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Project Title: EFFECT OF SPIRAL COIL ON HEAT TRANSFER IN DOUBLE PIPE HEAT EXCHANGER

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ABSTRACT

Nowadays heat exchanger is the most effective mean to interchange thermal energy of one fluid to other. This is done by using miscellaneous techniques which improves heat transfer rate includes active, passive and compound augmentation techniques. In most of the mechanical process industries, heat exchanger is the principal device used for heat transfer phenomenon. The present article is about the review on research work has been done on various augmentation technique used to enhance the heat transfer rate in last decade. This paper contains literature estimation of heat transfer enhancement using spiral inserts.

The present study gives the theoretical as well as practical analysis of double pipe heat exchanger using spiral coil. This investigation is carried out to improve thermal performance of double pipe heat exchanger. The heat exchanger includes two copper pipes of diameter 25.4 mm and 50.8 mm with spiral coil of 4 mm diameter. In this experiment, water used as a working fluid in which hot fluid inlet temperature extends from 50^{o}C to 80^{o}C and cold fluid inlet temperature is kept at 30^{o}C.

The present study deals with the passive augmentation techniques used in a double pipe heat exchanger using spiral coil. The mass flow rate is 0.0167 Kg/s. The inlet temperature of hot water has varied from 45 °C to 70 °C. Overall heat transfer coefficient has compared in this study for both counter flow as well as parallel flow. Overall heat transfer coefficient is enhanced up to 39.18 % at mass flow rates m_h = 0.0167 Kg/s and m_c = 0.0167 Kg/s at hot water inlet of 70 °C and cold water inlet of 30 °C. Experimentally, Overall heat transfer enhancement has been studied and also, the experimental results have been validated with CFD simulation (ANSYS Software).

INTRODUCTION

Heat transfer is the exchange of thermal energy between physical systems. The rate of heat transfer is dependent on the temperatures of the systems and the properties of the intervening medium through which the heat is transferred. The three fundamental modes of heat transfer are conduction, convection and radiation. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense is known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A much better estimate of its efficiency is obtained by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements of a heat exchanger.

Heat exchanger is a device used to exchange the heat from one fluid (hot fluid) to another fluid (cold fluid) with or without direct contact at different temperature. This exchange of heat takes place either to remove the heat from a fluid or to add heat to a fluid. For example, the heat exchanger used to remove the heat from the fluid is known as condenser or the heat exchanger used to add the heat to a fluid is known as boiler. Heat exchangers are broadly used in the refrigeration and air conditioning, petrochemical plants, sewage treatment, refineries, pharmaceuticals, food beverage and dairy industries, automobile radiators. According to application heat exchangers are classified on the basis of design features, nature of heat exchange process, relative direction of fluid motion and physical state of fluids.

Sorting of Augmentation Techniques:-

In general, Augmentation Techniques are categorized into three different techniques:

1) Active
2) Passive
3) Compound

1) Active Technique:-

The technique used to enhance the heat transfer rate by applying external power input is known as active augmentation technique. These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer.

2) **Passive Technique:-**

This method is used to create turbulence in the path of fluid flow by using inserts in tube. This turbulence in fluid flow increases the heat transfer rate from one fluid to other. These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices.

3) **Compound Technique:-**

When two or more methods incorporated simultaneously to obtain improvement in thermal performance of heat exchanger is termed as compound method. Hence obtained thermal performance of heat exchanger is greater than that produced by any one method of them when used individually.

Objectives

1) The prime aim of the present work is to determine overall heat transfer coefficient of double pipe heat exchanger using spiral coil.

2) To study the performance of double pipe heat exchanger in counter flow as well as in parallel flow

LITERATURE SURVEY

Some experimental investigation has been done on double pipe heat exchanger using spiral coil for the enhancement of the heat transfer. Most of the industrial researchers as well as academic researchers contributed in this field , the review of the research work carried out in this area are as follows:

Jay J. Bhavsar , V K. Matawala , S. Dixit [1] , they did the experimental analysis on spiral tube heat exchanger over the shell and tube heat exchanger. They concluded that with the use of spiral tube by varying mass flow rate of working fluid, the temperature of hot fluid decreases at the exit with increasing in mass flow rate of cold fluid. For the performance of the experiment they used hot oil and cold water as a working fluid. A coil is fabricated by bending the 12mm diameter copper tube into spiral coil of four turns. The investigation had done on the mass flow rate of working fluid i.e cold water and hot oil which ranges in the middle of 0.075 and 0.25 kg/s, and between 0.008 and 0.04 kg/s.The temperature of cold water and hot oil at the inlet had between 29 and 37^{o}C and between 70 and 56^{o}C.

N.C kanojiya , V.M Kriplani , P.V Walke [2] , they did the review on heat transfer enhancement in heat exchangers with inserts ,they concluded that if the swirl flow is generated by passive method using perforated twisted tape inserts and nanofluid, the heat transfer rate as well as heat transfer coefficient and friction factor increases while decrease in pressure drop takes place . It was shown that used of inserts in heat exchanger was beneficial for the heat transfer enhancement.

Kartik M. Vyas, Rajdip J. Gohil, Neel S. Patel, Prof. Mitesh B. Lalwani [3], gives the thermal analysis of tube in tube liquid spiral heat exchanger over shell and tube heat exchanger. A two copper pipes had used in the fabrication of the experimental set up in which ½" copper pipe used as a inner tube and 1" copper pipe used as outer tube , both the coil had shaped into spiral form to fabricate the set up of tube in tube heat exchanger. They used water as a working fluid. During the experimental analysis, the result obtained had the effectiveness of 33.80% in case of parallel flow and 40% in counter flow. By using tube in tube heat exchanger, more turbulence had offered to flow and better effectiveness can be obtained.

E.I. Jassim [4], did the experimental study on transient natural convection heat transfer from spiral coil in a spiral coil heat exchanger. He had compare the efficiency of spiral coil heat exchanger in horizontal as well as in vertical position of spiral coil in which he found that spiral coil in vertical position had shown more effectual than horizontal position in terms of transferring heat. He also found that by increasing number of loops of spiral coil per unit length could improve the heat transfer rate.

Ruchal G. Humbare, Suraj R. Gurav, S. B. Trimbake [5], had gone through the comparative study between helical coil heat exchanger and straight tube heat exchanger for parallel flow and counter flow. The overall heat transfer coefficient increases with flow rate in case of helical coil heat exchanger and 10 to 20% more than that of straight tube heat exchanger. Effect of curvature ratio and pitch of helical coil had shown as the curvature ratio increases, the heat transfer coefficient also increases while the pitch increases the overall heat transfer coefficient decreases.

Nikhil Lokhande, Dr. S. R. Nikam, Dr. K.N. Patil [6], had comparatively analysis the spiral heat exchanger and gasketed plate type heat exchanger using stainless steel as a material for plate making of plate heat exchanger with thermal conductivity 16.2 W/mK. This investigation concluded that the performance of gasketed plate heat exchanger was better than spiral plate heat exchanger, by using gasketed plate heat exchanger the overall heat transfer coefficient increased by 86.8% over spiral plate heat exchanger. The experimental investigation of plate heat exchanger had done on two different plate chevron angles , 65^{O} and 30^{O} in which it was found that the overall heat transfer coefficient increased by 26% in case of 65^{O} chevron angle as compared to 30^{O}.

Mahendra P. Nimkar, N. P. Mungle, S. A. Bobade, Dr. G. D. Mehta, Riddheshwar R. Bilawane [7], they did the theoretical and practical analysis of concentric tube heat exchanger using inner wavy tube. This experimental study deals with the performance of inner plain tube and inner wavy tube at different hot and cold fluid temperature. The mass flow rate of hot and cold fluid varies from 0.0167 Kg/s to 0.033 Kg/s and temperature limit is from 50^{0}C to 80^{0}C.They found enhancement of 47.66 % overall heat transfer coefficient maximum mass flow rates m_h = 0.033 Kg/s and m_c = 0.033 Kg/s at hot water inlet of 50 °C and cold water inlet of 34 °C by using inner wavy tube in concentric tube heat exchanger.

METHODOLOGY

Proposed Diagram of Experimental setup:

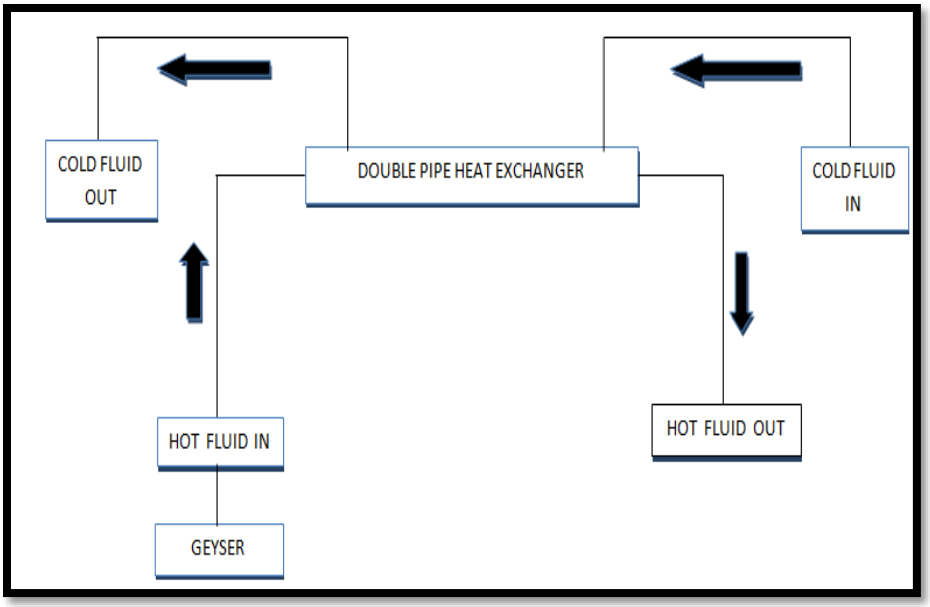


Figure 5.1.1: Line Diagram of Heat Exchanger

Fig. 5.1.2: Photographic view of experimental set-up

Specification of Spiral coil:

Sr No.	Elements	Dimension
1	Outer Plain Tube	Length=700 mm OD=50.8 mm ID= 48.8 mm Thickness =2 mm
2	Inner Plain Tube	Length= 800 mm OD= 25.4 mm ID= 23.4 mm Thickness= 2 mm
3	Spiral Coil	Length= 700 mm D = 4 mm
4	Pitch	35 mm
5	Material	Copper
6	Thermal Conductivity	385W/mk

Table 5.2.1: Specification of Double Pipe Heat Exchanger

DESIGN (Cad Model)

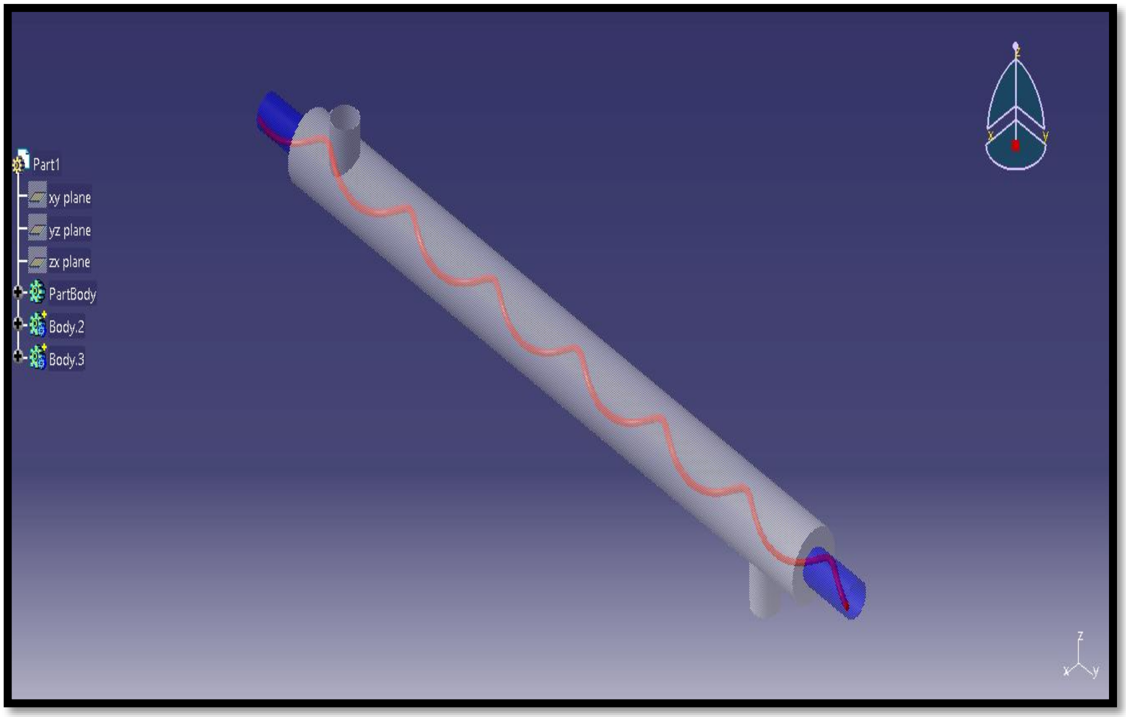


Fig. 5.3.1: CAD Model of Double Pipe Heat Exchanger

SOFTWARE USED

1) CATIA (Version:-V5-6 R2016 (R26))
2) ANSYS (Workbench 2019)

Components:

1) Water Geyser

2) Thermocouple

3) Control Panel

1. Water geyser:

Water geyser is used supplying hot water at different required temperatures. The water is heated between 60-80 °C. Capacity of water is 1Lit/min, maximum head 18M, 230 VAC 50Hz volts and watts 3 KW. Dimmer stat was employed to get water at required temperature by reducing or increasing voltage input to the geyser.

2. Thermocouples:

Four thermocouples were used for measurement of inlet and outlet temperature of hot and cold water along with digital temperature meter. The maximum limit of temperature measurement was 400 °C. The temperature meter used in in experimental setup was having 8 channels. The types of thermocouples used are of PT 100 type.

3. Control Panel

Control Panel is consists of temperature indicator used in experimental setup was having 8 channels, Two switches, one main switch which is used for on/off the set-up another switch is used for on/off the geyser and two AC indicator which indicated the on/off of geyser and experimental set-up.

Experimental Procedure:

1) Experiments have been studied by varying input parameters like mass flow rate of cold water as well as hot water and input temperature of hot water.

2) The mass flow rates used in experimentation is 0.0167 kg/sec for both cold and hot water.

3)The inlet temperatures of hot water have been varied from 45°C to 70 °C i.e. 45°C, 50°C, 60°C, 65°C, and 70 °C.

4) These input temperatures were achieved by controlling power input given to the water geyser. This power is controlled by dimmerstat. Input temperature of 50°C.

5) Cold water is kept 27°C and 30 °C throughout the experimentation which have been taken directly from tap.

6) Results are taken at steady state condition. Above experimental procedure are repeated for with spiral coil and without spiral coil for counter flow as well as parallel flow.

Experimental Readings:

Table 6.1. : Parallel Flow without Coil

m_h	m_c	T_{hi}	T_{ho}	T_{ci}	T_{co}
0.0167	0.0167	45	42	30	33
0.0167	0.0167	50	45	30	34
0.0167	0.0167	60	52	30	36
0.0167	0.0167	65	55	30	38
0.0167	0.0167	70	58	30	40

Table 6.2. : Counter Flow without Coil

m_h	m_c	T_{hi}	T_{ho}	T_{ci}	T_{co}
0.0167	0.0167	45	41	30	35
0.0167	0.0167	50	44	30	35
0.0167	0.0167	60	50	30	37
0.0167	0.0167	65	52	30	39
0.0167	0.0167	70	55	30	42

Table 6.3. : Parallel Flow with Coil

m_h	m_c	T_{hi}	T_{ho}	T_{ci}	T_{co}
0.0167	0.0167	45	40	30	34
0.0167	0.0167	50	43	30	37
0.0167	0.0167	60	48	30	39
0.0167	0.0167	65	50	30	40
0.0167	0.0167	70	53	30	43

Table 6.4. : Counter Flow with Coil

m_h	m_c	T_{hi}	T_{ho}	T_{ci}	T_{co}
0.0167	0.0167	45	39	30	35
0.0167	0.0167	50	41	30	38
0.0167	0.0167	60	46	30	41
0.0167	0.0167	65	48	30	44
0.0167	0.0167	70	50	30	47

Validation with CFD

The experimental set-up was validated for the Overall heat transfer coefficient obtained from CFD and comparing it with the overall heat transfer coefficient obtained from experimentation.

Case :- For counter flow with coil (T_{hi} = 50°C , m_h = m_c = 0.0167 kg/s).

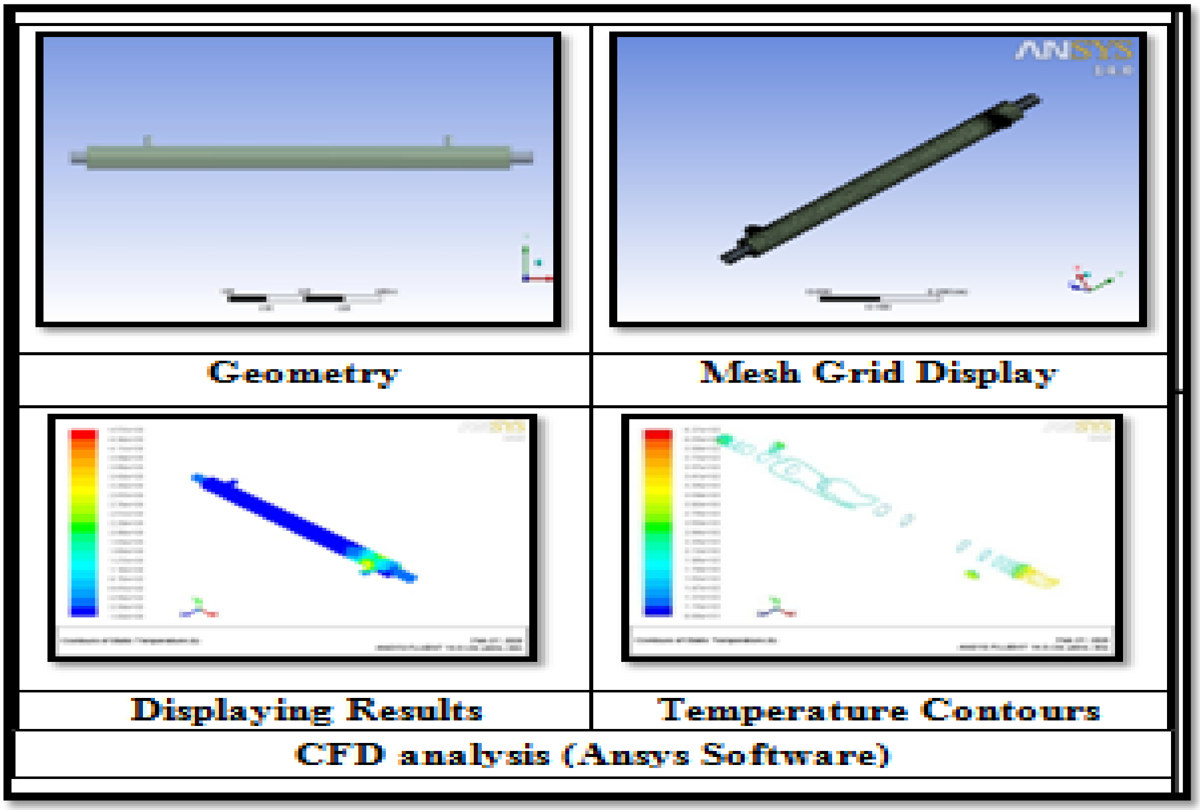
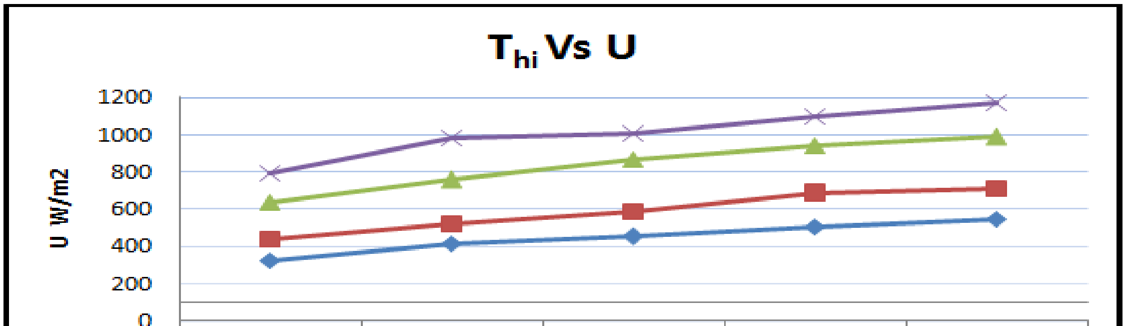


Fig. 8.1. : CFD Analysis

Table 8.1: CFD Results

Case	m_h	m_c	T_{hi}	T_{ho}	T_{ci}	T_{co}
Parallel flow without coil	0.0167	0.0167	50	44	30	35
Counter flow without coil	0.0167	0.0167	50	43	30	34
Parallel flow with coil	0.0167	0.0167	50	43	30	36
Counter flow with coil	0.0167	0.0167	50	41	30	38

RESULTS AND DISCUSSION



	45	50	60	65	70
Upp	320.0574284	416.1937159	450.1192057	502.7255439	545.7866451
Ucp	436.135327	518.7292101	583.7849654	680.3395105	710.0600654
Ups	637.8903347	754.3482975	862.11234	941.9012878	984.3926366
Ucs	792.1626667	981.3044858	1004.944783	1094.60731	1167.569931

Fig.9.1 : Variation of overall heat transfer coefficient under influence of plain tube and spiral coil at various hot water inlet temperature.

Above figure shows variation of overall heat transfer coefficient for different hot water inlet temperature varied from 45°C and 70°C sec and mass flow rates for hot water and cold water are 0.0167 kg/s with cold water inlet temperature of 30°C.It has been observed that the increase in hot water inlet temperature , the overall heat transfer coefficient also increase when mass flow rates of hot water and cold water remain same. Hence, the enhancement of overall heat transfer coefficient is **39.18%.**

CONCLUSIONS

The motive of experimentation is to examine the performance of double pipe heat exchanger in parallel flow and counter flow with or without spiral coil at different hot water inlet temperature and cold water inlet temperature kept at 30^{o}C with mass flow rate for hot and cold water is 0.0167 kg/s.As per the result obtained from experiment, it can be concluded as:

1) Overall heat transfer coefficient is enhanced upto 39.18% at hot water inlet temperature 70^{o}C and m_c=0.0167 kg/s , m_h=0.0167 kg/s and cold water inlet temperature 30^{o}C.

2) The performance of double pipe heat exchanger is improved by using spiral coil as compared to without coil in parallel and counter flow.

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