

Comparative Numerical Study on Serpentine and Helical Tube in Tube Heat Exchanger

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ABSTRACT: Heat ex-changers are the essential engineering systems with wide variety of application including many power factors ,nuclear reactors ,refrigeration and air conditioning systems, waste heat recovery systems, chemical and food industries. Natural convection is the process of heat transfer in which the flow of fluid is caused by density differences in the fluid occurring due to various temperature conditions. Here the fluid which surrounds a heat source receives heat ,becomes less dense and rises. The working fluid that is surrounding the high temperature fluid is cooled and then moves in to replace it. After that cooler fluids gets heated and the process continues, resulting convection current. Forced convection in heat ex-changer is the flow of heat from one moving stream to another stream through the wall of the pipe. The low temperature fluid removes heat from the comparatively high temperature fluid as it flows along or across it. If it moves along the hot stream then its called parallel flow and if they are across then its counter flow.

KEYWORDS: calculations on tube, design, numerical study, etc.

I. INTRODUCTION

Heat exchange between flowing fluids is one of the most important physical process of concern, and a variety of heat exchangers are used in different type of installations, as in process industries, compact heat exchangers in nuclear power plant, HVACs, food processing, refrigeration, etc. The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. The heat transfer occurs by three principles: conduction, convection and radiation. In a heat exchanger the heat transfer through radiation is not taken into account as it is negligible in comparison to conduction and convection. Conduction takes place when the heat from the high temperature fluid flows through the surrounding solid wall. The conductive heat transfer can be maximized by selecting a minimum thickness of wall of a highly conductive material. But convection is plays the major role in the performance of a heat exchanger. Depending on selection criteria, there are different types of Shell and Tube Heat Exchanger. With respect to the heat exchanger, we may distinguish the following designs: air-cooled, water-cooled and evaporation-cooled condensers. In the construction the following types of curved tubes are distinguished as:

1. Helically Coiled Tubes;
2. Spirally Coiled Tubes; and
3. Serpentine Tubes

II. OBJECTIVES

1. Todesign serpentine and helical coil-tube heat exchanger.
2. To analyze and study of the application of heat exchanger.
3. To study and analyze, the Heat transfer Process through heat exchanger.
4. To design a process for efficient and safe transfer of heat through heat exchanger.
5. To analyze thermal parameters by experimentally and numerically etc.

III. FUTURE SCOPE

More accurate method should be developed to determine the maximum heat transfer condition by designing different geometrical factor. By varying geometrical parameter calculate or compare different thermal parameter such as Nusselt number, friction factor, Reynolds number etc. Along with experimental and numerical analysis validation should be required. In this study single phase flow pattern is considered for numerical analysis but in future two or multiphase flow may be considered. Applicability of this model with strong centrifugal and torsional effects predominant in the case of flow through serpentine tube needs to be further investigated.

IV. EXPERIMENTATION

The experiment is to be carried out on the different range of temperature and flow rate and results are to be collected. The experiment is to be carried out on the selecting proper values, and also the decision is to be taken regarding the way of heat transfer.

V. EXPERIMENTAL SETUP

1. Description

Simple serpentine and helical coil-tube heat exchanger has been facing problems because of the lack of experimental data available regarding the behavior of the fluid in serpentine coils and also helical coils in case of heat transfer data, which is not the case in compact heat exchanger. So to the best of our effort, design a serpentine and helical compact heat exchanger and numerical analysis was carried out to determine the heat transfer characteristics for a heat exchanger by varying the different parameters like different temperatures and flow rate and also to determine the fluid flow pattern in this heat exchanger. Compare previous analysis data for another coil type heat exchanger. The objective of the project is to obtain a better and more quantitative awareness into the heat transfer process that occurs when a fluid flows in a serpentine and helical coiled tube. The study also covered the different types of fluid flow range extending from laminar flow through transition to turbulent flow. The materials for the study were decided and fluid taken was water and the material for the pipe was taken to be copper for its better conducting properties.

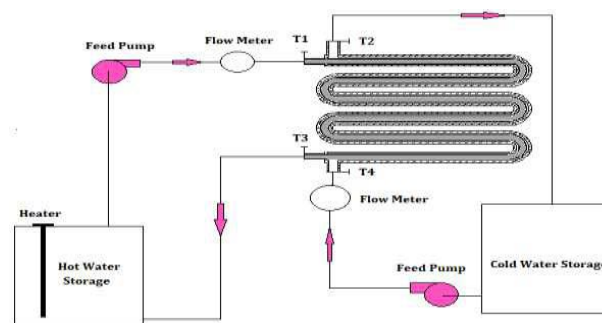


Fig. 1 Experimental Setup

1.1 Geometry of Serpentine Coil Tube Heat Exchanger

The schematic diagram of experimental set-up is shown in Fig 3.1. The set-up is a well instrumented single-phase heat exchanging system in which a hot water stream flowing inside the tube-side is cooled by a cold water stream flowing in the shell-side. The main parts of the cycle are tube in tube heat exchanger, centrifugal pump, storage tank, and heater. The heat exchangers include a copper tube and an insulated shell. The dimensions of the heat exchangers are illustrated in Table. The water in storage tank is heated using an electric heater. Reaching to a prescribed temperature, pump is started to circulate the hot water in the cycle.

A ball valve is used to control the flow rate of coolant water and hot water, respectively. To measure the flow rate of the cold stream/hot stream a flow meter is installed upstream of the heat exchanger. The inlet and outlet temperatures of hot and cold water were recorded manually using 4 glass mercury thermometers measure inlet and outlet temperature and thermocouple with 5 nodes inserted in the small holes made in the curvature tubes of each heat exchanger and sealed to prevent any leakage.

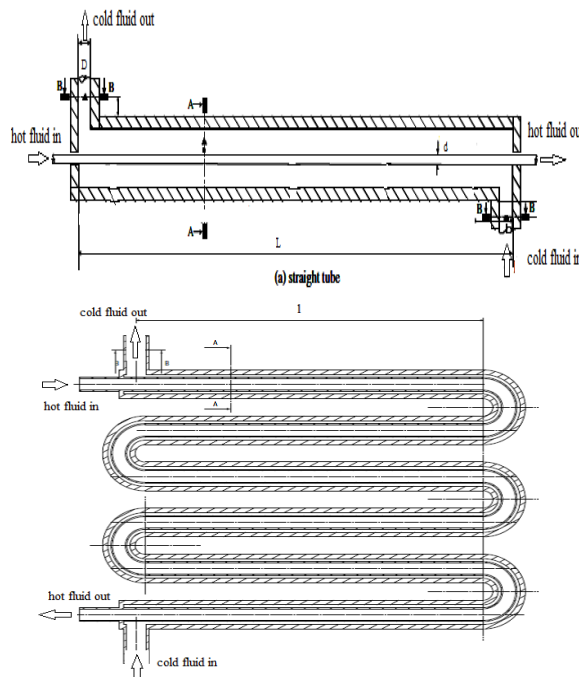


Fig. 2 Serpentine coil-tube in tube heat exchanger

1.2 Geometry of Helical Coil Tube Heat Exchanger

Heat exchangers are a broad term related to devices designed for exchanging heat between two or more fluids with different temperatures. Helical tubes are indirect contact or passive heat transfer devices. Due to the compact structure and high heat transfer coefficient, helical tube heat exchangers find extensive use in industrial applications such as power generation, nuclear industry, process plants, heat recovery systems, refrigeration, food industry, etc. The extensive research has done on helical tube for various configurations such as vertical, horizontal and inclined position.



Fig. 3 Helical coil tube in tube heat exchanger

Fig. 4 gives the schematic of the helical tube, $2r$ is the pipe inner diameter of tube, $2RC$ is the Tube diameter or pitch circle diameter, H is the Pitch, δ is the Curvature ratio, λ is the Non-dimensional pitch, α is the Helix angle of tube

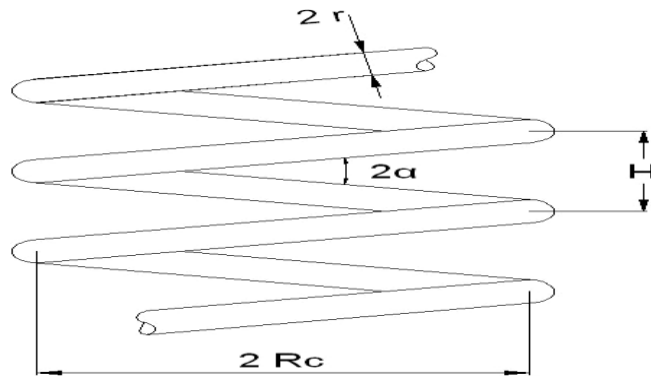


Fig. 4 Basic Geometry of Helical Tube

1.3 Design Parameter

Parameters of Serpentine Tube

The analysis of the serpentine tube in tube heat exchanger is carried out through following procedure:

1. The range of Re considered for the analysis is about 100 to 6000.
2. The velocity of the fluid flowing through the tube is calculated by considering the tube diameter (d) as 10 mm. The properties of the fluid flowing through the tube are taken at average temperature of 50°C (for the value of ρ and the present analysis considers the following dimensional and operating parameters.

Table. 1.3.1 Dimensional parameters of serpentine tube.

Sr. No.	Dimensional Parameters	Dimensions
1	Outer diameter of copper tube (Do)	10
2	Inner diameter of copper tube (Di)	9
3	Thickness of tube (t)	1
5	Inner diameter of shell (di)	28
6	Thickness of shell (t)	2
7	Curvature Radius (c)	35

Table. 1..3.2 Operating parameters range of serpentine tube in tube heat exchanger.

Parameter	cold water	hot water
Mass flow rate (Kg/s)	0.05	0.01-0.03
Initial temperature (°K)	303	323
Outlet Temperature (°K)	303-310	310-328



Table. 1.3.3 Properties of Hot and cold fluid of serpentine tube in tube heat exchanger.

Properties	Cold water	Hot water
Specific heat (C_p)	4178	4179.3
Viscosity (μ) ($N\cdot s/m^2$)	0.000753	0.00062
Density (ρ) (kg/m^3)	994.629	990.688
Thermal conductivity (k) $W/m^2 K$	0.6216	0.6352
Prandtl No. (Pr)	5.04	4.08

Parameters of Helicaltube

1. The helical tube is made from the copper seamless pipe having outer diameter of 10 mm and inner diameter of 9 mm. The helical tube is made of tube diameter of 55.
2. Number of turns is 9 Pitch is kept 20 mm. The axis of the tube is in the horizontal direction. The steam enters the tube from the top of the tank and passes through the tube.
3. While passing through the helical tube steam get condensed and leaves from the bottom of the tank.
4. The axial length of helical tube in tube is 180 mm. The pitch is 2 cm and the spacing between two adjacent tubes is 20mm.

TubeDimensions

Dimensions of the helical tube are given in table below:

Table. 1.3.4 Dimensions of the helical tube

ITEM	DIMENSIONS (mm)
Tube diameter (DC)	145
Helical tube outside diameter, do	10
Helical tube inside diameter, di	9
No. of turns in helical tube	9 (nos)
Curvature ratio,	0.06146
Axial length of helical tube	180
Tube pitch	20

VI. RESULTS AND DISCUSSIONS

In this section results from experiment and computations are presented and compared. Results are obtained for base temperature of 303 K and for various mass flow rates. Thermocouples were used to measure temperature in terms of milli Volts and were read in temperature using calibration graph of thermocouple wire. Computation results are obtained using ANSYS – CFD Post. Plots are plotted for parameters like temperature; pressure and velocity which help in evaluating the performance of the serpentine tube in tube counter flow heat exchanger and the serpentine tube in tube parallel flow heat exchanger. The variation in the experimental values may be caused due to many factors. Some of them are: fabrication errors, leakage of water, uneven base heating etc. It can also be viewed in the profiles that the temperature difference of the fluid decreases as the mass flow rate is increased. This shows that the heat transfer has increased due to increase in mass flow rate. The experimental results with comparison of CFD results are shown in the following tables,



Experimental Results of Serpentine Tube :-

For serpentine tube in tube HE for parallel flow										
Cold Water Flow Rate = 36LPH										
Sr No.	Hot flow	thi	tho	Cfd	tci	tco	cfcd	$\Delta T1$	$\Delta T1$	LMT D
1	36	323	315	320.70	303	307	313.03	16	12	13.90
2	60	323	315	324.03	303	308	314.36	15	12	13.44
3	70	323	315	325.94	303	309	315.10	14	12	12.97
4	90	323	316	327.17	303	309	315.62	14	13	13.49
5	110	323	317	328.03	303	310	316.00	13	14	13.49

Cold Water Flow Rate = 72LPH										
Sr No.	Hot flow	thi	tho	Cfd	tci	tco	cfcd	$\Delta T1$	$\Delta T1$	LMT D
1	36	323	313	316.60	303	305	308.08	18	10	13.61
2	60	323	313	320.47	303	306	309.36	17	10	13.19
3	70	323	313	322.86	303	306	310.15	17	10	13.19
4	90	323	314	324.47	303	307	310.71	16	11	13.34
5	110	323	314	325.64	303	308	311.13	15	11	12.89

For serpentine tube in tube HE for parallel flow										
Cold Water Flow Rate = 110LPH										
Sr No.	Hot flow	thi	tho	Cfd	tci	Tco	cfcd	$\Delta T1$	$\Delta T1$	LMTD
1	36	323	314	314.46	303	305	305.86	18	11	14.21
2	60	323	315	318.44	303	306	307.00	17	12	14.35
3	70	323	316	321.01	303	307	307.74	16	13	14.44
4	90	323	317	322.78	303	307	309.00	16	14	14.97
5	110	323	317	324.09	303	308	308.69	15	14	14.49

Experimental Results of Helical Tube :-



Hot flow	36	60	70	90	110	36	60	70	90	110
thi	323	323	323	323	323	323	323	323	323	323
tho	321.55	323.96	325.02	326.73	327.15	314.91	317.58	320.19	322.34	324.35
tci	303	303	303	303	303	303	303	303	303	303
tco	310.63	312.36	314.43	315.25	317.03	309.88	310.82	311.70	312.15	314.25
V tube	0.094	0.141	0.188	0.235	0.282	0.094	0.141	0.188	0.235	0.282
V shell	0.0120	0.0120	0.0120	0.0120	0.0120	0.0239	0.0239	0.0239	0.0239	0.0239
mc	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
mh	0.010	0.015	0.020	0.025	0.030	0.010	0.015	0.020	0.025	0.030
Q tube	478.52	566.70	666.75	655.09	733.45	756.02	966.65	1070.71	1113.76	1084.50
Q Shell	444.12	516.40	602.89	637.15	711.51	825.57	904.12	977.65	1015.25	1190.73
Qavg	461.32	541.55	634.82	646.12	722.48	790.80	935.38	1024.18	1064.51	1137.62
Q max	1378.74	1378.74	1378.74	1378.74	1378.74	2757.48	2757.48	2757.48	2757.48	2757.48

ϵ	0.335	0.393	0.460	0.469	0.524	0.287	0.339	0.371	0.386
U tube	182.07	212.70	257.46	249.52	290.85	337.48	408.06	431.31	431.06
U Shell	168.98	193.83	232.80	242.68	282.15	368.53	381.67	393.82	392.93
Error	(7.74)	(9.74)	9.58	(2.82)	(3.08)	8.43	(6.92)	(9.52)	(9.70)
Uo	175.53	203.27	245.13	246.10	286.50	353.00	394.86	412.56	412.00
1/UoAo	0.0476	0.0411	0.0341	0.0339	0.0292	0.0237	0.0212	0.0203	0.0203
1/ri ^{0.8}	6.6362	4.7978	3.8115	3.1884	2.7556	6.6362	4.7978	3.8115	3.1884
t _{avg/TUBE}	327.28	328.48	329.01	329.87	330.08	323.96	325.29	326.60	327.67
t _{avg/SHELL}	305.32	306.18	307.22	307.63	308.52	304.94	305.41	305.85	306.08
Re For Hot Fluid	1755.2 2	2632.84	3510.45	4388.06	5265.67	1755.22	2632.84	3510.45	4388.06

VI. CONCLUSION

It described a new special design for water to water serpentine tube and tube heat exchanger against standard design of helical tube in tube heat exchanger. Using serpentine tube and helical tube can be compared which one is good performed for an evaporator and condenser for different industries with different design. For this type of exchanger, we find heat transfer rate for different temperature range and flow rates. This exchanger is used in solar water heater and different industrial exchanger, cooling of refrigerants and engine oil with effectively. To demonstrate the feasibility of the serpentine tube in tube heat exchanger mechanisms, with help of experiment data.

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