Investigation of Heat Transfer Characteristics in Double Tube Heat Exchanger with Helical Turbulator Using CFD

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1 Introduction

In certain applications, heat must be transmitted from fluid to fluid through a solid barrier that is used for the separation of fluids at a different temperature. The heat exchanger comprises thermal mechanics and businesses, such as air-conditioning and coolers, solar collectors, petrochemical fields, geothermal energy systems, etc. Many methods of heat transfer development are known in order to raise the heat transfer coefficient and thus increase the heat exchangers' thermal performance and to minimize running costs. Due to steep increase in energy demand, the appliance of heat exchangers to various thermal systems has been common for the past few decades. So far, many design and development modifications of heat exchangers to improve geometry and efficiency have been made. Heat exchange systems are designed to increase the heat transfer and reduce the pressure drop by developing nature-based structures. A comprehensive long-term performance calculation based on experimental heat transfer and pressure drop outcome is required for the optimal

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P. Verma et al. (eds.), *Advancement in Materials, Manufacturing and Energy Engineering, Vol. II*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-16-8341-1_45

design of a heat exchanger. Almost all heat transfer strategies are expected to lead to a further decrease in pressure that leads to an increase in pump power consumption. Therefore, it is important to choose the technique for optimizing heat transfer with the supportable frictional loss. The modification or shift of the heated channel for the applications settled upon new techniques for heat transfer enhancement in the warming exchanger.

The heat exchanger is used for transferring thermal energy from the fluid to the solid, to the fluid, to a certain temperature, and thermal interaction. There is normally no extra fuel and collaborations in the heat exchangers. A significant difficulty in creating heat exchange systems is to improve the one-phase temperature transport, particularly when one phase of fluid flow is carried out on one side by thermal exchangers and the two-phase flows or transfers on the other. Condensing machines, evaporators, heat exchangers, and others are typical examples for a range of consumption and performance applications [1, 2]. The thermal transfer process improves the efficiency of a thermal transfer device. It normally means increasing the coefficient of heat transfer. Twisted tap inserts provide an inexpensive and effective approach for heat transfer optimization. Although the inserts can help to get the heat transferred, they can greatly decrease the inflow pressure. In any type of thermal systems, it is vital for the industry to increase thermal transmission capacity. In addition to the handling of primary oil, the weight and height often decrease [3].

Bhuiya et al. [4, 5] studied the structure of the twisted tape insert with different geometrical criteria, such as twist ratio and width ratio. In the tube, the heat propagation and friction effects are tracked single and double twisted tapes. The value of the twist ratio decreased considerably more heat transfer and friction. The twisted tape profile mainly disturbs the principal flow and therefore other geometrical variations are made use of the tweaking tape. An analysis was carried out on the turbulent forced convection with circular hole inserts in a circular vessel [6]. For a wide variety of Reynolds numbers inserts with various hole-spring ratios are investigated. Data reveal that using inserts results in an improvement between 35 and 51% in thermal transfer when evaluated with other inserts and single tube. Due to twisted tapes, Bhattacharya [7] researched the effects of swirl generators on energy transport using the SST model computationally. The analysis evaluated flow with Reynolds numbers and found that the characteristics of heat transfer usually increase, along with a higher-pressure decrease. The performance increase was found to be positive, however, only in such settings. In a second analysis, it has been concluded that it fits better than the smooth tube in a certain diameter and pitch. Thermodynamically desirable characteristics than other particles were given for the bluffing cylinders of suitable duration. Improvement techniques can be broadly categorized into passive and aggressive techniques. Passive techniques, such as raise of the roughness of tubes on the face or the attachment of swirl flow devices to a tube do not entail direct input of external force. By contrast, external inspection for required flow adjustment as well as an increasing thermal transfer rate is important for active processes [8, 9]. The thermal efficiency and fluent flow of a double pipe heat exchanger whose inner tube wall had been helically corrugated was numerically tested by Gorman et al. [10]. The results of the simulations showed that the heat transference rate in the helically corrosive dual-level heat exchanger was increased by 3 compared to that on the smooth wall-pipe heat exchanger for both parallel and counterflow. In addition, in the former the pressure increased by a factor of 2–4 in contrast with the latter.

Helical insert is one of the most important means of heat transfer in heat exchangers. Many researchers, with the aid of finite element analysis and the computational fluid dynamics (CFD), have analyzed, calculated, and checked their findings in various mechanical heat transfer applications [11–14]. Style improvements are required to boost thermal efficiency. The purpose of the project is to test the efficiency of the ANSYS CFX by a double-pipe heat-exchanger helical inserts by using CFD analysis. For thermal exchangers without the helical insert, the convective wall heat fluid and the temperature distribution along with the tubing would be studied in a comparative examination.

2 Double Tube Heat Exchangers

A major part of modern mechanical cooling systems is double tube heat exchangers (DTHE). The thermal transfer efficiency of a heat exchanger was generally decided upon. This study aims to examine the transfer of heat and entropic generation in numerical terms in a two-pipe helical heat swap with numerous cross sections. The findings were verified and a theoretical model for laminar convective heat transfer was developed. The previous literature has been published. The entropy balance equation for the open system is used for compiling entropy production. Given the numerical data, the effect of internal tube number and the inlet mass variance ratio of the tube were studied and addressed on the eccentricities and flow of co-flow and counter flow. In relation to the geometry, the pipe area, cross-sectional annulus area and internal pipe thickness are the same. The geometrics are called equivalent. The conclusions demonstrate the most effective method for heat transfer, pressure reduction, and entropy output to be achieved by the square cross section. A concentrated setup is best suited for low flow speeds, whereas a more eccentric exterior setup is better suited for high flux rates.

Rennie and Raghavan [15, 16] conducted experimental and computing tests on the two helical heat exchangers. There were modest problems with the average heat transfer coefficient between the parallel flow and the controller flow, but the counterflow is dramatically greater. In comparison, a higher percentage of the internal dean led to the higher average heat transfer coefficient. Boonsri and Wongwises [17] theoretical study and laboratory tests investigated the heat transfer properties of helical, crimmed, heat exchangers, and finned-tube heat exchangers. The flow rate of the water mass and the water inlet temperature have, however, seen to have a direct effect on the air outlet and water temperature.

3 Methodology

Research on the use of insert turbulators to maximize the transmission of heat is exponential because of positive outcomes. The literature repeatedly notes that inserting the insert in the tube has an important impact on heat transfer rate and pressure rises. From the past studies, the geometry incorporated in the region around the wall and not in the core stream can create turbulence. The most suitable types of insertions based on these results are guided wire inserts, ring inserts, and conical inserts. The decrease in pressure is also increased, but, with increasing temperature transfer rates, the belt implant can be demonstrated as effective. Due to friction with increased heat transfer rates, perforated ring inserts were found that minimize stress drop.

Twisted tape inserts provide a simple and economical way to optimize heat transfer. The flow pressure reduces considerably though inserts can be useful for thermal transfer. For the industry, the speed improvements of thermal transmission in all kinds of thermal devices are very important. Besides the savings in essential oil, size, and weight are both minimized. One of the most efficient techniques used for heat transfer in heat exchangers is the helical injection. Better thermal performance design is key [18]. The research aims to test the achievement of the heat exchanger dual tube with commercially available computer fluid dynamics (CFD) applications ANSYS CFX and the method Pro/Engineer modeling. The heat exchanger can also do a comparative study without helical inserts. For measuring of the heat transmission, heat transfer, and heat distribution coefficient along the conduit. The pressure control and flow propagation should be measured. Helical height inserts visualization of turbulence [19–21].

3.1 *Modeling of Heat Exchanger*

This is the first point in the continuum of study. A solid that determines the fluid flow area is the primary objective of geometry development. Current models have been compiled in dimensions and geometry descriptions. The heat exchanger would be modeled with helical inserts with the dimensions of diameter of inner and outer pipe are 12.5 and 25 mm, length of heat exchanger is 90 mm. The wire diameter of helical turbulator is 1.2 mm and length is 75 mm. Pitch distance varied at three different level in the turbulator are 4.25, 8.5, and 17 mm. Double tube heat exchangers modeling was done using Pro E Wild Fire 2.0 and exported in IGES format. The part modeling was used to construct the heat exchanger was represented in Fig. 1.

The advantages of applying geometric regions are that they are specifically related to the model and are connected with the model by moving geometry. The regions are automatically assigned when a new mesh is formed. The spatially discrete CFD model method is mesh development. Meshing is based on the discretization of the tetrahedron component. Meshed model is represented in Fig. 2. It is exported to the ICEM CFD tool in IGES format. This method used to create surface and volume

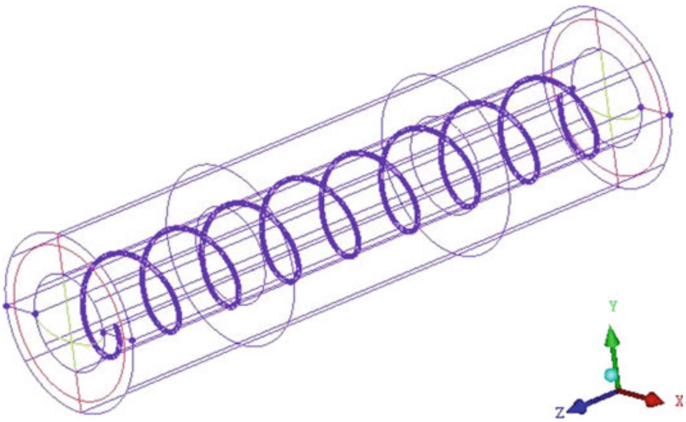

Fig. 1 Double tube heat exchanger with turbulator (pitch 8.5 mm)

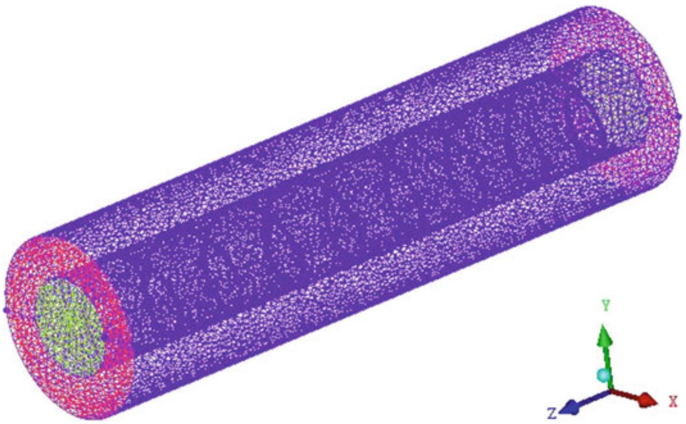

Fig. 2 Meshed Model of double tube heat exchanger with turbulator (pitch 8.5 mm)

meshes, specifying the meshing element form and mesh element type is tetrahedron, number of elements are 395,793 and nodes are 77,694.

Boundary conditions and heat exchanger specifications for CFD analysis are tabulated in Table 1, and boundary conditions and constraints are represented in Fig. 3. After defining all the conditions, the model is imported in CFX-Solver Module for doing iterative calculations and to generate result file. The solver control parameters have been specified in CFX-Pre-Module. Number of iterations preformed was 75 with Auto Time scale.

Table 1 Boundary conditions and heat exchanger specifications for CFD analysis

S. No.	Heat exchanger specifications	Domain data
1	Flow type and fluid	Counter-flow with water
2	Fluid domain	Double tube
3	Solid domain	Turbulator and tube surface
4	Tube and turbulator material	Copper and Aluminum
5	Inlet boundary conditions	28° C with 0.2 m/s (Cold Fluid)
		90° C with 0.2 m/s (Hot Fluid)
6	Outlet boundary condition	Pressure: 1 bar
7	Wall boundary conditions	Wall influence on flow: No slip Wall roughness: smooth wall

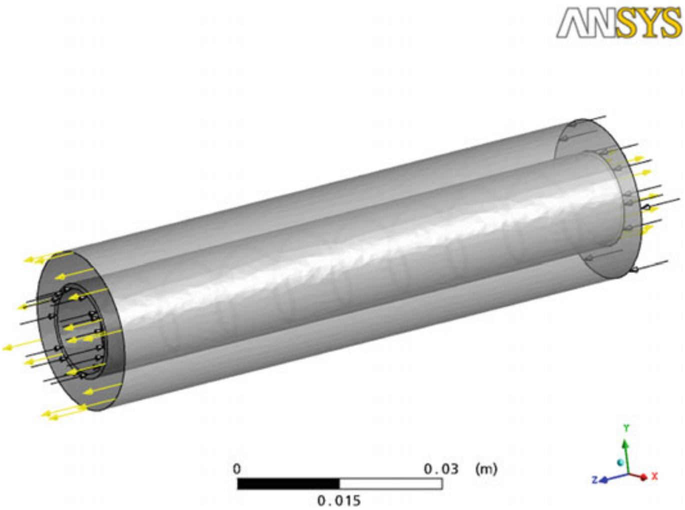

Fig. 3 Constraint of double tube heat exchanger with turbulator (pitch 8.5 mm)

4 Results and Discussion

4.1 Heat Transfer Distribution

The cold fluid heat exchanger temperature distribution with turbulators with different pitch lengths as shown in Fig. 4. Although, the fluid temperature changes in the heat exchanger outlet with the turbulator is contrasted with the heat exchanger without

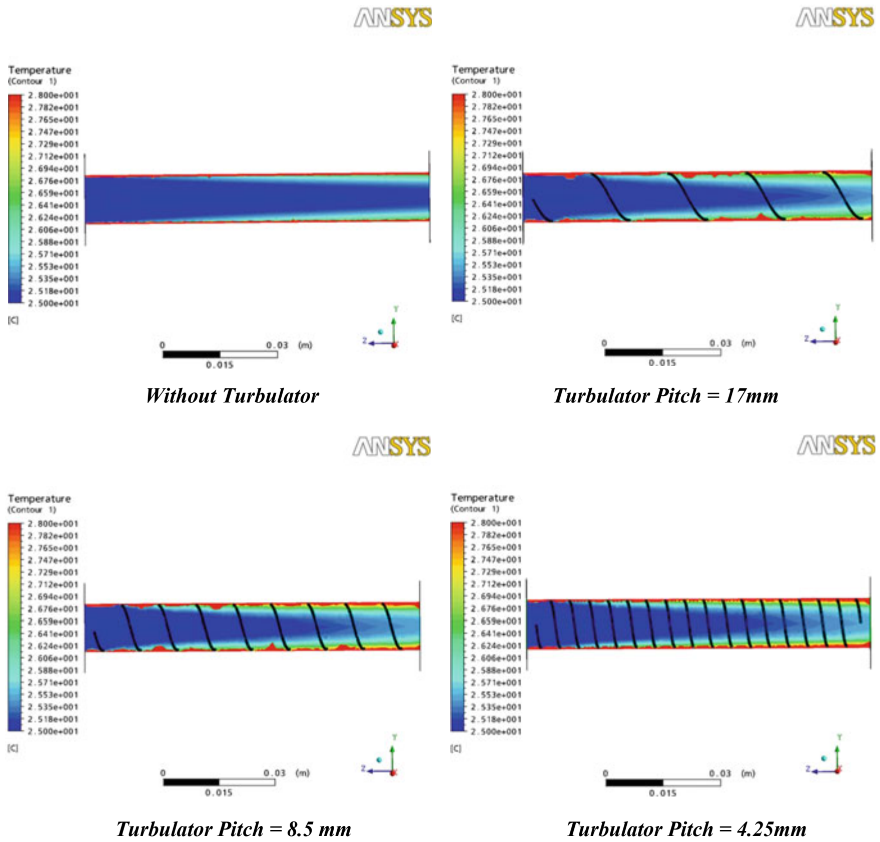

Fig. 4 Heat transfer distribution of double tube heat exchangers

the turbulator. As the fluid temperature rises further for 4.25 mm in pitch when contrasting turbulators with varying pitch lengths.

4.2 *Pressure Distribution*

The pressure distribution of the models as seen in Fig. 5. There is a rising pressure on the inlet and the pressure progressively reduces toward the outlet. The pressure distribution suggests that in this situation the pressure decrease is raised at the input of the turbulator pitch of 4.25 mm and when the flux begins. The other models demonstrate that the pressure at the inlet reduces.

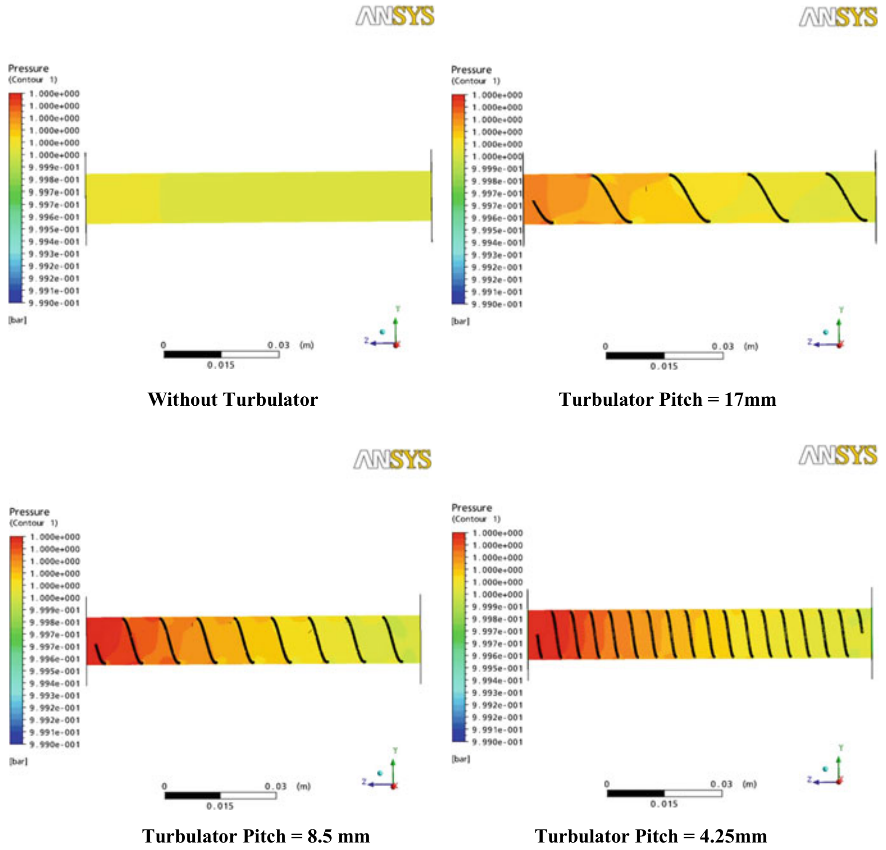

Fig. 5 Pressure distribution of double tube heat exchangers

4.3 *Turbulence Eddy Dissipation*

The eddy turbulence dissipation can be seen in Fig. 6. It applies to the lack of energy in the flow due to eddy. The findings indicate that turbulence dissipation at turbulator is more significant. Results suggest that turbulence eddy dissipation is more likely to occur as the flow reaches exhaust. For the turbulator pitch of 4.25 mm, improved turbulence eddy dissipation is observed.

The decreased pitch of 4.25 mm indicates the increased value from the Table 2 which contrasts all variables with a different pitch and without turbulator. The findings indicate that the heat transfer coefficient in the turbulator pipe has improved substantially. The values are high on turbulators for turbulator pitch 17 and 8.5 mm. The heat transfer coefficient has greatly improved and is above the outlet in the case of 4.25 mm pitch turbulator. There is a rising pressure on the inlet and the pressure progressively reduces toward the outlet. The pressure distribution suggests that in

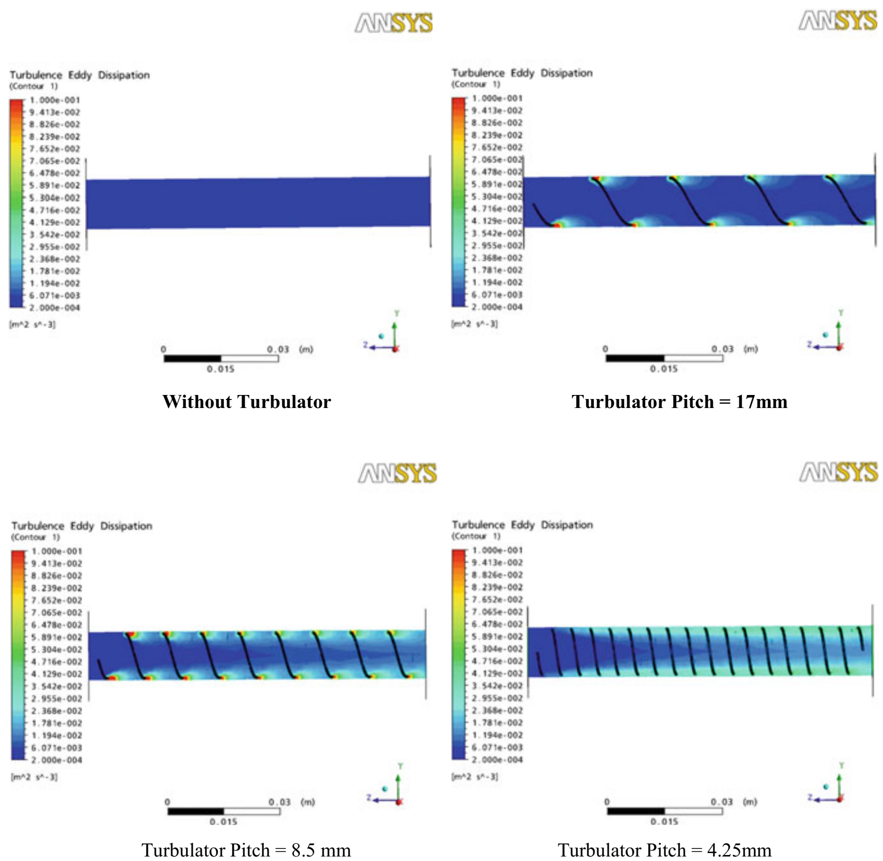

Fig. 6 Turbulence Eddy dissipation of double tube heat exchangers

Table 2 Comparative study on double tube heat exchangers with turbulator

Variable		Without turbulator	Pitch 4.25 mm	Pitch 8.5 mm	Pitch 17 mm
Heat transfer [°C]	Inlet	25.15	25.156	25.156	25.157
	Outlet	26.028	26.777	26.768	26.516
	Difference	0.874	1.621	1. 612	1.359
Pressure [bar]	Inlet	1.0000	1.0000	1.0000	1.0000
	Outlet	1.00004	1.00047	1.00043	1.00025
	Difference	0.00004	0.00047	0.00043	0.00025
Turbulence Eddy dissipation [$m^2\ s^{-3}$]		0.00092	0.01719	0.01324	0.00517
Variation in Percentage		–	1778.5	1346.15	464.49

this situation the pressure decrease is raised at the input of the turbulator pitch of 4.25 mm and when the flux begins. The other models demonstrate that the pressure at the inlet reduces.

5 Conclusion

The heat transfer technique boosts the performance of thermal exchangers. For better efficiency, the heat transfer coefficient must usually be changed. Twisted tape inserts are the cost-effective and simple way to optimize heat transfer. For dual tube heat exchanger research, the CFX technique has been used. Insert helical. The improvement in the thermal transference and heat stream of the wall was observed as the pitch difference decreases. For the lower pitch helical inserts, the wall distribution heat flow coefficient is uniformly distributed. The heat transfer coefficient has significantly increased by around 80% for 4.25 mm helical inserts. The intensity of turbulence has increased significantly at the lower pitch distance. When the pitch distance decreases the pressure drop and turbulence eddy dissipation increases significantly. At lower pitch distance, the pressure drop is significant which will increase the pumping power.

6 Future Work and Limitations

The main applications of this work are to improve the heat transfer characteristics in particularly turbulent flow. The future work is going to be carried out for different flow rate. The main limitations of this work is not suitable to laminar flow due to minimum heat transfer enhancement.

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