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CFD Analysis of Concentric Tube Heat Exchanger Using Twisted Tapes

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Abstract-In this paper, the three dimensional CFD modeling studies on heat transfer, friction factor and thermal performance of concentric tube heat exchanger using twisted tapes (Plain, V-cut, , Jagged V-cut) with different twist ratios (y=2.0, 4.0) are used. Twisted tapes are used to augment the heat transfer by creating turbulence in the fluid flow. Various methods are applied to increase thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices. Out of these twisted tape method is used to increase the thermal performance. Twisted tape inserts on effectiveness of heat exchanger has analyzed for different Reynolds Number. The maximum thermal performance factor was obtained by the Jagged V-cut twisted tape (H=50) insert compare to other twisted tapes. Simultaneously the friction factor has been analyzed..

Key words: CFD, Twisted tapes, V-cut, Heat transfer.

I. INTRODUCTION

Effective utilization of available energy becomes need of hour today. This obviously requires effective devising. When it concerns with heat energy the devices are heat exchangers. Heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running cost. Heat exchangers are used in variety of applications. Some of the applications of heat exchangers are-in process industries, thermal Power plants, air-conditioning equipments, refrigerators, radiators for space vehicles, automobiles etc. Increase in Heat exchanger performance can lead to more economical design of heat exchanger which can be help to make energy, material & cost savings related to a heat exchange process.

To increase the thermal performance of heat exchangers Heat transfer augmentation techniques are used. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system.

These techniques broadly divided in two groups viz. passive and active. Active techniques involves some external power input for the enhancement of heat transfer, some examples of active techniques induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc Passive techniques generally used in surface or geometrical modifications to the flow channel by incorporating inserts or additional devices, for example, use of inserts, use of rough surfaces etc.

The concentric tube heat exchanger consists of two tubes that are concentrically arranged. One of the fluid (either hot or cold fluid) flows through the tube and the other through the annulus. For a CTHX, two types of flow arrangements are possible - co-current and counter-current flow. In the parallel or co-current arrangement, the flow direction of the hot fluid will be the same as that of the cold fluid. In the counter-current arrangement, the flow direction of the hot and the cold fluids are opposite to each other. In present work passive technique of augmentation is used.

A lot of methods are applied to increase thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices. Out of these twisted tape method is used to increase the thermal performance. The Concentric tube heat exchanger is fitted with inner twisted tape and flow side protrusions to outer tube as additional inserts.

OBJECTIVES OF THE PROJECT

- The main objectives of the projects are to carry out the fluid (water) flow analysis of concentric tube heat exchanger using twisted tapes.
- The three dimensional CFD modeling Studies on heat transfer, friction factor and thermal

performance of concentric tube heat exchanger using twisted tapes (Plain, V-cut, Double V-cut, jagged V-cut) with different twist ratios (y=2.0, 4.0) are used.

II. LITERATURE SURVEY

S.R. Shabanian ,et.al.(2011) studied on the experimental and Computational Fluid Dynamics (CFD) modeling studies on heat transfer, friction factor and thermal performance of an air cooled heat exchanger equipped with three types of tube insert including butterfly, classic and jagged twisted tape. In the studied range of Reynolds number the maximum thermal performance factor was obtained by the butterfly insert with an inclined angle of 90°.

The results have also revealed that the difference between the heat transfer rates obtained from employing the classic and jagged inserts reduces by decreasing the twist ratio. The CFD predicted results were used to explain the observed results in terms of turbulence intensity.

Leonard et.al (2006) studied on the effect of internal aluminium fins with a star-shape cross-section on the heat transfer enhancement and pressure drop in a counter flow heat exchanger. A concentric-tube heat exchanger was used with water as the working fluid. The heat transfer rate increased by 12–51% over a plain tube value, depending on internal fin configurations used. However, the pressure drop also increased .Thus the results showed that a straight-fin configuration is the best to produce a heat transfer increase in a counter flow heat exchanger. Twisted fin configurations did not further increase the heat transfer rate.

P. Murugesan, et.al. (2011) Studied the effect of V-cut twisted tape insert on heat transfer, friction factor and thermal performance factor characteristics in a circular tube were investigated for three twist ratios (y=2.0, 4.4 and 6.0) and three different combinations of depth and width ratios (DR=0.34 and WR=0.43, DR=0.34 and WR=0.34, DR=0.43 and WR=0.34). The obtained results show that the mean Nusselt number and the mean friction factor in the tube with V-cut twisted tape (VTT) increase with decreasing twist ratios (y), width ratios (WR) and increasing depth ratios (DR).

Subsequently an empirical correlation also was formulated to match with experimental results with ±6% variation for the Nusselt number and ±10% for the friction factor.

Paisarn Naphon and Tanapon Suchana (2011) studied on the heat transfer characteristics and the pressure drop of the horizontal double pipe with coil-wire insert is investigated. The inner and outer diameters of the inner tube are 8.92 and 9.52 mm, respectively. The coiled wire is fabricated by bending a 1 mm diameter of the iron wire into a coil with a coil diameter of 7.80 mm. Cold and hot water are used as working fluids in the shell side and tube side, respectively. The test runs are performed at the cold and hot water mass flow rates ranging between 0.01 and 0.07 kg/s, and between 0.04 and 0.08 kg/s, respectively. The inlet cold and hot water temperatures are between 15 and 20 °C, and between 40 and 45 °C, respectively. The effect of the coil pitch and relevant parameters on heat transfer characteristics and pressure drop are considered. Coil-wire insert has significant effect on the enhancement of heat transfer especially on laminar flow region. Non-isothermal correlations for the heat transfer coefficient and friction factor are proposed. There is reasonable agreement between the measured data and predicted results.

Halit Bas and Veysel Ozceyhan (2012) Flow friction and heat transfer behavior in a twisted tape swirl generator inserted tube are investigated experimentally. The twisted tapes are inserted separately from the tube wall. The effects of twist ratios (y/D = 2, 2.5, 3, 3.5 and 4) and clearance ratios (c/D = 0.0178 and 0.0357) are discussed in the range of Reynolds number from 5132 to 24,989, and the typical one (c/D = 0) is also tested for comparison. Uniform heat flux is applied to the external surface of the tube wall. The air is selected as a working fluid. The obtained experimental results from the plain tube are validated by using well known equations given in literature. The using of twisted tapes supplies considerable increase on heat transfer and pressure drop when compared with those from the plain tube.

Hassan Hajabdollahi et.al (2011) studied Thermal modeling and optimal design of compact heat exchanger is presented in this paper. Fin pitch, fin height, cold stream flow length, no-flow length and hot stream flow length were considered as five design parameters. A CFD analysis coupled with artificial neural network was used to develop a relation between Colburn factor and Fanning friction factor for the triangle fin geometry with acceptable precision. Then, fast and elitist non-dominated sorting genetic algorithm (NSGA-II) was applied to obtain the maximum effectiveness and the minimum total pressure drop as two objective functions. The results of optimal designs were a set of multiple optimum solutions, called 'Pareto-optimal solutions'. It reveals that any geometrical changes which decrease the pressure drop in the optimum situation, lead to a decrease in the effectiveness and vice versa. Finally sensitivity analysis shows the increases of heat transfer surface area necessarily do not increases the pressure drop and it is case sensitive.

Paisarn Naphon, (2006) studied experimental study he used hot and chilled water in horizontal copper double tube heat exchanger fitted with aluminium twisted tape inside. He studied effects of relevant parameters on heat transfer and pressure drop. It was concluded that the twisted tape insert has significant effect on enhancing heat transfer rate. However, the pressure drop also increases. Correlation for heat transfer coefficient and friction factor based on the experimental data is also presented.

III. DESIGN AND ANALYSIS

PASSIVE HEAT TRANSFER AUGMENTATION METHODS

Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system.

Following Methods are generally used,

1. Inserts
2. Extended surface
3. Surface modifications
4. Use of additives.

Inserts

Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer. Different types of inserts are

1. Twisted tape and wire coils
2. Ribs, Baffles, plates

Twisted tape

Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow. Following are the main categories of twisted tape which are analysed earlier.

1. Full length twisted tape

These tapes have length equal to length of test section.

2. Varying length twisted tape

These are distinguished from first category with regards that they are not having the length equal to length of test section, but half length, ¾ th length, ¼ th length of section etc.

3. Regularly spaced twisted tapes

These are short length tapes of different pitches spaced by connecting together.

4. Tape with attached baffles

Baffles are attached to the twisted tape at some intervals so as to achieve more augmentation.

5. Slotted tapes and tapes with holes

Slots and holes of suitable dimensions made in the twisted tape so as to create more turbulence.

6. Tapes with different surface modifications

Some insulating material is provided to tapes so that fin effect can be avoided. In some cases dimpled surfaced material used for tape fabrication.

Common attributes of tape

1. Width

Small width tapes are preferred to minimize pressure drop.

2. Thickness

Thickness of the tape plays important role in its fabrication and also has contribution in fin effect

3. Pitch:

It is the distance between two consecutive twists measured axially.

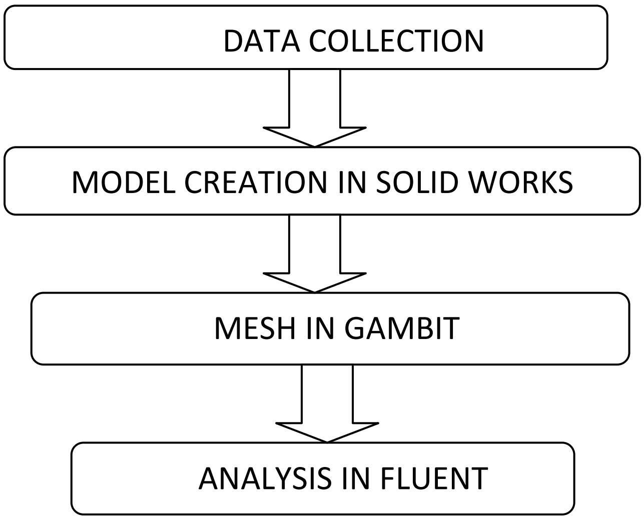
4. Twist ratio

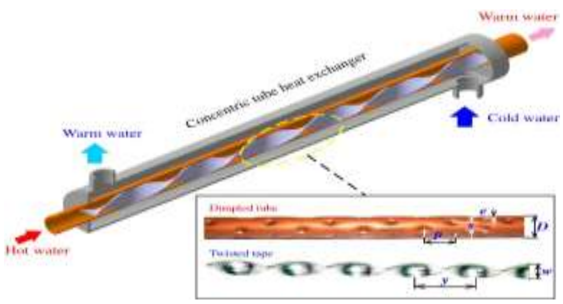
It is the ratio of pitch of tape to tape width. So, if width of the tape considered as a constant (as found generally) twist ratio depends on pitch only. Under this condition if pitch is more it means less number of turns.

***5.* Fin effect**

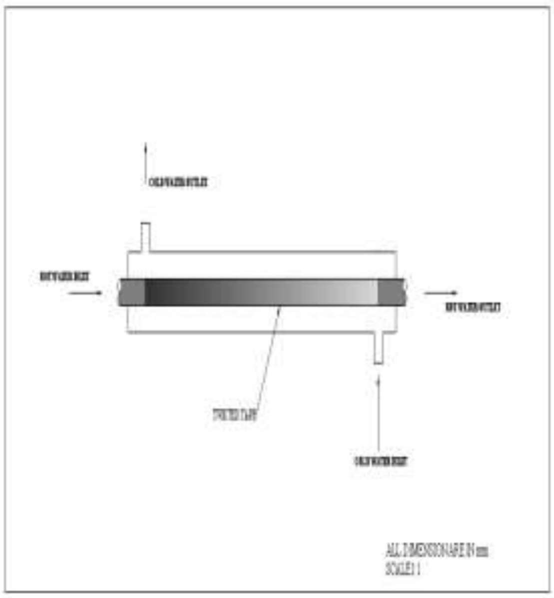
If the tape material is conductive then during the flow some heat will be absorbed by the tape material itself till its saturation. This is simply the loss of available heat energy.

METHODOLOGY





SPECIFICATIONS



Concentric Tube Heat Exchanger

Test Section
Length L= 2000mm
Outer tube inner Diameter do= 54.5mm
Inner tube inner Diameter di=25.0mm
Inner tube material=copper
Outer tube material=G.I

Twisted tape

Tape width (W) =23.5 mm
Tape thickness =1.5 mm
Tape pitch length (H, 180°) = 50,100 mm
Twist ratio (y=H/di) =2.0, 4.0
Width of V cut (w) =8 mm
Depth of V cut (de) =10mm
Material = Aluminum

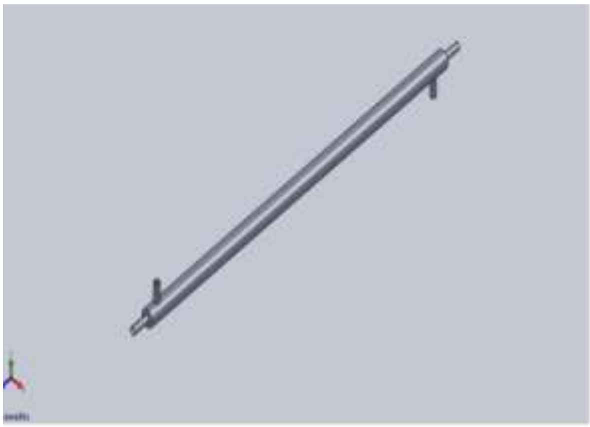
SOLID WORKS IMPORT AND MESHING

From Solid Works import to geometry meshing, our flexible tools allow you to automatically create meshes or hand-craft them. ANSYS meshing can extract fluid volume from a CAD assembly and automatically create tetrahedral or hexahedral meshes with inflation layers.

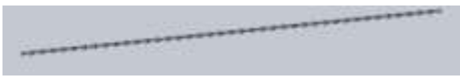
The integration of ANSYS Fluent into ANSYS Workbench provides users with superior bi-directional connections to all major CAD systems, powerful geometry modification and creation with ANSYS Design Modeler technology, and advanced meshing technologies in ANSYS Meshing. The platform also allows data and results to be shared between applications using an easy drag-and-drop transfer, for example, to use a fluid flow solution in the definition of a boundary load of a subsequent structural mechanics simulation.

Gambit and fluent are the two software's that are most widely used together as a package. In the simulation we have used gambit (2.4.6) and Fluent (6.3.26). Gambit as the preprocessing tool in my project.

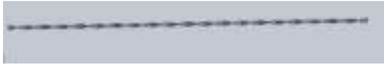
CONCENTRIC TUBE HEAT EXCHANGER SOLID MODEL



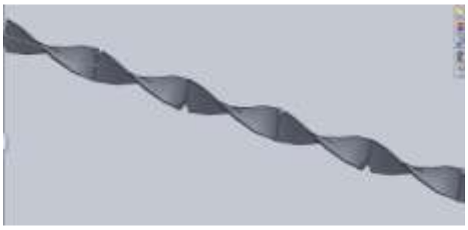
PLAIN TWISTED TAPE



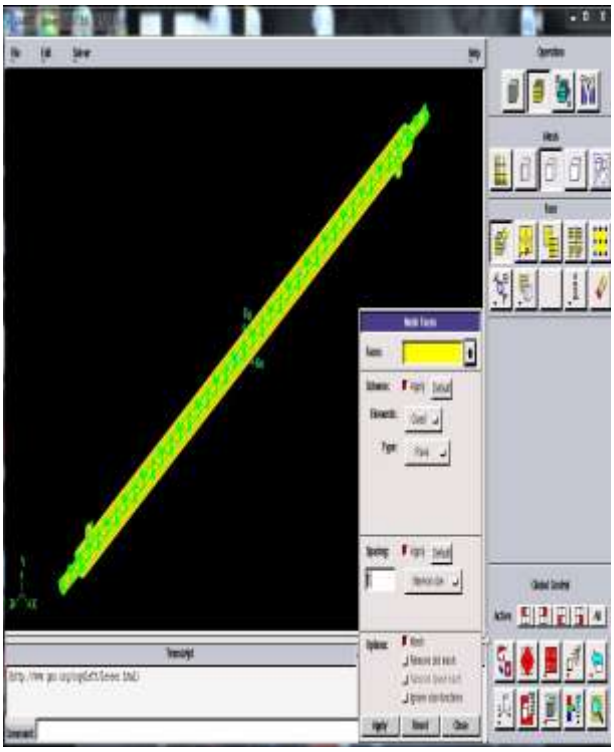
V-CUT TWISTED TAPE



V-JAGGED TWISTED TAPE



SOLID MODELLING



MESH FACES

FLUENT

CFD is a field of engineering which determines a numerical solution to set of equations of fluid flow by advancing the solution through space and time and obtain a numerical description of the complete flow field of interest. The enormous growth in computational power of computers in the past few years has helped in the increase of CFD solutions in various fields, including and especially automotive design. ANSYS Fluent software contains the broad physical modeling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Special models that give the software the ability to model in-cylinder combustion, aero acoustics, turbo machinery, and multiphase systems have served to broaden its reach.

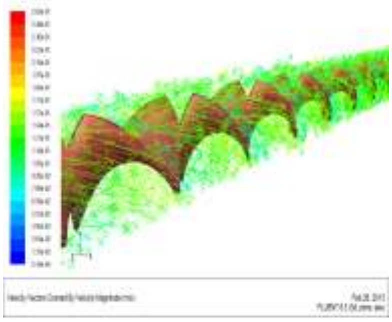
Today, thousands of companies throughout the world benefit from the use of ANSYS Fluent software as an integral part of the design and optimization phases of their product development. Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability. User-defined functions allow the implementation of new user models and the extensive customization of existing ones.

The interactive solver setup, solution and post-processing capabilities of ANSYS Fluent make it easy to pause a calculation, examine results with integrated post-processing, change any setting, and then continue the calculation within a single application. Case and data files can be read into ANSYS CFD-Post for further analysis with advanced post-processing tools and side-by-side comparison of different cases.

Turbulence Models

Fluent delivers cutting-edge turbulence modeling capabilities in an unparalleled breadth of models. These include several versions of the popular k-epsilon and k-omega models as well as the Reynolds stress model for highly anisotropic flows. Advanced scale-resolving turbulence models are also available: large eddy simulation (LES), detached eddy simulation (DES) and scale adaptive simulation (SAS). In addition, innovative transition models accurately predict flow in which the boundary layer transitions from laminar to turbulent regime.

GRID STRUCTURE



VELOCITY VECTORS

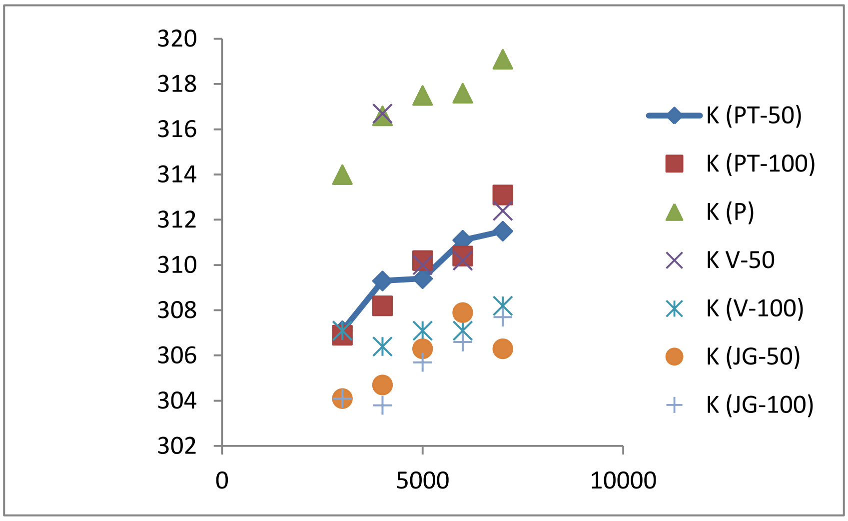
CONDITIONS:

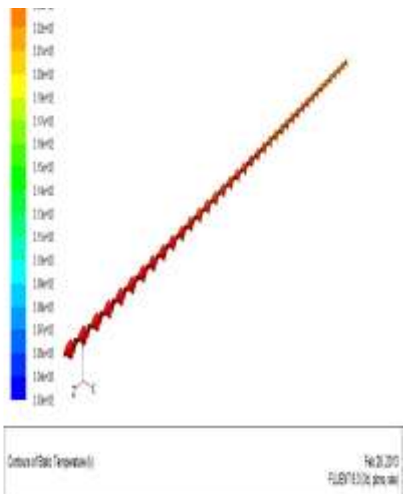
Hot water inlet=327K

Cold water outlet=303K

HOT WATER OUTLET TEMPERATURE DIFFERENCE

Re	K (PT-50)	K (PT-100)	K (P)	K (V -50)	K (V-100)	K (JG-50)	K (JG-100)
3000	307.1	306.9	314	307.1	307.1	304.1	304.1
4000	309.3	308.2	316.6	316.7	306.4	304.7	303.8
5000	309.4	310.2	317.5	310.0	307.1	306.3	305.7
6000	311.1	310.4	317.6	310.2	307.1	307.9	306.6
7000	311.5	313.1	319.1	312.4	308.2	306.3	307.7

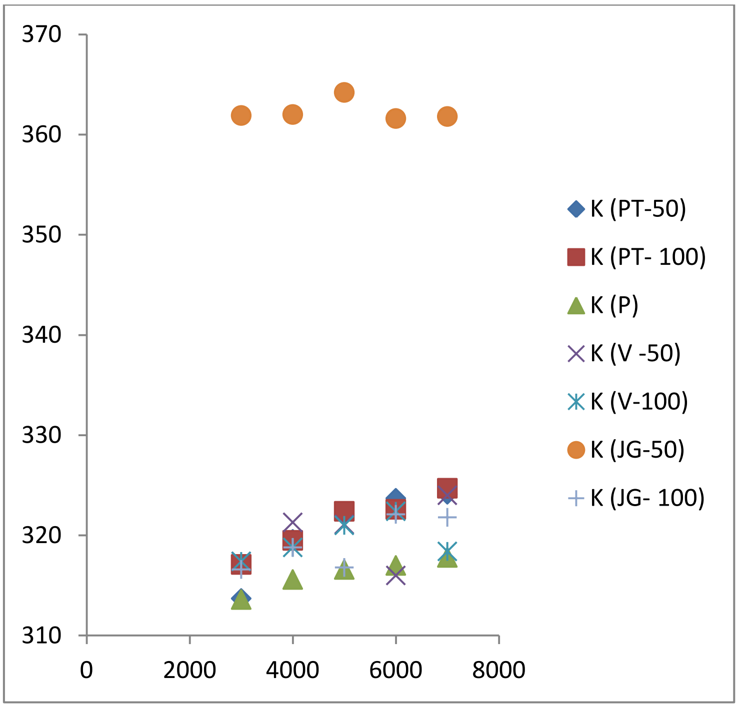




CONTOURS OF STATIC TEMPERATURE (TWISTED TAPE)

COLD WATER OUTLET TEMPERATURE DIFFERENCE

Re	K (PT-50)	K (PT-100)	K (P)	K (V -50)	K (V-100)	K (JG-50)	K (JG-100)
3000	313.7	317.1	313.6	317.4	317.4	361.9q	316.6
4000	319.6	319.5	315.6	321.3	318.8	362.0	318.8
5000	322.2	322.4	316.6	321.1	321.0	364.2	316.8
6000	323.7	322.6	317.0	316.0	322.4	361.6	322.1
7000	324.1	324.7	317.8	324.0	318.4	361.8	321.8



CONCLUSION

CFD analysis has been carried out to study on heat transfer of tape inserts on the performance of concentric tube heat exchanger. Effectiveness, overall heat transfer coefficient and friction factors are analyzed by using mentioned heat transfer augmentation methods. The three dimensional CFD modeling results showed that an increase in turbulence intensity could be one of the reasons for higher performance of Jagged V-cut twisted tape (H=50) compared with the other type of tapes.

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