

Experimental Investigation of an Innovative Water Heating System with CFD

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ABSTRACT: Heat transfer augmentation technique (passive, active or as well a combination of passive with active methods are normally used in area such as development industries, heating plus cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, and so on. Passive technique, anywhere insert be use into the flow passageway toward supplement the heat transfer charge, are beneficial compare by means of active techniques, for the reason that the insert manufacturing method is simple as well as these techniques can be easily working in an obtainable heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can take part in an vital task if a appropriate passive insert configuration be able to be preferred according to the heat exchanger functioning position. In the ancient times, a number of studies on the passive techniques of heat transfer augmentation have been reported. The current paper is a review on evolution with the passive augmentation techniques in the recent past and will be helpful to designer implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, and so on., are the mainly used passive heat transfer augmentation tools. In the current paper, highlighting the specified to works dealing with twisted tapes because, according to current studies, these are identified to be cost-effective heat transfer augmentation tools. The previous insert is set up to be appropriate in a laminar flow regime with the latter is right for turbulent flow. In the current paper stress is set on to work dealing with displaced insert into circular tubes (twist tap insert) and CFD based analysis in laminar plus turbulent flow. In this project we tried to enhance the Heat transfer rate with the help of Twisted Tape inserted into the tube.

KEYWORDS: CFD Analysis, Heat Transfer Enhancement technique, Twisted tape, Passive technique.

I. INTRODUCTION

The economy of any thermal system mainly depends on efficiency of the Heat Exchangers used in it. The efficiency of Heat Exchanger can be raised by using appropriate method of heat transfer augmentation. The method used for heat transfer enhancement should satisfy the condition of maximum heat transfer and minimum pressure drop. Heat exchangers be used in various process ranging from conversion, utilization and recovery of thermal energy into different industrial, commercial and domestic applications. Some common example consist of steam generation and condensation in power and cogeneration plants, sensible heating and cooling in thermal processing of chemical, pharmaceutical and agricultural products, fluid heating, petrochemical, biomedical and food processing plants serve to heat and cool different type of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously rising with the unit power and the volume of production. Different techniques are in employment to progress the heat transfer rates, which are commonly referred to as heat transfer enhancement, augmentation otherwise intensification technique. Whereas, the active techniques require a little power externally, for example electric or acoustic fields, surface vibration, mechanical aid, fluid vibration, injection, suction, jet impingement, etc. Some latest techniques like CFD analysis are used for the reason that this provides qualitative and sometimes even quantitative prediction of fluid flows by means of, mathematical modeling, numerical method, software tools (solvers, pre and post processing utilities) CFD enables to carry out numerical experiments.

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1.1 CLASSIFICATION OF AUGMENTATION TECHNIQUES

In general, heat transfer augmentation technique is classified as in three broad categories:

- (a) Active method,
- (b) Passive method,
- (c) Compound method.

The active and passive methods are described with examples as following subsections. A compound method is a fusion method in which both active and passive methods. The compound method involves complex design moreover hence has limited applications.

[a] Active method

This method involves some external power input for the improvement of heat transfer and has not revealed to a large extent potential owing to complexity in design. Furthermore, external power is not easy to provide in several applications. Some examples of active methods are induced pulsation via cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc.

[b] Passive method

This method does not necessitate any external power input and the additional power required to improve the heat transfer is taken from the available power in the system, which ultimately leads to a fluid pressure drop. The heat exchanger industry has been determined for better thermal contact (enhanced heat transfer coefficient) and reduced pumping power in order to get better the thermo hydraulic efficiency of heat exchangers. A good heat exchanger design should have an efficient thermodynamic performance, that is minimum production of entropy or minimum destruction of available work (exergy) in a system incorporating a heat exchanger. It is nearly impossible to stop exergy loss totally, but it can be minimized through an efficient design.

[C] Compound Method

When any two or more of these techniques are employed simultaneously to get enhancement in heat transfer that is greater than that produced by either of them when used separately, is stated as compound enhancement. This method contains complex design and that's why has limited applications.

II. SYSTEM DEVELOPMENT

2.1 Heat Exchangers:-

Heating and cooling of materials and fluids is an essential part of processing, production, and fabrication and shop floor jobs in engineering practice. Heat exchangers are used for the above purpose by utilizing the basic principles and correlations of heat transfer along with other relevant physical and engineering principles.

2.2 Classifications of Heat Exchangers

There are several types of heat exchangers which may be classified on the basis of a) Nature of heat exchange process b) Relative direction of fluid motion c) Design and constructional features. Based on the nature of heat exchange process a) Direct contact heat exchangers b) Indirect contact heat exchangers.

2.3 Concentric tube heat exchanger

Concentric tube heat exchangers are used in a variety of industries for purposes such as material processing food preparation and air-conditioning. They create a temperature driving force by passing fluid streams of different temperatures parallel to each other separated by a physical boundary in the form of a pipe. This induces forced convection, transferring heat to and from the product. The thermodynamic behaviour of concentric tube heat exchangers can be described by both empirical and numerical analysis. The simplest of these involve the use of correlations to model heat transfer however the accuracy of these predictions varies depending on the design.

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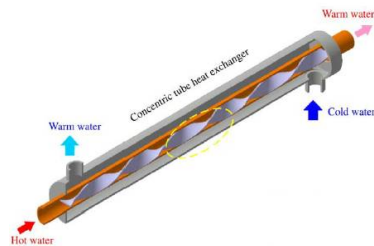


Fig.1. Concentric Tube Heat Exchanger

III. EXPERIMENTAL SET UP

Fig 2 shows the schematic diagram of the experimental setup. It is a double pipe heat exchanger consisting of a calming section, test section, rotameters, overhead water tank for supplying cold water & a constant temperature bath for supplying hot water with in-built heater, motor & the temperature indicator. The test section is a smooth copper tube with dimensions of 600mm length,; Outer MS pipe-75 mm ID, and 61 mm OD. The outer pipe is well insulated using asbestos rope to reduce heat losses to the atmosphere. Two calibrated rotameters, with the flow ranges 1 to 5 LPM and 300 to 1250 LPH, are used to measure the flow of cold water. The water, at room temperature is drawn from tank using gravity flow. Similarly a rotameter is provided to control the flow rate of hot water from the inlet hot water tank. Four RTDs measure the inlet & outlet temperature of hot water & cold water (T1 –T4) through a multipoint digital temperature indicator. Fig shows photograph of the setup.

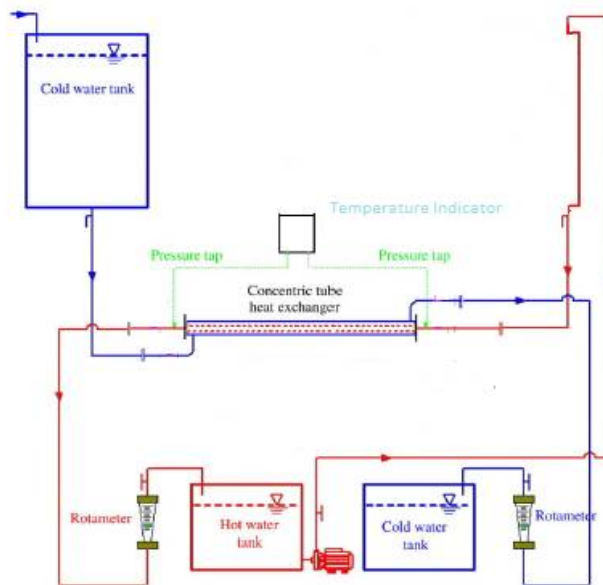


Fig.2.Schematic Diagram of the Test Apparatus.

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- Assembly Used For Construction of Twisted Tube:

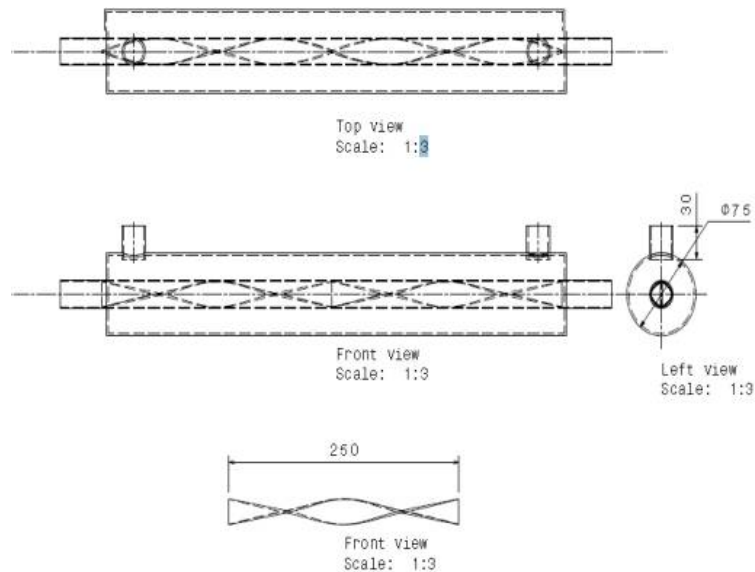


Fig. 3.Assembly for 250 mm Twisted Tape



Fig .4. Photograph of the Experimental Setup

IV. EXPERIMENTAL PROCEDURE

As shown in figure 3, the cold water is pass through rotameter which measures the flow rate of clod water supply. As indicated in photo of experimental set up, there are two heat exchangers, one which contain plain rod and another contain 250 mm length twisted tube. In this experiment we will show the heat exchanger difference between the plain rod and twisted rod. Heater is inserted in to the tank, which gives the hot water supply to the system. Another rotameter is attached to the passage of hot water supply which mwarsures the flow rate for hot water. As the system starts it will gives the temperature reading at hot inlet and hot outlet and cold inlet and cold outlet. In this project we carried out the work by using 250 mm length twisted tape assembly.

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V. SPECIFICATIONS OF HEAT EXCHANGER USED

The experimental study is done in a double pipe heat exchanger having the specifications as listed below:-

Specifications of Heat Exchanger:

Inner pipe ID = 22mm

Inner pipe OD=25mm

Outer pipe ID =75mm

Outer pipe OD =61mm

Material of construction=

Inner tube=copper

Outer tube=MS

Heat transfer length= 500mm

5.1. TYPES OF INSERTS USED:

For experimentation, twisted tape inserts made from aluminium strips of 250 mm is used.

VI. COMPUTATIONAL FLUID DYNAMICS

6.1 Definition:

[11] 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 programme in order to obtain the flow variables throughout the flow domain.

VII. PERFORMANCE ANALYSIS

7.1. METHODOLOGY

Following methodology used to evaluate performance by using CFD analysis.

- Identification of flow domain
- Geometry Modeling.
- Grid generation.
- Specification of boundary Conditions.

7.2. SEQUENCE OF OPERATION:

Without Inserts:

Initially the CFD experiment is carried out with water as the moving fluid through pipe section without any inserts.

With Insert:

Three geometries of inserts are considered for CFD analysis i.e. twisted tape insert.

7.3. GEOMETRIC MODELLING, MESHING AND RESULT:-

Heat exchanger is modelled using CATIA V5 software. It is an assembly of all the parts. A concentric tube heat exchanger (with twisted tape), heat exchanger (without inserting any twisted tape) is modelled according to the dimensions of practically available heat exchanger.

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7.3.1. GEOMETRIC MODELLING, MESHING AND RESULT FOR PLAIN TUBE:-

- GEOMETRIC MODELING FOR PLAIN TWISTED TUBE:

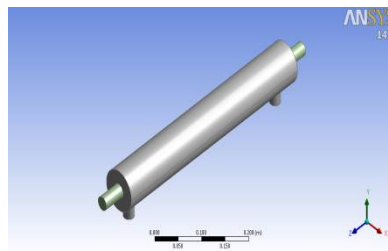


Fig. 5. Geometric modeling for Plain twisted tube

- MESHING FOR PLAIN TUBE:-

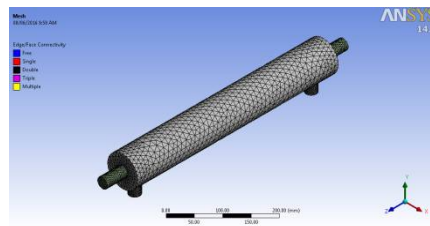


Fig.6.Meshing for Plain tube

Statistics	
☐ Nodes	12409
☐ Elements	36788
Mesh Metric	None

Results-

Tho=317k

Tco=315k

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- **RESULT OF CFD FOR PLAIN TUBE:-**
- **COUNTER STATIC TEMPERATURE OF HOT WATER OUTLET:**

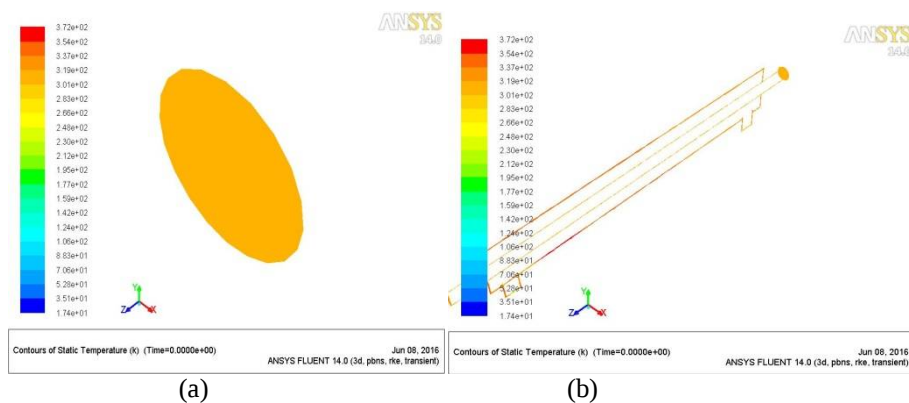


Fig.7 (a), (b) Counter static temperature of hot water outlet

- **COUNTER STATIC TEMPERATURE OF COLD WATER OUTLET:**

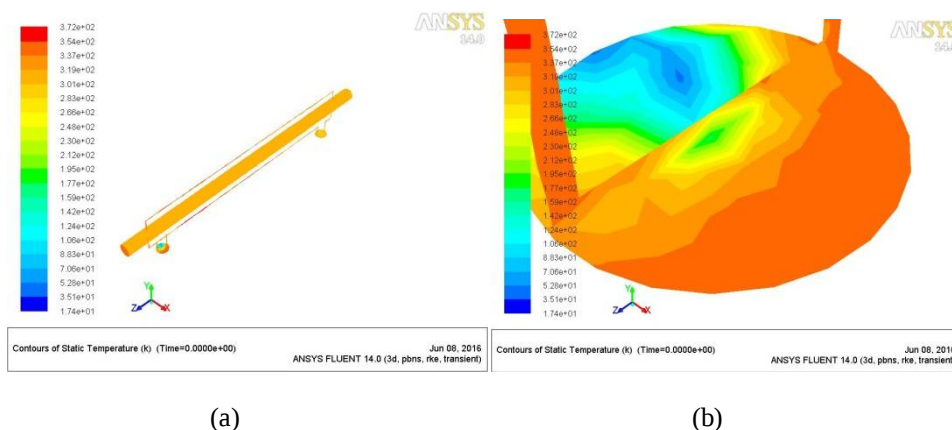


Fig. 8. (a), (b), Counter static temperature of cold water outlet

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7.3.2. GEOMETRIC MODELLING, MESHING AND RESULT FOR 250 MM TWISTED TUBE:-

- GEOMETRIC MODELING FOR 250 mm TWISTED TUBE:

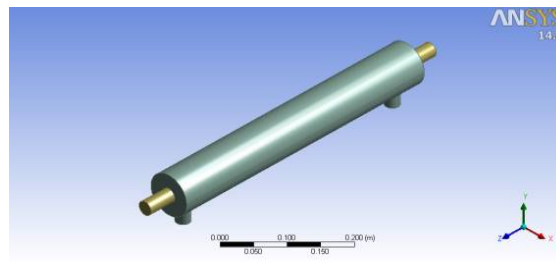


Fig. 9. Geometric modeling for Twisted tube

- MESHING FOR 250 mm TWISTED TUBE-

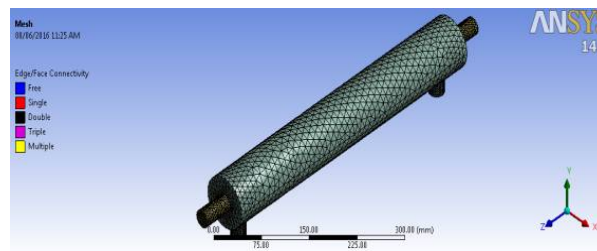


Fig. 10. Meshing for Twisted tube

Statistics	
☐ Nodes	12996
☐ Elements	37556
Mesh Metric	None

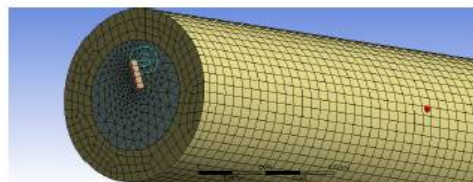


Fig.11.Meshed Heat Exchanger with Twisted Tape

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MESHING REPORT:-

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1. File Report

Table 1. File Information for FFF 2

Case	FFF 2
File Path	C:\Users\PRASHANT\Desktop\Twisted Tape Ansys\25014.6_files\dp0\FFF-2\Fluent\FFF-2-2-00034.dat.gz
File Date	14 June 2016
File Time	10:35:44 AM
File Type	FLUENT
File Version	14.0.0

2. Mesh Report

Table 2. Mesh Information for FFF 2

Domain	Nodes	Elements
cu_pipe	7767	23277
part2	300	96
zone3 500_pipe	3586	10666
All Domains	11653	34039

3D Viewer Table Viewer Chart Viewer Comment Viewer Report Viewer

3. Physics Report

Table 3. Domain Physics for FFF 2

Domain - cu_pipe	
Type	cell
Domain - part2	
Type	cell
Domain - zone3 500_pipe	
Type	cell

Table 4. Boundary Physics for FFF 2

Domain	Boundaries
cu_pipe	Boundary - contact_region_2 trg
	Type INTERFACE
	Boundary - contact_region_5 src
	Type INTERFACE
	Boundary - hot_in
	Type MASS-FLOW-INLET
	Boundary - hot_out
	Type PRESSURE-OUTLET
part2	Boundary - wall cu_pipe
	Type WALL
	Boundary - contact_region src
	Type INTERFACE

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part2	Boundary - contact_region src
	Type INTERFACE
	Boundary - contact_region trg
	Type INTERFACE
	Boundary - contact_region_2 src
	Type INTERFACE
zone3 500_pipe	Boundary - contact_region_3 src
	Type INTERFACE
	Boundary - wall part2
	Type WALL
	Boundary - cold_in
	Type MASS-FLOW-INLET
	Boundary - cold_out
	Type PRESSURE-OUTLET
	Boundary - contact_region_3 trg
	Type INTERFACE
	Boundary - contact_region_5 trg
	Type INTERFACE
	Boundary - wall 3 500_pipe
	Type WALL

- **RESULT OF CFD FOR TWISTED TUBE:-**
- **COUNTER STATIC TEMPERATURE OF HOT WATER OUTLET:**

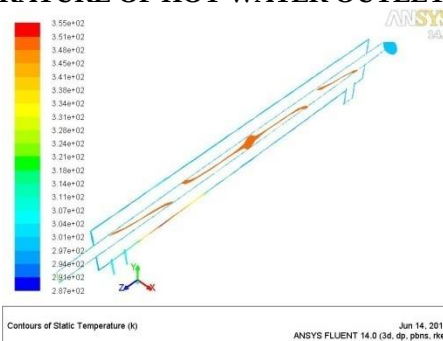


Fig.12. Counter static temperature of hot water outlet

- **COUNTER STATIC TEMPERATURE OF COLDWATER OUTLET:**

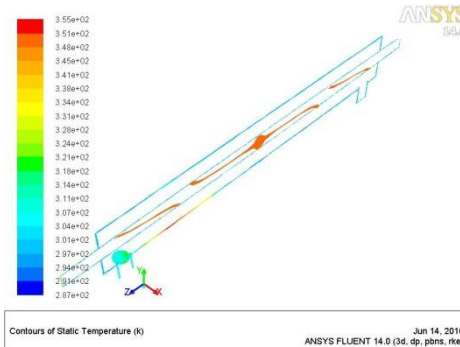


Fig.13. Counter static temperature of cold water outlet

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7.4. ANALYSIS

After the completion of meshing the design is opened in ANSYS Fluent. In fluent boundary conditions are given as per requirement and the solution is initialized and calculations are iterated. After the calculation is converged the contours are to be plotted.

Boundary Conditions

Condition	Parameter	Inlet	Outlet
All conditons	Mass flow Rate	mh=0.3 kg/hr and mc=600kg/hr	
	Temperature	Thi=75 ocand Tci=30o C	
	Pressure	300000Pa	300000Pa

Inlet- Temperature and mass flow rate

outlet- Pressure

Wall- no slip conditons

VIII. RESULT AND DISSCUSSION

Experimental investigations on enhancement of turbulent flow heat transfer with mesh inserts in a horizontal tube under forced convection with water flowing inside are carried out along with CFD analysis. CFD analysis is carried out by taking double pipe heat exchanger with cold and hot fluids with incorporating twisted tape inserts . According to above CFD analysis experiment is performed on the plane conditions and 250 mm twisted tube . In this project the experimental set up is based on the 250 mm length of twisted tube. By experimental work this gives the high heat transfer rate using twisted tube as compared to plane tube. The result as per using 250 mm twisted tube are shown in below,

Table 1.Temperature Data of Experimental Set Up

Sr. No.	Type	Condition	Hot water temp. (Tho) °C	Cold water temp. (Tco) °C
1	Plane	In	30	8
		Out	28	10
2	Twisted	In	29	8
		Out	26	12

IX. CONCLUSION

This report presents the comprehensive study on the heat transfer characteristics using rotating twisted tape insert. This work make use of the concept of heat enhancement to develop a design methodology. According to the study, heat transfer rate is greatly influenced by the flow rate of the fluid flowing in the system. Higher heat transfer rate can be obtained at high RPM of twisted tape and flow rate of flowing water. For heat enhancement using twisted tape, the methods used in the experiments were promising. Although, this method had helped us to understand the significance of RPM and flow rate that govern the heat transfer characteristics. There is still need of further research to conclude the systems behavior with inclusion of the friction factor parameter.

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