Middle-East Journal of Scientific Research 24 (S2): 157-162, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.24.S2.137

Improvement of Heat Transfer Rate in Shell and Tube Heat Exchanger Using Twisted Tube Inserts

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Abstract: Shell and tube heat exchanger is the common type of heat exchanger used in oil refineries and other large chemical processes and is meet for high pressure applications. In most of the heat exchangers, the counter and parallel flows pass through the shell side to the tube side. Researches are carried out to improve the heat transfer rate by modifying the geometry of the shell and tube side of the heat exchangers. Researchers used fins, along with Nano fluids to improve the heat transfer rate. In this research, the twist tapered insert is introduced and the simulation is carried out using ANSYS-CFD package to improve the heat transfer rate. The major consideration of the project are the pitch of the twisted inserts. The simulation is carried out using three different pitches 60mm, 55mm and 50mm with the normal concentration of water. The result is observed that 50mm pitch of the twist insert gives the high heat transfer rate. Also it is observed that reducing the pitch gives high heat transfer rate.

Key words: Twist inserts · CFD · Pitch 50mm · Heat transferand tube side

INTRODUCTION

Heat exchanger equipment built for effective heat transfer from hot medium to cold medium. The media may be separated by a solid wall, or they may be in direct contact. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end and travel in parallel to one another to the opposite side. In counter-flow heat exchangers the fluids enter the body from opposite ends. The counter design is most effective, in that cold medium can transfer the most heat from the heat transfer medium. The exchanger's performance can also be affected by the addition of fins in one or both directions that induce turbulence. To choose a suitable heat exchanger, the system designers would firstly consider the design limitations for each heat exchanger type. Though cost is often the first criterion estimated, there are several other important selection criteria which include:

- Pressure limits
- Thermal Performance including temperature ranges
- Type of product Mixture (liquid/liquid, particulates or high-solids liquid)
- Fluid flow capacity
- Maintenance and healing
- Materials required for production
- Ability and ease of future expansion

A shell and tube heat exchanger is a type of heat exchanger designs. Shell and tube heat exchangers consist of tube bundles. These tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes, thus it can either afford the heat or absorb the heat required. There are several thermal design features that are to be taken into account when conniving the tubes in the shell and tube heat exchangers. The parameters are Tube diameter, Tube thickness, Tube length, Tube pitch, Tube Layout, Baffle Design.

Selection of Tube Material: To transfer heat unique, the tube material must have good thermal conductivity. Because heat is transferred from a hot side to a cold side over the tubes, there is a temperature difference through the width of the tubes. Due of the affinity of the tube material to thermally expand contrarily at various temperatures, thermal stresses occur during operation. This is in accumulation to any stress from high pressures from the fluids themselves. The tube material also should be well-suited with both the shell and tube side fluids for long periods under the operating conditions such as

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temperatures, pressure to minimize deterioration such as corrosion. All of these requirements call for careful selection of strong, thermal conductive, corrosion unaffected, high quality tube materials. Typical metals, include copper alloy, stainless steel, carbon steel, nonferrous copper alloys, Inconel, nickel, Hastelloy and titanium. Poor choice of tube material might result in a leak over a tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure.

Heat Transfer: Heat transfer is a science that deals with the energy transfer between two bodies due to temperature difference. Also, heat transfer is a method by which internal energy from one substance transfers to another substance. An understanding of heat transfer is critical to analyze a thermodynamic process, such as those that take place in heat engines and heat pumps. There are three modes of heat transfer such as Conduction, Convection and Radiation. Hac Mehmet *et al.* [1], investigated experimentally and numerically to reduce the heat exchanger sizes and heat transfer enhancements. In their study, the heat transfer and friction coefficient characteristics of a concentric tube heat exchanger with different pitches of coiled wire turbulators were considered. The numerical simulations were performed by using a three dimensional CFD computer code. The results were correlated in the form of Nusselts number as a function of Reynolds number and Prandtl number. The heat transfer improvements using turbulators were 2.28, 2.07 and 1.95 times better than the smooth tube for pitch distances of 15, 30 and 45 mm, respectively. Shyy Woei Chang *et al.* [2], performed an experiment to study about heat transfer and pressure drop measurements in three test tubes fixed with single, twin and triple twisted-tapes with Reynolds number varying from 1,500 to 14,000. Heat transfer augmentations from the plain-tube conditions in three test tubes decrease with the increase of Re, whereas the descending rate decreases with the increase of twisted-tape in the tube. These twisted-tapes generate the more effective heat transfer improvements in laminar flow regime than in turbulent flow regime. Yonghua You *et al.* [3], analyzed the performances of the inserts from a viewpoint of entropy generation. Effects of arrangement method and geometrical considerations on entropy generations of laminar heat transfer in the tubular flow are investigated. Results show that entropy generation rates caused by non-staggered strips are about 81.1% that of staggered alignment. Paisarn Naphon [4], investigated the heat transfer characteristics and the pressure drop of the horizontal double pipe with coil-wire insert. Cold and hot water are used as working fluids in the shell side and tube side, respectively. The effect of the coil pitch and relevant considerations on heat transfer characteristics and pressure drop are considered. Coil-wire insert has significant effect on the improvement of heat transfer especially on laminar flow region. Mourad Yataghene *et al.* [5], Considered a scraped surface heat exchanger for Newtonian and Non-Newtonian fluids using electrochemical procedure and authenticated the experimental results with the two dimensional numerical simulation with hybrid mesh along with refined grids in between the tips.

Modeling Details: The Fig. 1 shows the cross sectional view of the tube where insert is modelled to the above given dimensions with different pitches. The heat transfer is also noted in the figure.

Geometry Preparation: The model is prepared to the following dimensions using the Creo 3.0 software.

Table I: model dimensions

Shell diameter	160mm
Shell length	704mm
Tube diameter	16mm
Tube length	612mm
Shell thickness	6mm
Tube thickness	1mm
Baffle thickness	6mm
Twist insert length	612mm
Twist insert thickness	1mm
Pitch	60mm, 55mm, 50mm

The Fig. 1 shows the cross sectional view of the tube where insert is modelled to the above given dimensions with different pitches. The heat transfer is also noted in the figure.

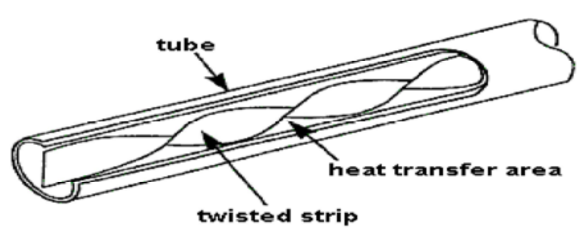

Fig. 1: Cross sectional view of the tube

The Fig. 2 shows the complete model of the shell and tube heat exchanger with the pitch of the insert as 50mm. The model indicates the cold fluid and hot fluid inlet and outlet regions.

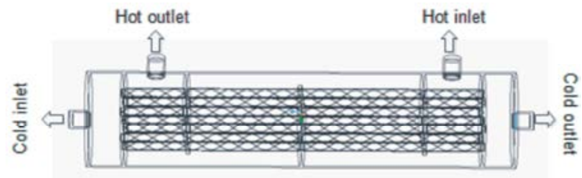

Fig. 2: Model of shell and tube heat exchanger

Mesh Selection: The surface model was imported into the meshing tool GAMBIT 2.4.6 as iges file format to develop the finite volume model. The single volume of heat exchanger is segregated into three volumes, such as cold water volume, hot water volume and shell volume. Then the three volumes where meshed separately with Tet/hybrid elements. Based on the grid independence study the elemental size of 5 mm is chosen and it contains approximately 12, 67,000 elements.

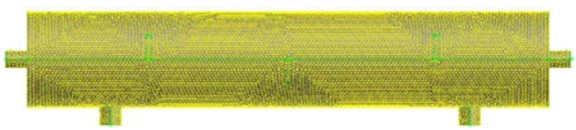

Fig. 3: Meshed elements

The Fig. 3 shows the elements separation using the meshing software. It contains numerous small elements.

Analysis Methodology: After creating the mesh, the analysis are carried out using the Ansys CFX module. In the pre-processing, we start the processing of the input boundary data to get the three different domain and see whether the numerically generated surface grid approximates the given geometry and the flow boundary well. The boundary conditions are given in the Table II.

Table II: Boundary conditions

Medium	Position	Temperature (°C)	Pressure (N/m^2)	Mass flow rate (Kg/s)
Cold water (water)	Inlet	25	$10e^5$	1
	Outlet	-	1 atm	1
Hot water (water)	Inlet	80	$10e^5$	1
	Outlet	-	1 atm	1

The grid should have sufficient numbers of points where important features like boundary layer are resolved and also examine the grid qualitatively with regard to grid stretching and skewness. The solver is set to perform 100 iterations to get the accuracy of the results. The last but most important part of CFD activity is the post-processing of the results obtained by numerical solution of the governing equations for the given problem. The CFD activity as a whole is the numerical simulation of the flow, analysis and interpretation of the results. The flow-solver solves a system of equations governing the flow with proper boundary conditions where free-stream Reynolds number is specified. The solutions files contain highly detailed information of the flow field like pressure gradient, velocity components, temperatures and heat transfer coefficients.

RESULTS AND DISCUSSION

Twist tapered fins are used inside the tube side. The fluid used for iteration is water. This type of fin used in the heat exchanger is to stagnate the hot water in the tube side. This makes the hot water in the tube side to improve the heat extraction rate in the shell side. The iterations are made by varying the pitch of the twist insert as 60mm, 55mm and 50mm.

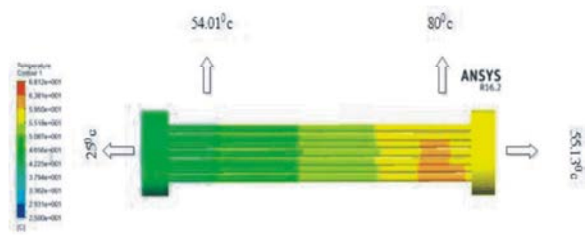

Fig. 4: Temperature distribution on tube side without fin

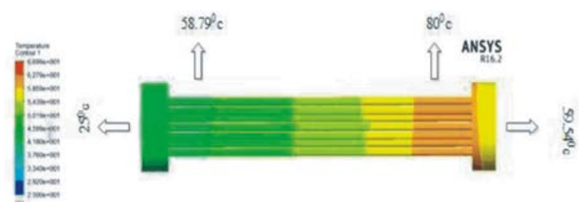

Fig. 5: Temperature distribution on tube side with fin pitch 60mm

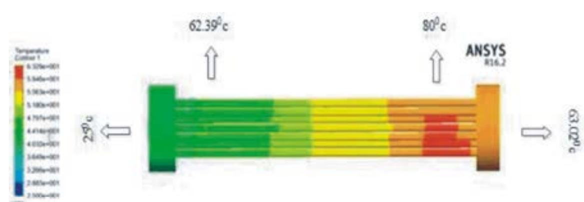

Fig. 6: Temperature distribution on tube side with fin pitch 55mm

The Fig. 4, 5, 6 shows the cold fluid and hot fluid outlet temperatures for the without fin and with fin for the pitches 60mm and 55mm in the shell and tube heat exchanger.

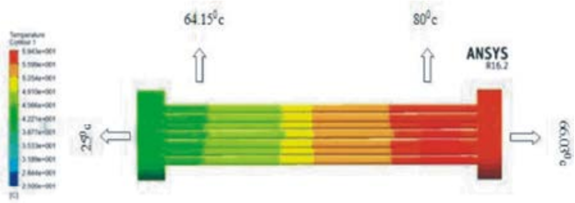

Fig. 7: Temperature distribution on tube side with fin pitch 50mm

The Fig. 7 shows the temperature distribution on the cold fluid and hot fluid due to the effect of twist insert 50mm along with water concentration. It is evident that the temperature distribution is very high in the cold outlet when compared to the other pitch values. As a result of iterations various results are taken such as cold outlet temperature, hot outlet temperature and heat transfer coefficient. The values are taken for the different pitch value of the insert. The variations are noted in the graphical plots by changing the pitch of the twist insert the temperature difference are noted. The following table gives the values of cold outlet temperature for the different concentrations of the Nano fluid with fin pitch 50mm.

Table III: Cold outlet temperature for without fin and with fin

	Cold outlet temperature (°C)			
Fluid used	Without fin	With fin pitch 60mm	With fin pitch 55mm	With fin pitch 50mm
water	55.13	59.54	63.02	66.03

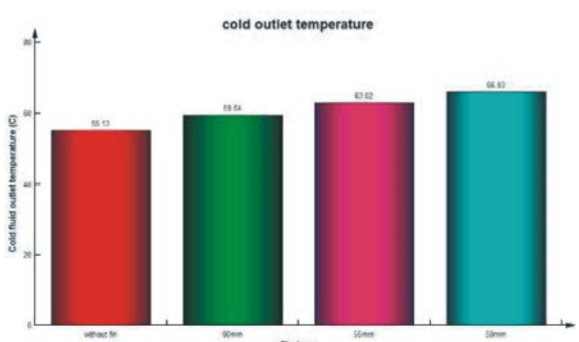

Fig. 8: Comparison of cold fluid outlet temperature without fin and with fin

From the Fig. 8 we can identify that the cold fluid outlet temperature increase with decrease in pitch value. The cold fluid outlet temperature is higher for a heat exchanger with fin rather than without fin.

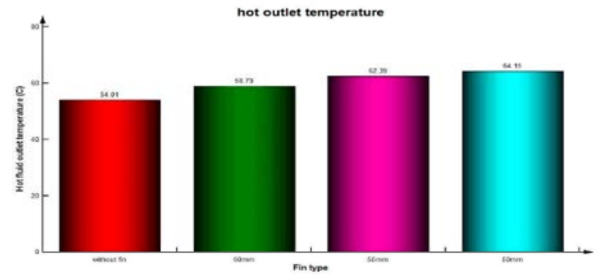

Fig. 9: Comparison of hot fluid outlet temperature without fin and with fin

From Fig. 9 we find that hot fluid outlet temperature decreases with increase of cold fluid outlet temperature thus indicating the transfer of heat from one medium to the other medium.

Heat Transfer Rate: The heat transfer rate of the cold fluid is estimated based on the given below relation.

$Q = mC_p (T_1-T_2)$

where 'Q' is heat extraction rate in kW, 'm' is mass flow rate in kg/s, 'C_p' is specific heat at constant pressure in KJ/kg °C and 'T_1' and 'T_2' are inlet and outlet temperature of cold fluid in °C.

Table IV: Heat transfer rate

	Heat transfer rate (KW/Hr)			
Fluid used	Without fin	With fin pitch 60mm	With fin pitch 55mm	With fin pitch 50mm
Water	105.12	123.57	138.12	150.71

It is inferred from the Fig. 10 that the heat transfer rate in with fin heat exchanger with 50mm pitch is increased by 22% than with fin heat exchanger with pitch 60mm. thus it reveals that decreasing the pitch value increases the heat transfer rate. Also we observed that heat transfer rate is increased by nearly 55% comparing without fin and with fin inserts.

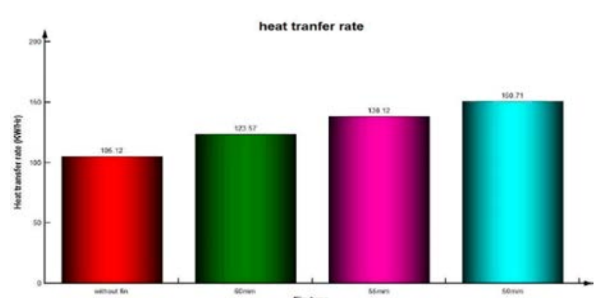

Fig. 10: Comparison of heat transfer rate without fin and with fin

Reynolds Number and Nusselts Number: Nusselts number is predicted due to the effect of the heat transfer coefficient. In the present study, the heat transfer coefficient and Nusselts number of heat exchangers with fin and without fin were studied numerically. The heat transfer coefficient is directly obtained from the CFX results. The Nusselts number is calculated from the following relations are used.

$$\mathrm{Nu} = \frac{hD_h}{k}$$

where 'Nu' is Nusselts number, 'h' is heat transfer coefficient in W/m^{2} ^{0}C, 'D_h' is hydraulic mean diameter in m and 'k' thermal conductivity in W/m °C.

The hydraulic mean diameter for without fin using the tube diameter and with fin the following relation is used for finding the hydraulic mean diameter.

$$D_h = \frac{4A}{P}$$

were 'D_h' hydraulic mean diameter in m, 'A' cross sectional area in m^2 and 'P' is a wedded perimeter in m.

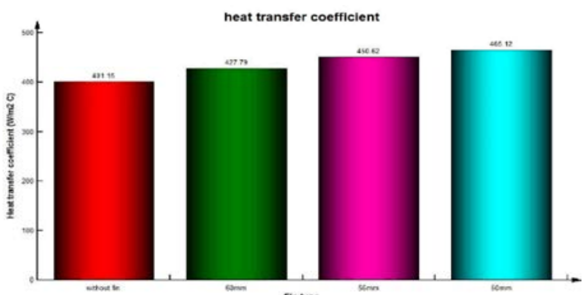

Fig. 11: Heat transfer coefficient for without fin and with fin

Fig. 11 shows the graph for the heat transfer coefficient which is taken from software contour results. It is evident that heat transfer coefficient increases with decrease of pitch values. These values are taken for calculating Nusselts number to verify thermal conductivity of the fluid.

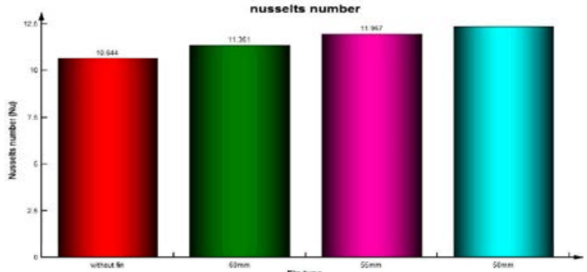

Fig. 12: Nusselts number for without fin and with fin

Fig. 12 shows that Nusselts number without fin and with fin with different pitches. The Nusselts number is decreased with introduction of the twist tapered inserts. For reason increase the volumetric concentration of water and increase the thermal conductivity of water. The above relation shows that thermal conductivity is inversely proportional to Nusselts number. The thermal conductivity increases with increase in the volume concentration of water and decreases the Nusselts number.

The following relation is used to find the Reynolds number

$$Re = \frac{\rho v D_h}{\mu}$$

were 'Re' is Reynolds number, ☻ is density of the liquid in kg/m^3, v is velocity of the liquid, D_h is mean hydraulic diameter in m and ☻ is dynamic viscosity of liquid in kg/m s.

The value of Nusselts number increase with the increase of shell side Reynolds number both without and with fin. Reynolds number lies >5000 from the relation. Hence the flow is turbulent flow.

CONCLUSION

A numerical investigation of thermal and pressure drop characteristics in a tube equipped with tapered twisted tape under uniform wall heat flux conditions were carried out with different pitches 60mm, 55mm and 50mm. The effects of taper insert were studied. The numerical results are reported in forms of heat transfer coefficient, cold outlet temperature and hot outlet temperature. The major findings are summarized as follows:

- The use of the tubes equipped with tapered twisted tapes resulted in better heat transfer than the use of the plain tube.
- Heat transfer rate increased with decreasing pitch value.

The tapered twisted tape with pitch = 60mm gave lower mean Nusselts number than the one with pitch = 55mm and 50mm by around 1.09% and 2.13% respectively. This can be explained that as the taper angle increases, the heat transfer rate intensity induced by a tapered twisted tape become stronger, resulting in good fluid mixing between wall and core regions. Heat transfer improvement and friction loss increased with decreasing twist ratio. The tapered twisted tape with pitch = 50mm gave higher heat transfer rate as 10% by comparing with other pitch values. It can be explained that the twisted tape with smaller twist ratio owns more twist numbers, thus induces more consistent turbulent flow with stronger swirl intensity. The result is also observed that the heat transfer rate increased by 55% when comparing with the without fin and with fin results.

- The flow inside the tube is turbulent.

Reynolds number lies above 5000 from the graph. Hence the flow is turbulent flow.

REFERENCES

1. Hac Mehmet Sahin. Es ref Baysal, Ali Rıza Dal and Necmettin Sahin, 2015. Investigation of heat transfer enhancement in a new type heat exchanger using solar parabolic trough systems, International journal of Hydrogen Energy, 22(5): 21-28.
2. Shyy Woei Chang, Ker-Wei Yu and Ming Hsin Lu, 2006. Heat Transfers in Tubes Fitted with Single, Twin and Triple Twisted Tapes, A Journal of Thermal Energy Generation, Transport, Storage and Conversion, 32(15): 201-236.
3. Yonghua You, Aiwu Fan, Yuming Liang, Shiping Jin, Wei Liu and Fangqin Dai, 2014. Entropy generation analysis for laminar thermal augmentation with conical strip inserts in horizontal circular tubes, International Journal of Thermal Sciences, 88(12): 201-214.
4. Paisarn Naphon, 2006. Effect of coil-wire insert on heat transfer enhancement and pressure drop of the horizontal concentric tubes, International Communications in Heat and Mass Transfer, 33(12): 753-763.
5. Mourad Yataghene, N. Ramakoteswaraa Rao, G. Leena and S.V. Ranganayakulu, 2013. Synthesis, Applicationsn and Challenges of Nano Fluids, Journal of Heat and Mass Transfer, 2(11): 21-28.