CFD Analysis on Performance of Double Pipe Two Pass Heat Exchanger

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Abstract— Heat exchangers with the convective heat transfer of fluid inside the tubes are frequently used in many engineering applications. Some of the applications of double pipe heat exchangers are in pasteurization, digester heating heat recovery, pre-heating, and efficient cooling. Double pipe heat exchangers are often used in the chemical, food processing, oil & gas industries. In this work includes heat transfer augmentation in the double pipe two pass counter flow heat exchanger using twisted tapes with water as working fluid. For this study the heat transfer coefficient, friction factor and enhancement ratio of double pipe counter flow two pass heat exchanger with twisted tapes inside the inner pipe at various Reynolds number using Computational Fluid Dynamics (CFD) software. The three dimensional solid modeling of two passes double pipe heat exchanger is developed using ANSYS FLUENT14.0. The present study explores the effects of twisted tapes on heat transfer and fluid friction characteristics in a heat exchanger tube under turbulent flow conditions. Further, the simulations with different twist ratios of 10, 15, and 20 and for plain tube are conducted and results are compared with that of analytical and experimental results.

Key words: CFD Software, Ansys Fluent

I. INTRODUCTION

Heat exchangers are so common and very useful in heating and cooling systems in various types of industries such as petrochemical and oil organizations, power plant stations and even in residential areas [1]. The design procedure of heat exchangers is complex because it needs the analysis of heat transfer rate, pressure drop and efficiency plus issues like long term endurance and easy maintenance. One of the main categories of increasing heat transfer methods is called as passive technique [2]. It means that there is no need for any kind of extra power source and the heat transfer can increase just by using modified surfaces or modified geometries. This method includes the techniques such as treated surfaces, rough surfaces, extended surfaces, and coiled tubes, and displaced enhancement devices, vortex generator devices and additives to the fluids [3]. Also twisted tape is one of the main inserts which can improve heat transfer rate and it is studied through this current project. At any time that twisted tape inserts are used, in conjunction with the augmentation in the heat transfer rate, the pressure drop increases. So that any augmentation devices used in the heat exchanger should be optimized according to the benefits of heat transfer and the higher pumping cost rate [4]. Twisted tape inserts increase the heat transfer coefficients with an increase in the pressure drop. Because of the design and application convenience, they are widely used over decades to generate the swirl flow in the fluid. The size of the heat exchanger can be reduced significantly by using twisted tapes in the heat exchanger for a specified heat load. Thus twisted tape provides an economic advantage over the fixed cost of the equipment [5].

II. EXPERIMENTAL DETAILS

A. *Material Used:*

- Carbon steel
- Aluminum
- Stainless Steel 304, 316
- Copper
- Other stainless steel types

B. *Geometry Modeling:*

The analysis is performed on a double pipe heat exchanger with mentioned specifications. This model is developed in ANSYS WORKBENCH 14.0 by using some operations like extrude, sweep, arc by three points etc.

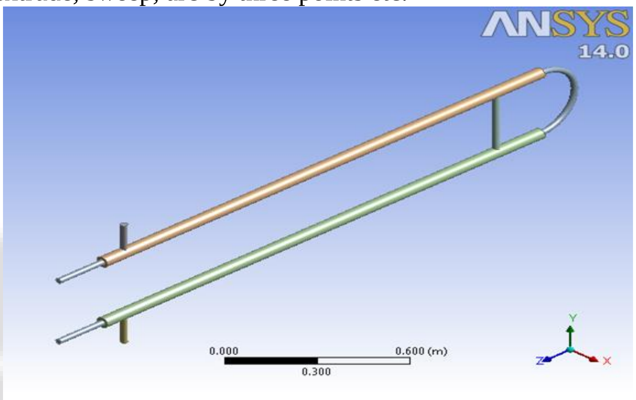

Fig. 1: Double pipe two pass heat exchanger model

C. *Meshing of Geometry:*

The mesh element considered is hexahedral shape in inner pipe by using inflation. The number of elements 808525 andnodes417422. Named selections are also given in meshing. And insulation is provided at the outer wall of annulus.

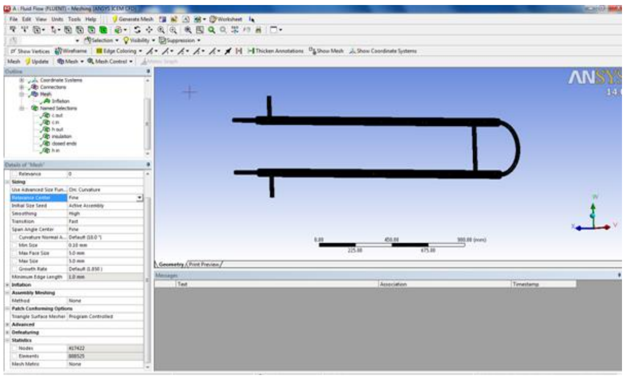

Fig. 2: Meshing of double pipe heat exchanger

D. *Outlet Boundary Conditions:*

At the outlet, the pressure boundary condition is specified as a constant value equal to zero gauge pressure. Backflow total temperature, percentage turbulence intensity, and hydraulic diameter are also specified. The average of hot and cold fluid inlet temperatures is taken as backflow total temperature.

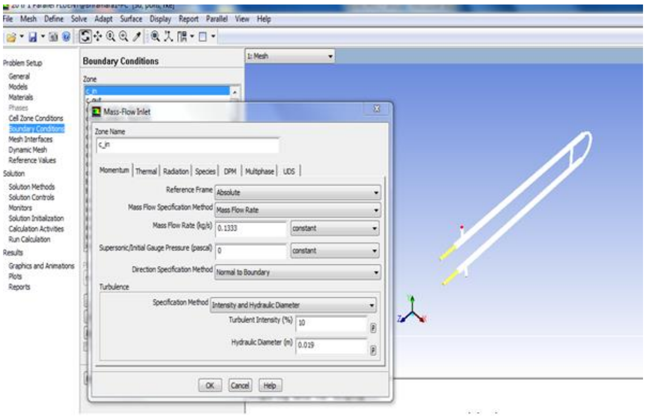

Fig. 3: Representation of boundary conditions

III. SOLUTION

The CFD method follows the use of commercial software ANSYS FLUENT 14.0 to solve the problem. The solver in ANSYS-FLUENT used a pressure correction based SIMPLE (Semi Implicit Method for Pressure Linked Equations) algorithm with 2nd order upwind scheme for discrediting the convective transport terms.

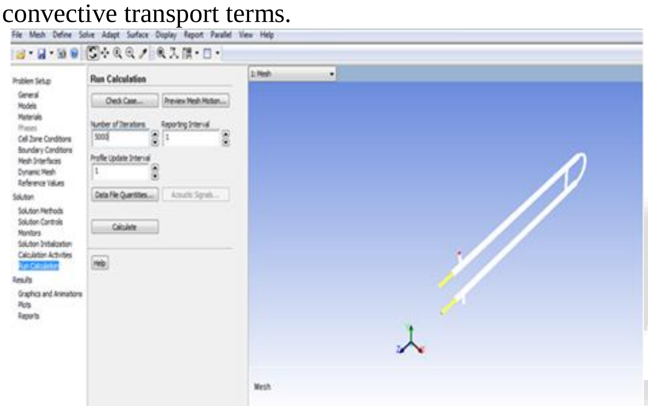

Fig. 4: Representation of run calculation

Initialization must be done before running the solution. After convergence is reached, observed the values of heat transfer coefficient and pressure drop from reports. Friction factor values are calculated by using these pressure drop values.

Finally compared all the values of heat transfer coefficient, friction factor values, overall enhancement ratio obtained from all the investigations and estimated the heat transfer enhancement.

IV. RESULTS AND DISCUSSIONS

A. *Plain Tube:*

Figure 5 shows the variation of heat transfer coefficient with Reynolds number for a plain tube heat exchanger without inserts. As the cold water flow rate is increasing by keeping hot water flow rate constant, resulting in the degree of turbulence, there by Reynolds number is increasing which is enhancing the Nusselt number. So there by convective heat transfer coefficient also increasing. Therefore, it can be inferred that the mass flow rate of the fluid in a plain tube is directly responsible for the heat transfer coefficient. With increase in mass flow rate of the cold fluid the variation in heat transfer coefficient is decreasing.

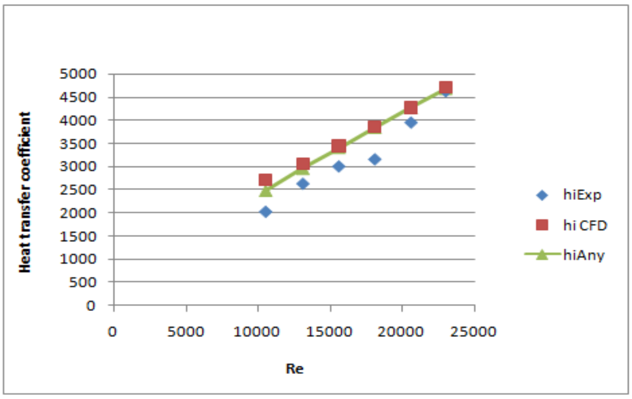

Fig. 5: Comparison between analytical, experimental and CFD heat transfer coefficients at various Reynolds numbers for plain tube.

B. *Twist Ratio 10:*

Figure 6 shows the variation of heat transfer coefficient with Reynolds number for a heat exchanger with twisted tape insert of twist ratio 10. The use of a twisted tape inserted inside a circular tube results into an enhancement of heat transfer rate as they cause the turbulence in the flow with swirling moment. The local heat transfer coefficients are found to be increasing to very high values. It can be inferred that there is almost 29 percent increase in heat transfer coefficient value with twist ratio 10 when compared to plain tube without inserts. This twist ratio is giving highest heat transfer rate compared to remaining two twist ratios.

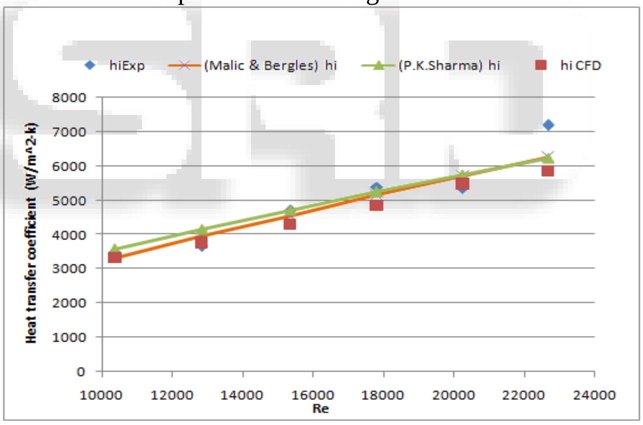

Fig. 6: Comparison between analytical, experimental and CFD heat transfer coefficients at various Reynolds numbers for twist ratio 10

C. *Twist Ratio 15:*

Figure 7 shows the variation of heat transfer coefficient with Reynolds number for a heat exchanger with twisted tape insert of twist ratio 15. The CFD values are found to be in agreement with the values determined by other investigations. The use of a twisted tape inserted inside a circular tube results into an enhancement of heat transfer rate as they cause the turbulence in the flow with swirling moment. The local heat transfer coefficients were found to be increasing to very high values. It can be inferred that the mass flow rate of the fluid in a heat exchanger with twisted tape insert is directly responsible for the heat transfer coefficient. It is observed from the plots that the values of heat transfer coefficient in the tube with twisted tape insert of twist ratio 15 are higher compared to the plain tube, but lower compared to the tube with twisted tape inserts with twist ratio 10. This is because of decreased surface area in twist ratio 15 compared to twist ratio 10.

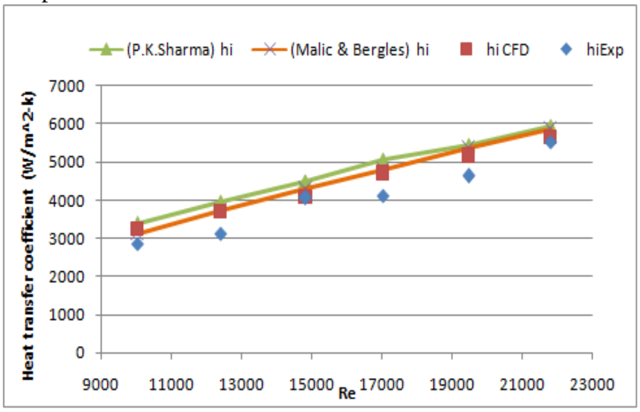

Fig. 7: Comparison between analytical, experimental and CFD heat transfer coefficients at various Reynolds numbers for twist ratio 15

D. *Twist Ratio 20:*

Figure 8 shows the variation of heat transfer coefficient with Reynolds number for a heat exchanger with twisted tape insert of twist ratio 20. The use of a twisted tape inserted inside a circular tube results into an enhancement of heat transfer rate as they cause the turbulence in the flow with swirling moment. The increase of heat transfer is found to be depending on the Reynolds number. Therefore, it can be inferred that the mass flow rate of the fluid in a heat exchanger with twisted tape insert is directly responsible for the heat transfer coefficient. It is observed from the plots that the values of heat transfer coefficient in the tube with twisted tape insert of twist ratio 20 are higher compared to the plain tube, but lower compared to the tube with twisted tape inserts with twist ratios 10 and 15.

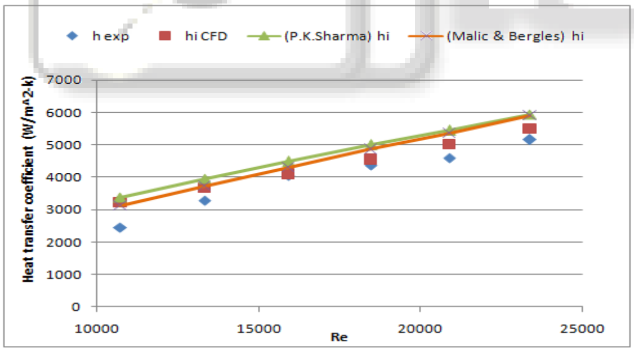

Fig. 8: Comparison between analytical, experimental and CFD heat transfer coefficients at various Reynolds numbers for twist ratio 20

V. CONCLUSIONS

Numerical investigation of heat transfer coefficient of double pipe heat exchanger with and without twisted tape inserts of different twist ratio at different cold water flow rates under turbulent conditions has been investigated.

- It is observed that Nu number is increasing with cold fluid flow rate resulting in increase in turbulence which results in increase in heat transfer coefficient and increase in friction factor.
- With increase in twist ratio from 10 to 20 heat transfer coefficient and friction factor are decreasing.
- Numerical results indicated that there is 28.29 % increment in heat transfer coefficient value when compared to plain tube and tube with twisted tape at twist ratio 10.
- There is close approximation, an error of around 5.25% between experimental and CFD value and 5.43% between analytical and CFD value of heat transfer coefficient for twist ratio 10.
- There is close approximation, an error of 9.15% between experimental and CFD value and 1.83% between analytical and CFD value of heat transfer coefficient for plain tube.
- It is observed that there is 61.13% increase in friction factor with twist ratio 10 and enhancement ratio is observed to be 1.19 with twist ratio 10 compared to plain tube.

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