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Numerical Simulation & Enhancement of Heat Transfer using Twisted Tape with Alternate Pitch

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Abstract

The current research work is based on the optimization of heat transfer of heat exchanger by implementing the twisted helical tape in cold and hot flow pipe. In order to increase the heat transfer rate, helical-tape inserts have enhancing the convective heat transfer in heat exchangers. In general, helical tape insert introduces swirl flow inside the tube, which consequently disrupts a thermal boundary layer on the tube surface. A virtual analytical model has been developed to study the performance of helical-tap insert at annulus of the inner pipe. It has been observed that there is a good agreement between the results for Nusselt number and friction factor. SST k-ω turbulent model has been selected as better turbulent model for further simulation. From the results, it has been found that, by using helical-tape inserts the heat transfer enhancement takes place in the expense of pressure drop.
Keywords: FVM- Finite Volume Method, 2 D Two Dimensional, FDM- Finite Difference Method

I. Introduction

Heat exchanger is a device that facilitates the exchange of heat between two fluids that are at different temperatures. Heat exchangers are used for both the purpose to remove heat from a fluid and to provide heat to a fluid. Common examples of heat exchanger are boiler, condenser, super heater, economizer, automobile radiators. Heat exchangers are commonly used in practice in a wide range of applications, from heating and air conditioning systems in a household, to chemical processing and power production in large plants.

The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. A majority of heat exchangers used in thermal power plants, chemical processing plants, air conditioning equipment, and refrigerators, petrochemicals plants serve to heat and cool different types of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously increasing with the unit power and the volume of production. This involves huge investments annually for both operation and capital costs. Hence it is an urgent problem to reduce the overall dimension characteristics of heat exchangers. The need to optimize and conserve these expenditures has promoted the development of efficient heat exchangers.

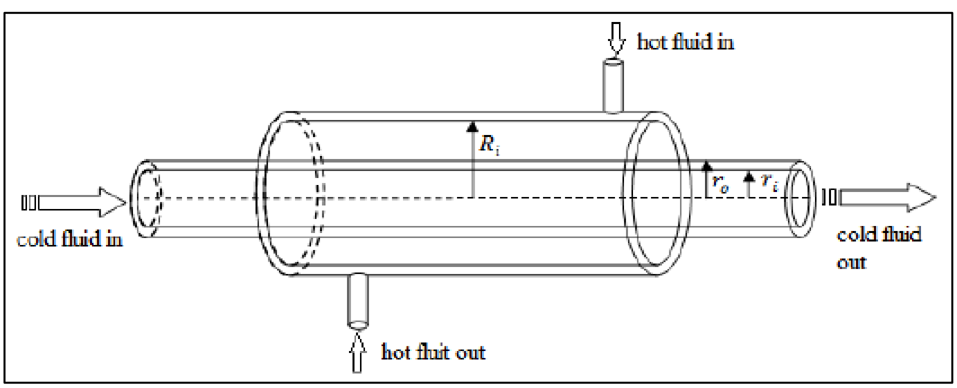

Fig. 1: Heat Exchanger

II. PROBLEM IDENTIFICATION

Heat exchanger is one of the most important equipment in steel, power and many other industries due to its applications. Many researchers had worked on this topic and several research is going on currently. Here we also try to improve the efficiency and effectiveness of heat exchanger by applying twisted tape inside the cold and hot domin. Generally, a perfect insulation is practically hard task to obtain due to some physical and atmospheric problem in simple HE. Also, the proper engagement between cold and hot fluid is not up to mark. Therefore, these problems can be overcome by using the twisted tape inserts inside the pipe.

III. OBJECTIVE

Effectiveness of heat exchanger can be increased without significant change in the circuit is possible by only one way i.e. by increasing flow of cold fluid in the inlet valve and alsoicresing the time of engagement between hot and cold water. However if we increase the flow in cold inlet in the tube type Heat Exchanger, then by the application of twisted tape the rate of heat transfer will also increases. For calculation of enhancement for heat exchanger belongs to modeling of tube with helical-tap insert. It provides the detailed information about the mathematical model of tube with helical-tap. A 3-dimensional model of a tube with helical-tape has been prepared.

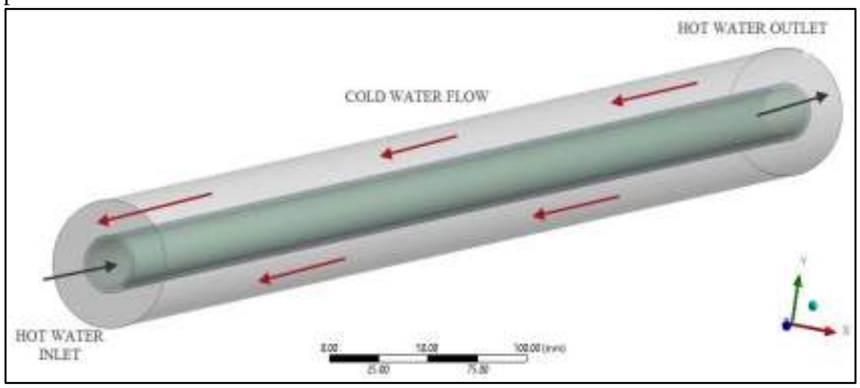

Fig. 2: CFD Model of Smooth Tube

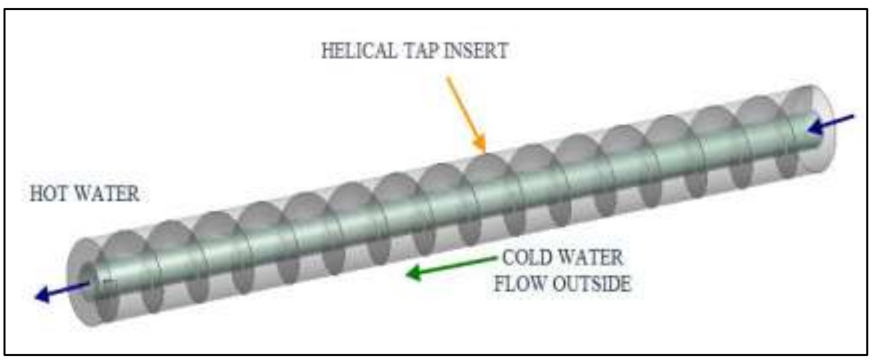

Fig. 3: CFD Model of Helical-Tap Inserts at Annulus of Inner Tube

For analysis of our work the input data and boundary condition will be taken in [1] which is experimentally investigate the heat transfer phenomenon.

Table – 1
Input Data for Convective Heat Transfer Analysis

Length of tube	2.2 m
Inner diameter of inner pipe, d_i	0.022 m
Outer diameter of inner pipe, d_o	0.026 m
Inner diameter of outer pipe, D_i	0.054 m
Outer diameter of outer pipe, d_o	0.058 m
Material of pipe	Copper
Inner pipe fluid	Cold water(300K)
Annulus fluid	Hot water(353k)

Table - 3.2
Properties of Water

Density, ρ	998.2 kg/m^3
Specific Heat Capacity, C_p	4182 J/kg K
Thermal Conductivity, k	0.6 W/m K
Viscosity, μ	1.003×10^{-3} kg/m s

IV. METHODOLOGY

A. Solid Modelling of Helical Tape Heat Exchanger

Modelling of twisted tape heat exchanger has been done in Ansys design modeler workbench by using several design tools like extrude helix and swift commands. Step by step modelling process has define here to clearly understand the design process in Ansys workbench.

Current research work is based on three different phases for analysis of results. In Phase I we critically analysis the result obtained by using the simple pipe for both hot and cold water with copper pipe and in Phase II we used the helical tape in cold and hot water to analyse the performance of heat exchanger and in Phase III we are using the different configuration of helical tape and twisted tape by varying the pitch of the tape.

S. No.	Parameter	Size	Diagram
1	Pitch	50	
2	Pitch	100	
3	Pitch	150	
4	Pitch	200	

Fig. 4: Assembly of Helical Twisted Tape Heat Exchanger

B. Meshing of Geometry

In the pre-processor phase, along with the geometry of the structure, the constraints, loads and mechanical properties are defined. Thus, in pre-processing, the entire body is completely defined by the geometric model. The model or structure represented by nodes and elements is called "mesh".

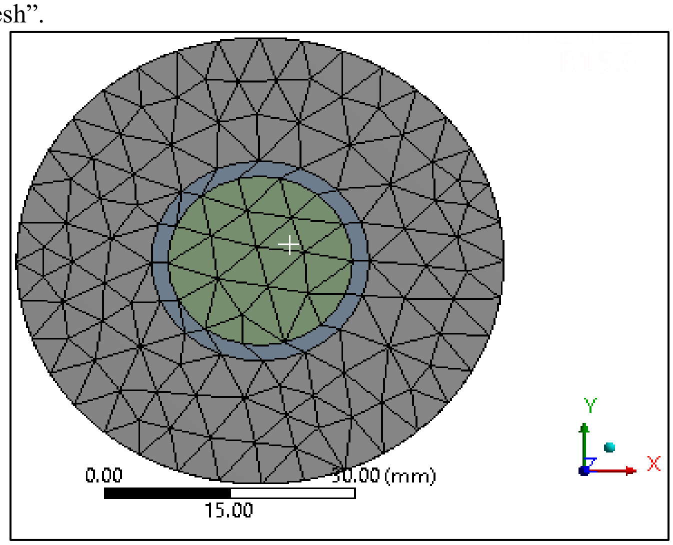

Fig. 5: Meshing of Helical Twisted Tape Heat Exchanger

C. Boundary Condition of Helical Tape Heat Exchanger

The boundary condition of twisted tape is assigned in the meshing workbench by applying name selection and selects the phase of the flow for both domin. The hot water flow inside of the helical tape and the cold-water flow outer pipe which is subjected to twisted tape throughout the pipe length.

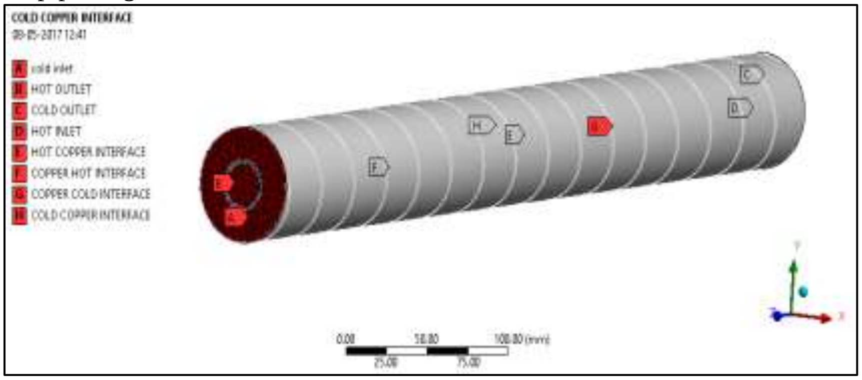

Fig. 6: Boundary Condition of Helical Twisted Tape Heat Exchanger

V. RESULT & DISCUSSION

The current research work is based on the optimization of heat transfer from the hot to cold domin. In order to find out the optimum configuration of pitch for hot and cold pipe we divided the whole work in three different phases. In Phase one we had taken simple pipe for both the fluid and find out the result based on different velocity of cold fluid and in phase two we create the helical tape and twisted tape in both the tube then perform the same operation with given boundary condition and in our final phase the parameter of pitch is vary from 50 to 200 in step of 50 and creating the four different model of heat exchanger.

A. CFD Result of Plain Heat Exchanger without Helical Tape [Phase I]

In order to validate the result obtained by simulation of plain heat exchanger we compare the result of CFD analysis with the result of Padalkar et al [1] and Bharat bhushan [2]. After the 400 simulation in between the time and energy with respect to x and y-axis. Here the inlet velocity of cold water vary from 0.376 to 0.50 m/s while the inlet velocity of hot water kept constant at 0.127 m/s.

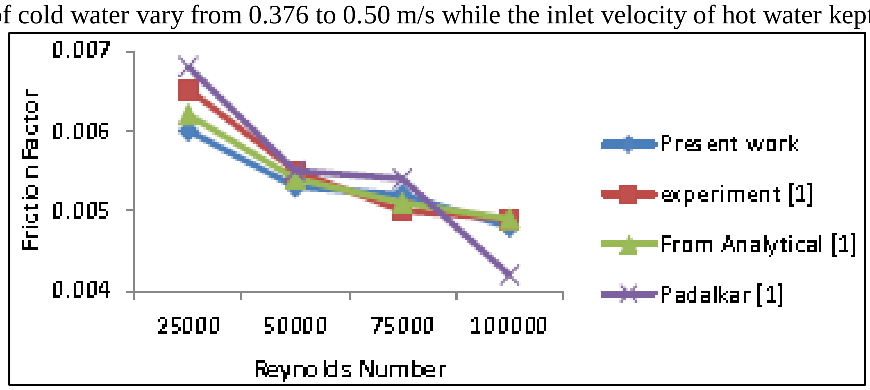

Fig. 7: Comparison between Different Approaches of twisted Tape HE

B. CFD Result of Twisted Tape Heat Exchanger [Phase II]

In order to improve the heat transfer capacity of heat exchanger a twisted helical tape is implemented in cold and hot pipe flow path. Due to the helical path the laminar flow is converted into the helical path and the engagement between the cold and hot fluid is increase so the heat transfer capacity is improves as compare to the simple pipe flow heat exchanger.

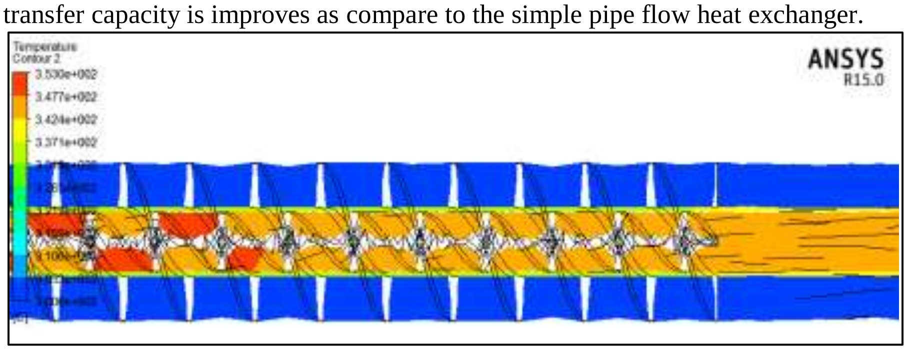

Fig. 8: CFD result of Twisted Tape Helical Heat Exchanger

C. CFD Result of Twisted Tape HE with Different Pitch Length [Phase III]

In order to improve the heat transfer of HE and to study the effect of pitch length in the nussalt number and friction coefficient we vary the pitch length from 50 to 200 mm in step of 50. So there are four different configuration of Twisted tape HE. Here we kept the boundary condition same as other simulation while the inlet velocity of the hot fluid is vary from 0.376 to 0.5 m/s.

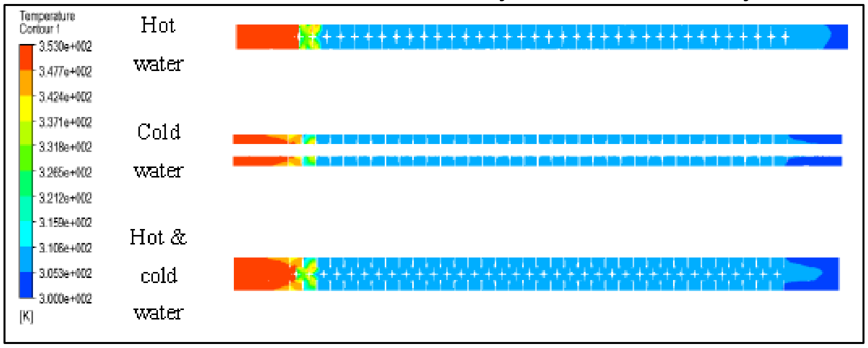

Fig. 9: Temperature Distribution in cold and hot wall of HE at Re = 9945

VI. CONCLUSION

The Phase III consist of different configuration of pitch length of twisted tape HE and analysis is performed under the same boundary condition to get the better result and optimum parameter of pitch length. The destitution of friction factor along the Reynolds number is given in the figure below. The maximum value of Friction Factor obtained at the Reynolds Number 9964. While minimum value lie in 16975 Reynolds number.

Finally, we concluded that the insertion of a twisted tape in a plain tube increase the thermal performance of the tube and furthermore if the pitch of helical twist is less then it increases the tube's thermal performance more.

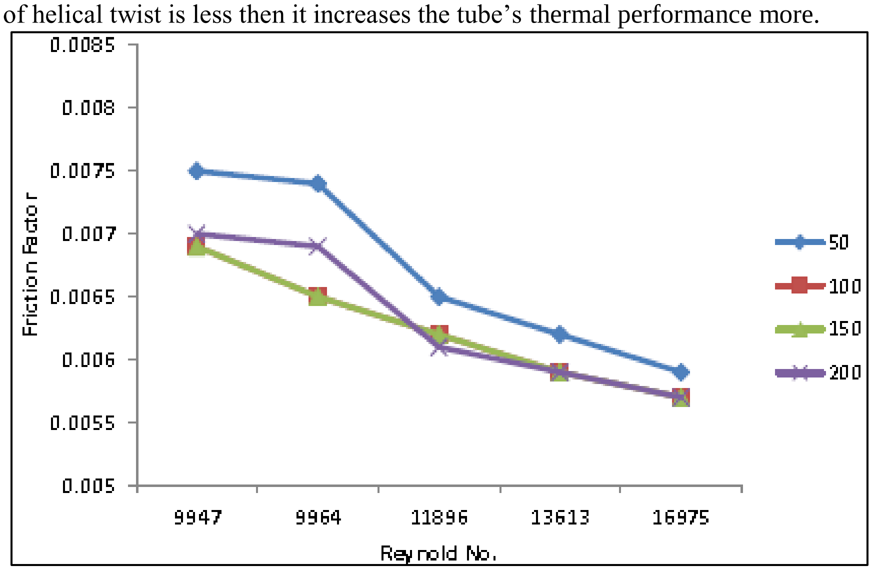

Fig. 10: Relationship between the Friction Factor and Reynolds Number

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