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AN EXPERIMENTAL STUDY OF CAPILLARY HELIX TUBE DIAMETER OPTIMIZATION USING NEURAL NETWORK TOOL USING ANSYS TOOL

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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.

Keyword Pipe, Finite volume method , Two dimensional finite difference method , ANSYS

Introduction

It is well known that heat transfer is considerably improved if the flow is stirred and mixed well. This has been the underlying principle in the development of enhancement techniques that generate swirl flows. Helical tape insert mixes the bulk flow well therefore heat transfer increases [12]. Among the techniques that promote secondary flows, helical-tape inserts are perhaps the most convenient and effective. They are relatively easy to fabricate and fit in the tubes of shell-and-tube or tube-fin type heat exchangers.

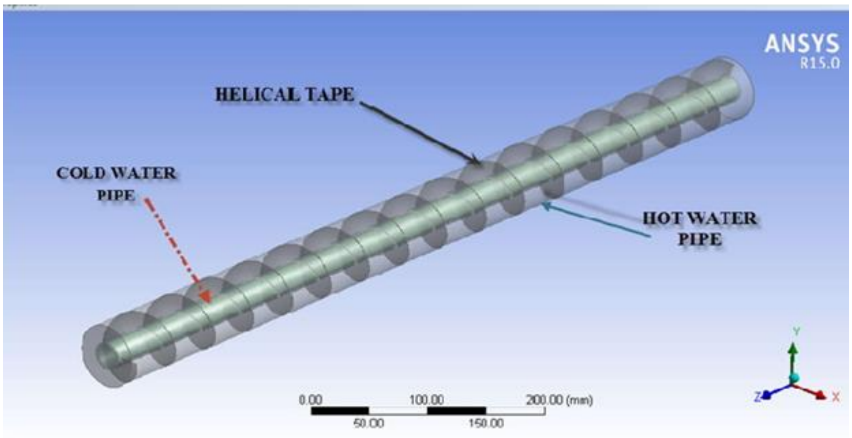

Figure 1 CFD model of helical-tap at annuals of inner pipe

Heat transfer enhancement may occur for three reasons:

1. The tape reduces the hydraulic diameter, which affects an increased heat transfer coefficient, even from zero tape twist.

2. The twist of the tape causes a tangential velocity component. Hence, the speed of the flow is increased near the wall. The heat transfer enhancement is a result of increased shear stress at the wall. Also heat transfer is enhanced by mixing fluid from the core region (cold) with fluid in the wall region (hot).

Literature review

Atul S. Padalkarand R J Yadav [1] This paper represent CFD investigation to study the heat transfer characteristics of air flow inside a circular tubewith a fully decaying, partially decaying and partly swirl flow. Four combinations of tube with twisted-tape inserts, half- length upstream twisted tape condition (HLUTT), half-length downstream twisted tape Condition (HLDTT), full-length twisted tape (FLTT), inlet twisted tape (ILTT) are considered along with plain tube (PT) for comparison.3D numerical simulation was performed for an analysis of heat transfer and fluid flow for turbulent regime. The results of CFD investigations of heat transfer, and friction aracteristics are presented for the FLTT, HLUTT, HLDTT and the ILTT along with a velocity and temperature profiles analysis in comparison with the PT case.

Durgesh Bhatt and Priyanka M Javhar [2], This paper presents the design of a shell-and- tube heat exchanger usually involves a trial and error procedure where for a certain combination of the design variables the heat transfer area is calculated and then another combination is tried to check if there is any possibility of increasing the heat transfer coefficient. Since several discrete combinations of the design configurations are possible, the designer needs an efficient strategy to quickly locate the design configuration having the minimum heat exchanger cost. In this particular problem the tube metallurgy and baffle spacing are being changed the results are obtained. In current paper the baffle spacing andtube metallurgy are the parameters considering change and effect of the same of heat transfer coefficient have been considered.

Thavamani J, at all, [3], In this paper the shell and tube heat exchanger (STHE) has been designed to cool the water from 60^{o} C to 51^{o} C. The experimental work is fabricated with the components of the exact dimensions as derived from the designing using CATIA and ANSYS. Tests are conducted on heat exchanger under the direction of flow, insulations under the atmosphere conditions. The observations and the result are discussed in the paper.

Guihong Pei and Liyin Zhang [4], the influence on the rock-soil temperature is approximately 13 % higher for the double-U heat exchanger than that of the single-U heat exchanger. The extracted energy of the intermittent operation is 36.44 kw·h higher than thatof the continuous mode, although the running time is lower than that of continuous mode, over the course of 7 days. The thermal interference loss and quantity of heat exchanged for unit well depths at steady-state condition of 2.5 De, 3 De, 4 De, 4.5 De, 5 De, 5.5 De and 6 De of side tube spacing are detailed in this work. The simulation results of seven working conditions are compared. It is recommended that the side-tube spacing of double-U underground pipes shall be greater than or equal to five times of outer diameter (borehole diameter: 180 mm).

Methodology

CFD Analysis of Model

Computational Fluid Dynamics (CFD) is the use of computer-based simulation to analyze systems involving fluid flow, heat transfer and associated phenomena such as chemical reaction. A numerical model is first constructed using a set of mathematical equations that describe the flow. These equations are then solved using a computer programmed in order to obtain the flow variables throughout the flow domain. Since the advent of the digital computer, CFD has received extensive attention and has been widely used to study various aspects of fluid dynamics. The development and application of CFD have undergone considerable growth, and as a result it has become a powerful tool in the design and analysis of engineering and other processes. In the early 1980s, computers became sufficiently powerful for general-purpose CFD software to become available.

CFD procedure

All commercial CFD packages involve sophisticated user interfaces to input parameters andto examine the results. Hence all the codes consist of three main elements:

- Pre-processor
- Solver
- Post-processor

Pre-processing

Pre-processing is the input of a flow problem to a CFD program by means of an operator friendly interface and the subsequent transformation of this input into a form suitable for use by the solver. The steps involved in this are:

- ➢ Definition of geometry.
- ➢ Grid generation.
- ➢ Selection of the phenomena or system to be modeled.
- ➢ Definition of fluid properties.
- ➢ Boundary conditions specification.

Solver

Solver involves the following steps:

- Approximation of the unknown flow variables by means of simple functions.
- Discretization by substitution of the approximations into the governing flow equations.
- Solution of algebraic equations.

Post-processor- All the leading CFD packages are equipped with versatile datavisualization tools. These include:-

- Domain geometry and grid display
- Vector plots
- Line and shaded contour plots
- Colour postscript output
- The mathematical modelling of a flow problem is achieved basically through three steps:

Result and Discussion

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 tox and y axis and heat exchanger we got following result which shown on table No1 below. Here the inlet velocity of cold water vary from 0.376 to 0.50 m/s while theinlet velocity of hot water kept constant at 0.127 m/s.

Table 1 CFD result of plain tube at different velocity

S No	Inlet VelocityOf Hot Water (M/S)	Inlet Temp Of Hot Water (K)	Inlet Temp Of Cold Water (K)	Inlet Velocity Of Cold Water(m/s)	Outlet Temperature Of Hot Water (K)	Outlet Temperature Of Cold Water (K)
1	0.127	353	300	0.376	348	324
2				0.400	345	3318
3				0.425	346.5	320
4				0.45	342.7	317
5				0.50	340.9	324

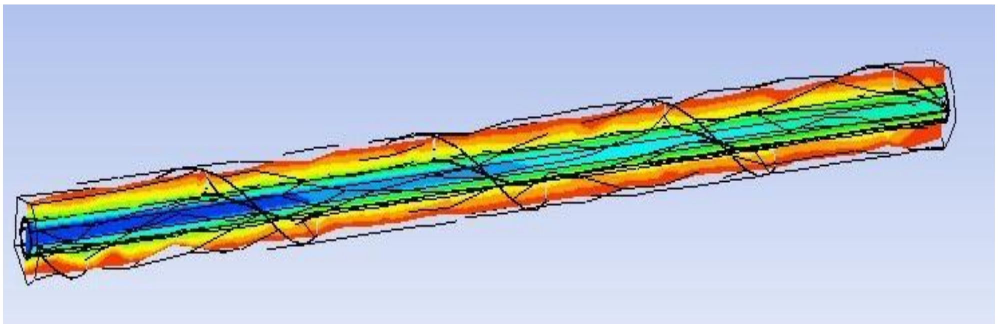

Fig 2 CFD result of plain tube heat exchanger

After calculating the outlet temperature of hot and cold fluid , we calculate the Friction Coefficients for different Reynolds Number have been calculated as per the following relation and verified with the findings of Padalkar et al [1].

the comparison between the values of friction factorsmentioned in reference [1] and values obtained by the present work.

Table 2 Comparison of friction factor for different Approaches

ReynoldsNumber	Friction Factor			
	Presentwork	experiment[1]	From Analytical [1]	Padalkar [1]
25000	0.0060	0.00652	0.0062	0.0068
50000	0.0053	0.0055	0.0054	0.0055
75000	0.0052	0.005	0.0051	0.0054
100000	0.0048	0.0049	0.0049	0.0042

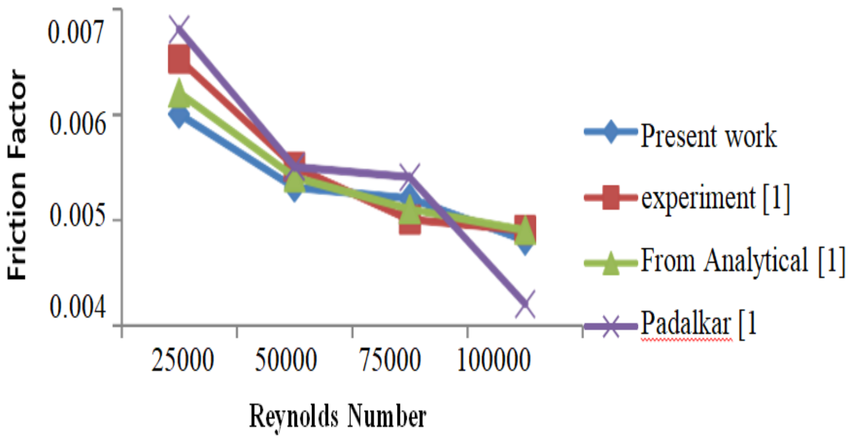

Fig. 3 Comparison between different approaches of twisted Tape HE

Graph below represent the comparisons of the above mentioned values and affirms this fact that simulation done on plain tube by the present work is fully validated.

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. The result obtained by implementation of twisted tape is given below.

Table 3 CFD result of twisted Tape HE at different velocity

S No	Inlet Velocity of Hot Water(M/S)	Inlet Tempof Hot Water (K)	Inlet Tempof Cold Water (K)	Inlet Velocity of Cold Water(m/s)	Outlet Temperatureof Hot Water(K)	Outlet Temperatureof Cold Water (K)
1	0.127	353	300	0.376	335.1	311
2				0.4	333.7	320
3				0.425	331.6	324
4				0.45	337.4	317
5				0.5	330.6	325

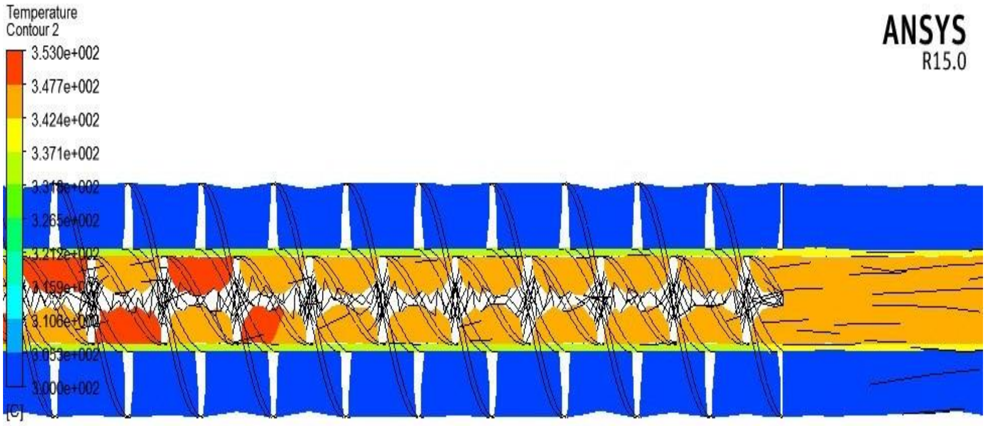

Fig. 4 CFD result of Twisted Tape helical heat exchanger

CFD Result of Twisted Tape HE with different Pitch length [Phase III]

In order to improve the heat transfer of HE and also 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. Herewe 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.After calculating the outlet temperature of hot and cold fluid by CFD analysis further we calculate the skin friction coefficient and Nussalt number to find out the nature ofthe flow within different pitch length. The Reynolds number and friction factor are calculated by applying empirical formula in ansys workbench y using expression and function formula.

Table 4 CFD result of twisted Tape HE at different velocity & Pitch Length

S No.	**pitch**	**Inlet velocity ofhot fluid m/s**	**ReynoldsNo. RL**	**Frictionfactor f**	**NusseltNo.**
1		0.376	9947	0.0075	112
2		0.4	9964	0.0074	128
3	50	0.425	11896	0.0065	167
4		0.45	13613	0.0062	176
5		0.5	16975	0.0059	224
6		0.376	9951	0.0069	157
7		0.4	9967	0.0065	188
8	100	0.425	11797	0.0062	221
9		0.45	13515	0.0059	248
10		0.5	16776	0.0057	272
11		0.376	9950	0.0069	148
12		0.4	9984	0.0065	198
13	150	0.425	11797	0.0062	234
14		0.45	13615	0.0059	257
15		0.5	16476	0.0057	283
16		0.376	9952	0.007	143
17		0.4	9967	0.0069	181
18	200	0.425	11698	0.0061	210
19		0.45	13586	0.0059	249
20		0.5	16684	0.0057	259

The temperature contour of the hot and cold domin is given below in figure no 6.3and it show better result as compare to the simple HE due o the helical path of flow and also sharp edges of corner provide more turbulence and engagement etween thehot and cold water so the rate of heat transfer is also high in twisted helical tape.So, it gives good mixing of the fluid. Thus, it results in less increase of heat transfer compare with plain tubes. Fig.5 6 shows the flow pattern Velocity streamlines Helical Tape pitch length 50 mm Re=9945.

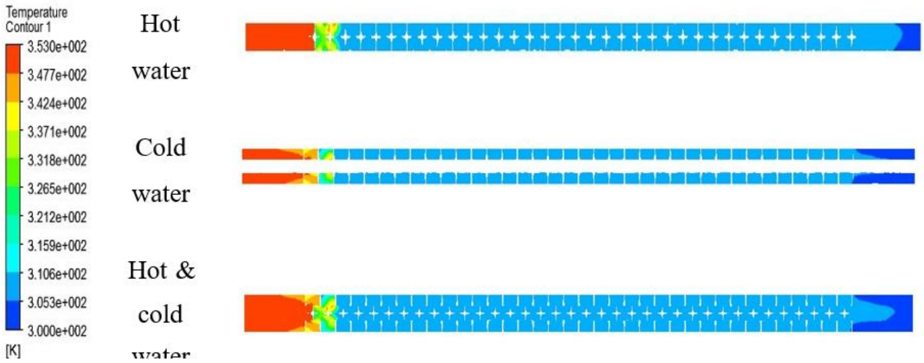

Fig.5 :Temperature Distribution in cold and hot wall of HE at Re=9945

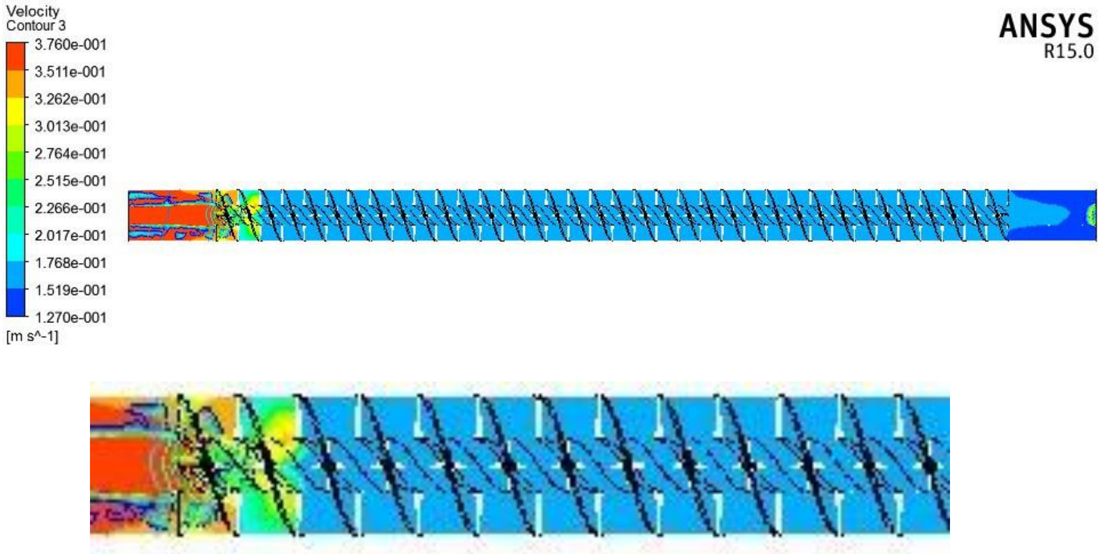

Fig.6 :velocity contour of cold and hot fluid at Re=9945

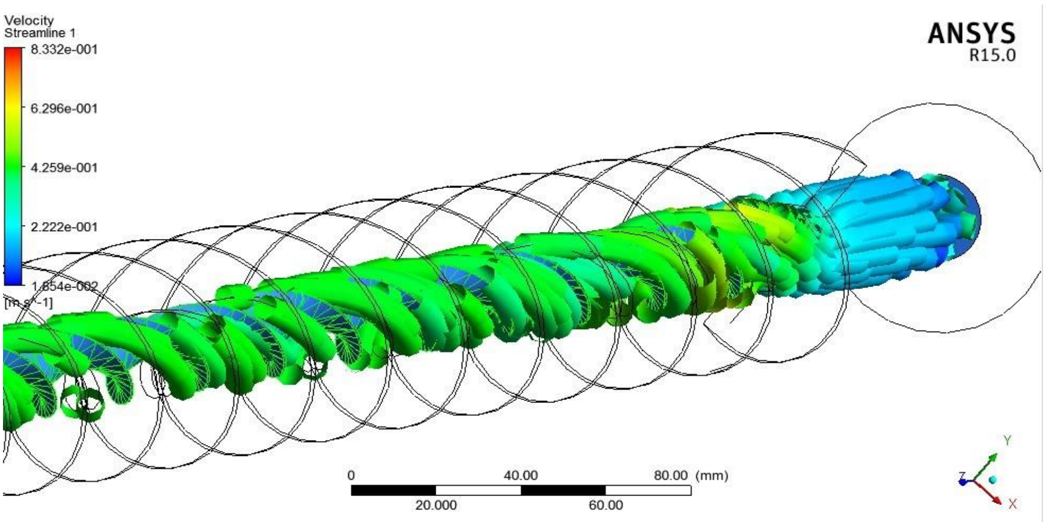

Fig.7 :path of flow in hot flow domin

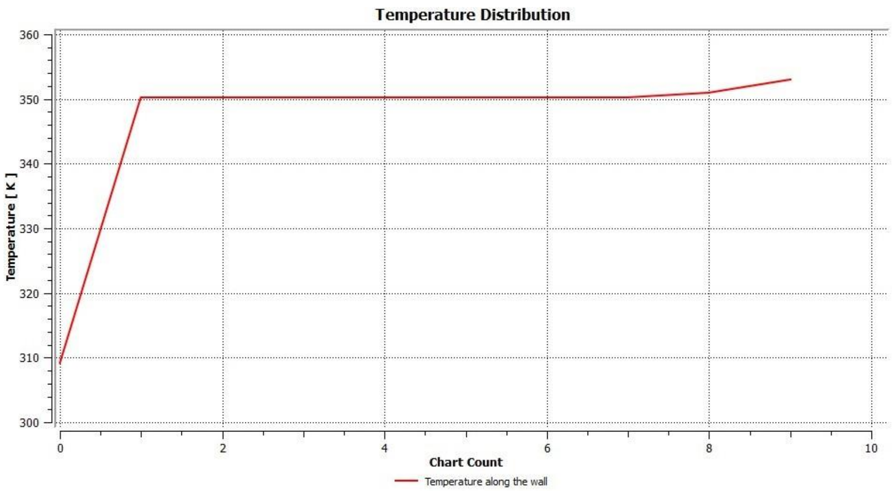

Fig.8 Temperature Distribution graph along the wall

The figure 7 & 8 shows the flow pattern and distribution of temperature along the wall of copper pipe. Due to the helical or swirl path of hot & cold water it engage max time with the other fluid so the rate of heat transfer is increased as compared to the simple HE.the temperature along the wall in cold fluid is increased with respect to the length of wall upto 400 mm but goes constant after these length and again it increases with the length of pipe

CONCLUSION

1. With clear that the CFD result of simple HE shows very good agreement with the analytical and experimental method also with the padalar approaches. The corresponding friction factor is very close to the experimental method.

2. With the tabulation data of Twisted HE with respect to the different velocity and Reynolds number. The table show that when the velocity of cold fluid is increases the heat transfer rate is also increases and it goes down at 0.45 m/s velocity. And again it goes increases with the velocity at 5m/s.

3. The Phase III consist of different configuration of pitch length of twisted tape HE and analysis is performed under the same boundary condition t get the better result and optimum parameter of pitch length. the maximum value of Friction Factor obtained at the Reynolds Number 9964. While minimum value lie in 16975 Reynolds number.the relationship between the nussalt number and Reynolds number for twisted tape HE. Show it is clear that when the value of Reynolds number increases the nussalt number also increases.

4. 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 lessthen it also increases the tube's thermal performance more.

5. Area Weighted Average of the fluid's temperature at the outlet of the tube has been increased due to the insertion of a twisted tape in the tube. The reason for the increment of these parameters is that, due to the insertion of a twisted tape a vortex flow is created in the pipe which helps the fluid to take more and more heat from the tube wall. The vortex has been shown below.

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