite having to halt operations in order to clean their pipes, cleaning systems for in-line use can be produced. The entangled tape method is one such approach.

The twisted tape inserts have been used as a heat transfer enhancement device in last few decades and particular most widely used in heat exchangers to reduce their size and cost. Depending upon the application, twisted tapes are used with different twist ratio, with varying twist direction, fit and loose tape insert, full and short tape insert, perforated insert, insert with peripheral cuts, etc.

Twisted tapes (TT) are also one of the well-known swirl generators due to their easy installation and low cost. In general, swirl flow improves the fluid mixing between the tube walls and core region leading to more effective thermal boundary layer disruption and thus enhances the heat transfer rate.

These benefits associated with thermal performance enhancement have led to developing various modified TT to improve the thermal performance of heat exchangers.

II. LITERATURE REVIEW

Farhan, Ammar et al. (2021) The energy and exergic study of a V-shaped corrugated solar air heater (VCSAH) integrated with the woven ribbon insert were investigated analytically and numerically (TTI). The TTI becomes contained in the air ducts created either by absorber and rear surfaces. For a broad variety of Reynolds (Re) numbers in practical weather results, the effect of geometry parameters including such braided belt ratio (Y) and channel number (N) on thermo hydraulic efficiency is investigated. The findings show that as Y decreases, VCSAH-thermo TTI's order to generate energy first rises to a particular value of Re to achieve its optimum value, then decreases. Whenever the TTI is applied, the optimum number of channels for maximum thermo-hydraulic performance is N=5.

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Mashayekhi et al. (2021) Al2O3-water nano fluids used in combination with fixed and rotating twisted tape inserts aim to increase the rate of heat transfer in a flat tube. The simulations are performed by varying the design parameters, including the angular velocity of the twisted web, the Reynolds number and the volume concentration of the nano fluids. It has been found that inserting a twisted ribbon into a tube substantially increases the heat transfer coefficient and the friction factor relative to the smooth tube.

Kulkarni et al. (2021) enhanced heat exchanger thermal efficiency that affects electricity, material, and amperes; cost reductions led to the introduction of the use of several heat transfer enhancement techniques. Through decreasing the thermal resistance in a heat exchanger, augmentation techniques improve convection heat transfer. Twisted ribbons, a type of passive heat transfer enhancement techniques that have shown significantly good results in previous studies.

Tiwari, Arun Kumar et al. (2021) among a double concentric tube heat exchanger, another additional tube was added. The whole thing is done with the conditions with heat transfer from turbulent fluid through fluid in mind. The impact of various thermal parameters, such as total heat transfer or performance, was the subject of the project using the WO3 / water nano fluid with so many different inserts such as twisted tape, rib and porous plate.

Hakim et al. (2021) performed numerical simulations to investigate the improvement of heat transfer in a tube equipped with a rectangular cut braided tape insert and to compare the data with a smooth tube. For this, CFD (Computational Fluid Dynamics) was used to simulate the three-dimensional model with the appropriate boundary conditions. The numerical results show that the flow field can be adjusted and the boundary layer thickness can be reduced by inserting the rectangular cut braided tape insert so that the heat transfer can be improved in the pipe. Water was used as a working fluid.

Paneliya, Sagar et al. (2021) studied and reported the performance of a heat exchanger equipped with an X-shaped ribbon insert. The total heat transfer coefficients, efficiency, friction factor, including decrease in fluid pressure flowing through to the U-tube fitted with an X-shaped ribbon insert were calculated across an experimental investigation. Along with its availability but machine ability, mild steel had been used to make X-shaped ribbon inserts. Two 1m long X-shaped tape inserts the 2.4m long U-shaped tunnel was filled with them.

Liaw, Kim Leong et al. (2021) Underneath a steady wall temperature, numerically analyze the heat transfer of turbulent flow in a helical tube with the twisted ribbon insert. A three-dimensional computational fluid dynamics model was proposed and verified using experimental data and correlations. Following that, the model was used to evaluate turbulent convection heat transfer in straight or helical tubes with or without a heat exchanger twisted ribbon insert. The influence of both the torque ratio as well as the Reynolds number at the input are often evaluated to get a full picture of both the heat transfer efficiency.

Bhattacharyya et al. (2021) experimentally and numerically studied the effect of BTT on heat transfer performance in new triangular axial corrugated tubes is. To increase the thermohydraulic performance, a corrugated pipe with inserts is offered.

Farshad et al. (2019) exhibited loss of exergy and heat transfer from a mixture of aluminum oxide and H2O through a solar collector. The finite volume method was used, considering it feasible. Said turbulence model was selected for its best concordance with previous experimental results. To ensure the accuracy of the code, comparisons with numerical and experimental outputs were provided for different Reynolds numbers (Re), number of revolutions (N) and diameter ratio (D *).

Tusar et al. (2019) presented a three-dimensional computational study of conjugate heat and mass transfer performed using the "ANSYS FLUENT Computational Fluid Dynamics (CFD) software package to study the effect of insert torque on heat transfer and fluid flow performance. A survey was conducted for airflow at 300 Kelvin and Reynolds number between 3642 and 21857 through a pipe with a constant wall heat flux of 8000 W / m2. Validating against the Gneilski and Petukhob models," the influence of both the 3.46 and 7.6 torque ratio inserts mostly on Nusselt number, friction factor, and thermal efficiency factor of both the pipe were investigated using the current model.

Nakhchi et al. (2019) "Analyze the thermal performance of the turbulent flow inside the heat exchanger tube equipped with alternating axis braided belt (CCTA). Design parameters include Reynolds number (5000 <Re <15,000), cross section width ratio (0.7 <b / D <0.9) , cross section length ratio (2 <s / D <2.5) and the torsion ratio (2 <e / D <4) .

Nakhchi et al. (2019) The flow structure and thermo-hydraulic output of turbulent flow through a circular tube filled for twisted belts of various cut shapes were investigated using a numerical analysis. For two sets of specific cuts, the cutting geometries were rectangular for various cutting ratios of 0.25 b / n 0.75 and 0.25 c / w 1. (single and double cut). Experimental evidence from the literature was used to test the three-dimensional simulations.

Singh et al. (2019) The thermal properties and flow characteristics of such a fluid in a circular tube containing elliptical inserts were investigated experimentally and

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computationally. The hydraulic diameter, which is 6.81 cm, is used as main axis. "The height ratio (= b / D) has also been considered as a new parameter with three values: 0.45, 0.66, and 0.74.

"CFD analysis of tubes with circular inserts through vertical twisted tapes (CVTT) and elliptical inserts for vertical twisted tapes (EVTT) When comparing to smooth tube, heat transfer improvements range from 3–8 times for CVTT placed in full length and TPF from 1.19–2.63 times for CVTT placed in TL length."

Tusar et al. (2019) performed a three-dimensional (3D) computational fluid dynamics (CFD) analysis to study heat transfer performance and fluid flow characteristics using a helical screw tape insert in the pipeline flow. The geometry of the inserted tube has been improved by using a helical coil, i.e. wound in wire with a torque ratio of 1.92.

Gorjaei et al. (2019) consider inserting twisted ribbon and turbulent flow of nano fluids (passive techniques) in order to improve heat flow through the curved tube Copper is used for the curved tubing and braided tape. The evaluation segment (curved tube) is submerged in even a hot water pool. A three-step process is often used to process the water/Al2O3 nano fluid. Influences of volumetric flow rate, nano particle concentration, including twisted ribbon insert onto convective flow heat transfer coefficient, The Darcy friction factor as well as the Nusselt number were examined. The curved tube for twisted ribbon insert increases the heat transfer coefficient through convection through up to 31%, according the findings.

Sarviya et al. (2018) described experimental work on increasing heat transfer employing woven tape with continuous cutting edges, a modern form of insert. The friction factor and Nusselt number for a current twisted ribbon insert with separate twist ratios of 3 and 5 are being determined. To ensure the validity of the experimental findings, the flat tube and traditional twisted ribbon data were cross-checked with normal correlations.

III. RESEARCH METHODOLOGY

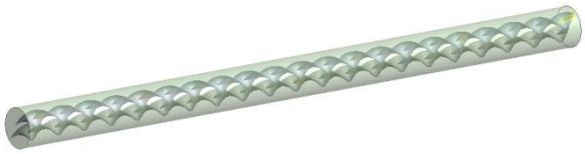
1. Model Description:

1.1 Physical model

Figure 3.1 depicts the heat exchanger's framework with twisted ribbon inserts. To maximize the heat transfer rate, two twisted ribbons are inserted into heat exchanger tube, and air (fluid) with a different Reynolds number is added. The copper pipe is 3000mm long with the a 50.8mm inner diameter (D) and a total length of 1000mm. The tapes used were twisted aluminum foil tapes with a twist ratio of y / w = 4.24mm wide (w) and 96mm twist length (y). The aim of both the ongoing project is to figure out how fast heat transfers in a circular tube with entangled ribbons. The Reynolds (Re) number as well as the geometry of tube are the parameters of concern.

The heat source is provided in the pipe wall and the heat input is kept around 10kW.

(a) Dia=50.8, Length=1000



(b) Dia=60.8, Length=1000

(c) Dia=50.8, Length=2000

(d) Dia=80, Length=3000

Fig 1. Pipe having 2 twisted tapes inserts.

Table 1. Main geometry data for testing (Sombat Tamna, 2015).

Pipe diameter	50.8mm
Pipe length	1000 mm
Pitch of twisted tape	96 mm
Width of tape	24 mm
Thickness of tape	0.8 mm
Material of tape	Aluminium
Material of tube	Copper

1.2 Meshing of Domain:

The meshing of the solid modeling is an important step so as to give the solid modeling the required nodes and element for performing a finite element analysis of the model. The meshimg used is hexagonal grid.

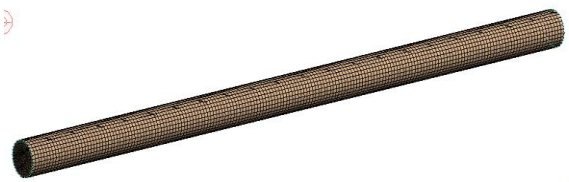


Fig 2. Mesh model.

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IV. RESULTS AND DISCUSSION

1. Result:

For the first case, diameter of tube is taken 50.8 mm and length 1000mm. For the second case the diameter is increased and length is kept constant, diameter is constant and length is increased for third case, and for fourth cases both length and diameter is increased.

Table 2. Simulation runs corresponding to different Reynolds no.

Case	Reynolds no.	Diameter(m)	Velocity(m/s)	Inlet temperature, Tin (K)	Outlet temperature Tout (K)	Twall(K)
dia=50.8 mm, length=1000 mm	15000	0.0508	4.614071	300	446	784
	20000	0.0508	6.152094	300	440.202	773.808
	25000	0.0508	7.690118	300	434.4794	763.7485
dia=60.8 mm, length= 1000mm	25000	0.0608	6.425296	300	422	782.88
	25000	0.0608	6.425296	300	416.514	772.7026
	25000	0.0608	6.425296	300	411.0993	762.6574
dia=50.8 mm, length=2000 mm	15000	0.0508	4.614071	300	587	887
	20000	0.0508	6.152094	300	579.369	875.469
	25000	0.0508	7.690118	300	571.8372	864.0879
dia=80 mm, length=3000 mm	15000	0.0808	2.900926	300	572	931
	20000	0.0808	3.867901	300	564.564	918.897
	25000	0.0808	4.834876	300	557.2247	906.9513

For the numerical simulation, the Reynolds number for each case is varied from 15000 to 25000 in steps of 5000 contributing to three sub cases for all four cases hence a total of 12 cases are studied and the results are compared.

2. Result Analysis Diagrams:

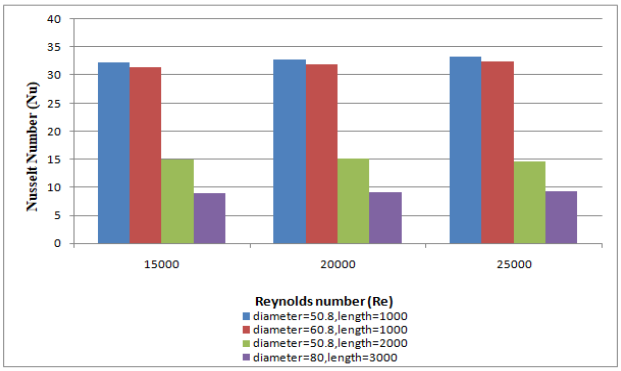

Fig 3. Variation of Reynolds number with Nusselt Number.

The above graph shows that,

- The Nusselt number also increases with the increase in Reynolds number.
- With the increase in diameter of tube, the nusselt number is decreasing
- With the increase in length of tube, the nusselt number is decreasing

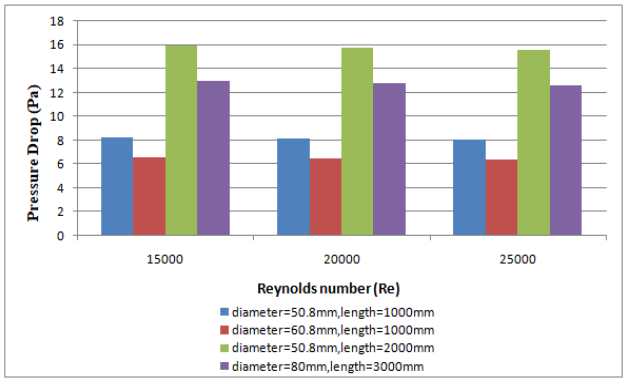

Fig 4. Variation of Reynolds number with pressure drop.

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The above graph shows that,

- The pressure drop increases with the increase in Reynolds number.
- With the increase in diameter of tube, the pressure drop is decreasing
- With the increase in length of tube, the pressure drop is increasing

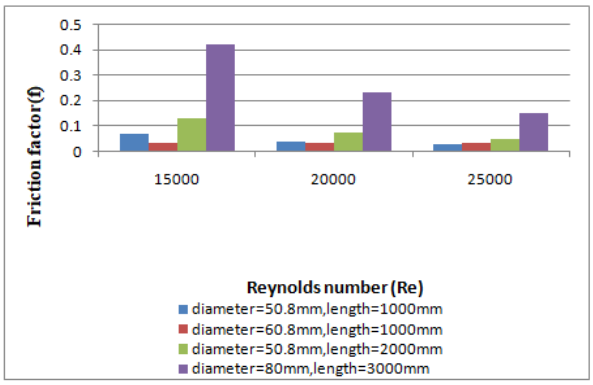


Fig 5. Variation of Friction factorin pipe.

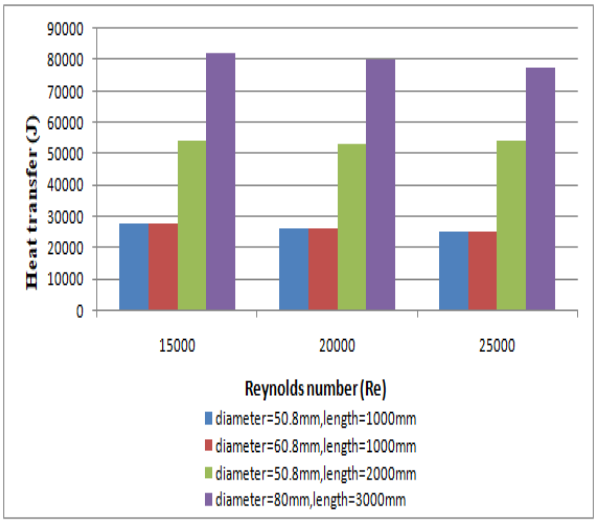


Fig 6. Heat transfer variation in pipe.

3. Comprehensive Performance Analysis:

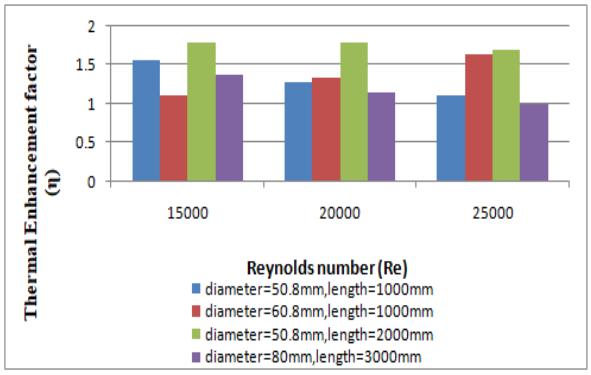


Fig 7. Variation of thermal performance factor for pipe with double tape.

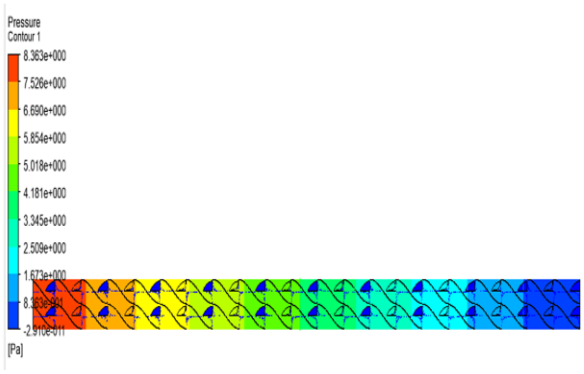
The thermal performance enhancement factor ηrelates the thermohydraulic performance of a twisted tape insert pipe with without tape insert pipe

$$\eta = \frac{Nu}{Nu_p}\left(\frac{f}{f_p}\right)^{-\frac{1}{3}}$$

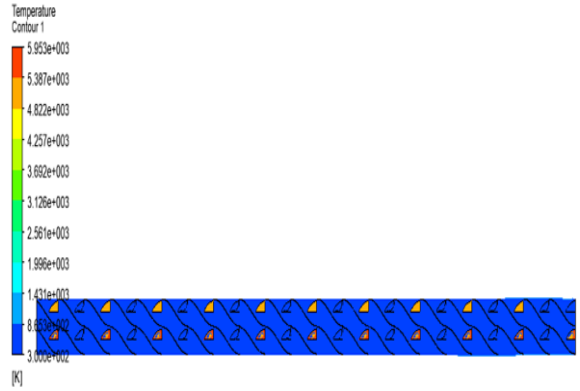
4. Contour Diagrams:

The contour diagrams for the axial velocity, pressure and temperature in the mid-section of the tube for tape inserts are shown below.

Case 1: Dia=50.8mm, Length=1000mm

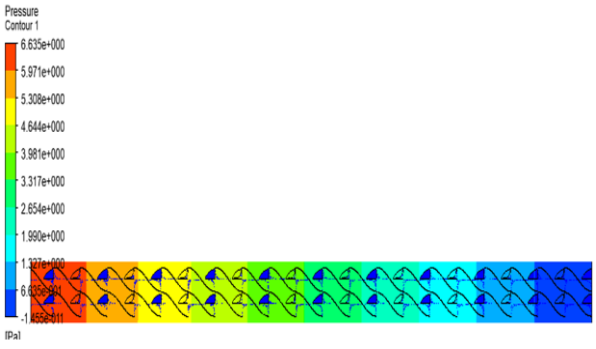


(a) Pressure contour.

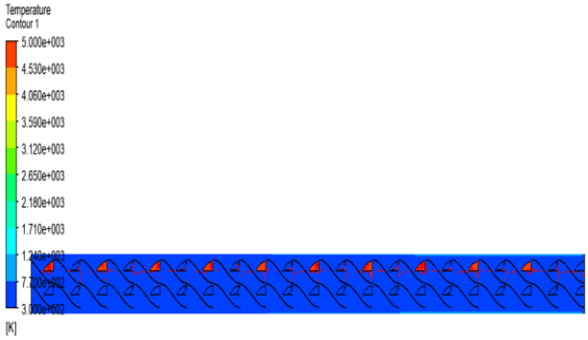


(b) Temperature contour.

Case 2: Dia=60.8mm, Length=1000mm

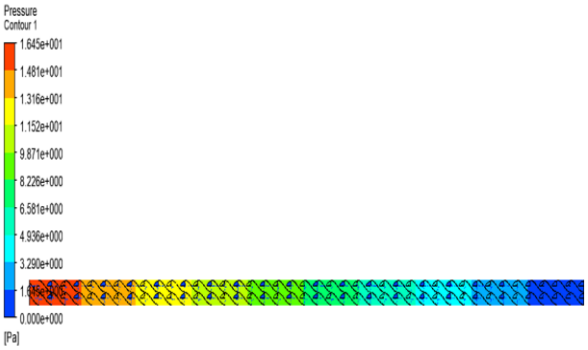


(a) Pressure contour.

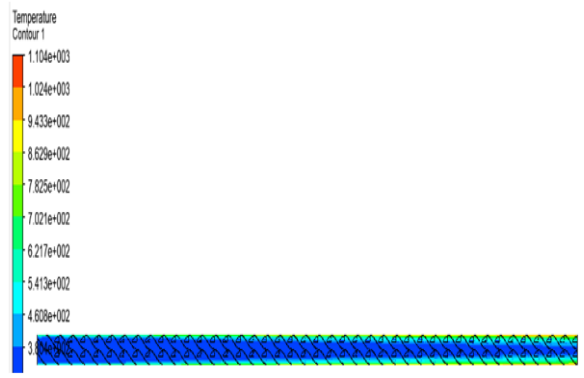


(b) Temperature contour.

Case 3: Dia=60.8mm, Length=1000mm

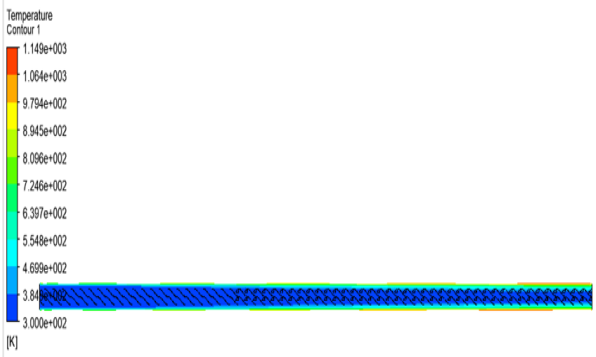


(a) Pressure contour.



(b) Temperature contour.

Case 4: Dia=80mm, Length=3000mm



(a) Temperature contour.

(b) Pressure contour.

Fig 8. Contour Diagrams.

V. CONCLUSION

In this study, a parametric study is performed to investigate the effects of twisted tapes inside the heat exchanger on the different parameters such as pressure drop (Δp) ,Heat transfer coefficient (h), Nusselt number (Nu), and Friction factor (f).

The following results are drawn from the above analysis;

- With the increase in diameter of tube (20% increase), (keeping length constant) the heat transfer is increasing by .01%, pressure drop (Δp) is decreasing by 20%, Nusselt number (Nu) is also decreasing by 2.6% and hence the thermal enhancement factor is also decreasing by 28.7%.

- With the increase length of tubes (by 100%), (keeping diameter constant), the heat transfer is increasing by 49 %, pressure drop (Δp) is increasing by 48%, Nusselt number (Nu) is decreasing by 92% and the thermal enhancement factor is increasing by 13%.

- With the increase in both length and diameter of tubes, the heat transfer is increasing, pressure drop (Δp) is decreasing by 56%, Nusselt number(Nu) is decreasing by 72% and the thermal enhancement factor is increasing by 12%.

From the above results it can be concluded that the increase in diameter results in decrease in heat transfer while increase in length is preferable for increase in heat transfer rate. Hence, among the selected four designs, the fourth case with diameter=80mm, and length=3000mm is the most preferable one.

REFERENCES

[1] Mashayekhi, Ramin, Hossein Arasteh, Pouyan Talebizadehsardari, Apurv Kumar, Morteza Hangi, and Alireza Rahbari. "Heat transfer enhancement of nanofluid flow in a tube equipped with rotating

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twisted tape inserts: A two-phase approach." Heat Transfer Engineering (2021): 1-16.

[2] KULKARNI, KG, SY BHOSALE, and SN SATPUTE. "Experimental Investigation of Heat Transfer Enhancement of Corrugated Twisted Tape Insert with Cfd Analysis." JournalNX 1, no. 2: 1-8.

[3] Tiwari, Arun Kumar, Summaiya Javed, Hakan F. Oztop, Zafar Said, and Naimish S. Pandya. "Experimental and numerical investigation on the thermal performance of triple tube heat exchanger equipped with different inserts with WO3/water nanofluid under turbulent condition." International Journal of Thermal Sciences 164 (2021): 106861.

[4] Hakim, M. U., M. W. Hridoy, M. I. Islam, and M. S. Rayhan. "Numerical study of heat transfer enhancement through a circular tube fitted with and without rectangular cut twisted tape insert." In IOP Conference Series: Materials Science and Engineering, vol. 1017, no. 1, p. 012019. IOP Publishing, 2021.

[5] Paneliya, Sagar, Sakshum Khanna, Jeet Mehta, Vishal Kathiriya, Umang Patel, Parth Prajapati, and Indrajit Mukhopdhyay. "An Experimental and CFD Analysis on Heat Transfer and Fluid Flow Characteristics of a Tube Equipped with X-Shaped Tape Insert in a U-Shaped Heat Exchanger." In Proceedings of the 7th International Conference on Advances in Energy Research, pp. 1331-1348. Springer, Singapore, 2021.

[6] Liaw, Kim Leong, Jundika C. Kurnia, and Agus P. Sasmito. "Turbulent convective heat transfer in helical tube with twisted tape inserts." International Journal of Heat and Mass Transfer 169 (2021): 120918.

[7] Bhattacharyya, Suvanjan, Ali Cemal Benim, Rachid Bennacer, and Kunal Dey. "Influence of Broken Twisted Tape on Heat Transfer Performance in Novel Axial Corrugated Tubes: Experimental and Numerical Study." Heat Transfer Engineering (2021): 1-22.

[8] Farshad, Seyyed Ali, and M. Sheikholeslami. "Nanofluid flow inside a solar collector utilizing twisted tape considering exergy and entropy analysis." Renewable Energy 141 (2019): 246-258.

[9] Tusar, Mehedi, Abdullah Noman, Majedul Islam, Prasad Yarlagadda, and Bodius Salam. "CFD study of heat transfer enhancement and fluid flow characteristics of turbulent flow through tube with twisted tape inserts." Energy Procedia 160 (2019): 715-722.

[10] Nakhchi, Mahdi Erfanian, and J. A. Esfahani. "Sensitivity analysis of a heat exchanger tube fitted with cross-cut twisted tape with alternate axis." Journal of Heat Transfer 141, no. 4 (2019).

[11] Nakhchi, M. E., and J. A. Esfahani. "Numerical investigation of rectangular-cut twisted tape insert on performance improvement of heat exchangers." International Journal of Thermal Sciences 138 (2019): 75-83.

[12] Singh, Satyendra, Lokesh Pandey, HimanshiKharkwal, and HimanshuSah. "Augmentation of thermal performance of heat exchanger using elliptical and circular insert with vertical twisted tape." Experimental Heat Transfer (2019): 1-16.

[13] Tusar, Mehedi, Kazi Ahmed, Muhammad Bhuiya, PalashBhowmik, Mohammad Rasul, and NanjappaAshwath. "CFD study of heat transfer enhancement and fluid flow characteristics of laminar flow through tube with helical screw tape insert." Energy Procedia 160 (2019): 699-706.

[14] Gorjaei, ArashRezaei, and AzadehShahidian. "Heat transfer enhancement in a curved tube by using twisted tape insert and turbulent nanofluid flow." Journal of Thermal Analysis and Calorimetry 137, no. 3 (2019): 1059-1068.

[15] Sarviya, R. M., and VeereshFuskele. "Heat transfer and pressure drop in a circular tube fitted with twisted tape inserts having continuous cut edges." Journal of Energy Storage 19 (2018): 10-14.

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