"DETERMINATION OF EXPERIMENTALLY OVERALL HEAT TRANSFER COEFFICIENT FOR U-TUBE, HELICAL AND SPIRAL COILS OF SAME LENGTH UNDER ISOTHERMAL CONDITION"

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Abstract: Heat exchanger is important appliance in field of thermal, heat mass, fluid flow, as in nuclear reactor, steam power plant, fertilizers factory, etc. It is seen from literature that heat transfer in helical and spiral is found to be higher than U-tube due to introduction of secondary flow. For sizing of heat exchanger overall heat transfer coefficient plays very significant role. However, there is no single evidence in the literature for the comparison of overall heat transfer coefficient for same surface area under same experimental conditions which is significant for industrial heat exchanger design. Therefore present work is under taken to conduct experiments under same experimental condition for above said three different geometries under turbulent flow for same length. Experiments were carried out for different flow rates under isothermal and turbulent conditions. Overall heat transfer coefficients obtain from three different geometries like helical coil, spiral coil and u-tube coil heat exchanger of same length are reported in this work. Range of Reynolds number was kept 2000<Re<12000. From the experimental result it was found that the overall heat transfer coefficient for Spiral coil is higher than U-Tube coil and helical coil.

Keywords *– U-Tube coil, Helical coil, Spiral coil, Nusselt No.*

I. INTRODUCTION

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

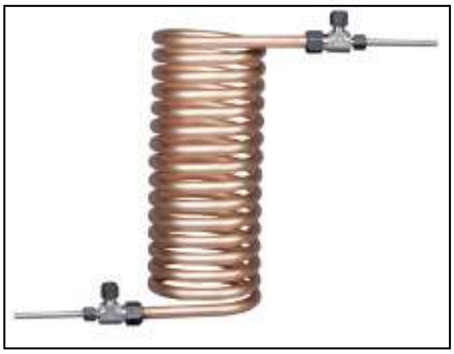

Fig.1Helical coil

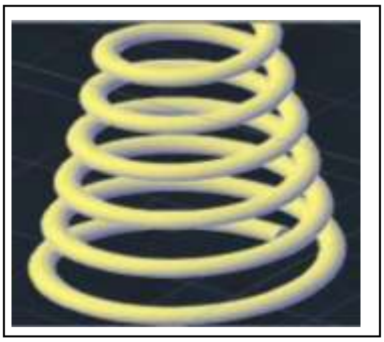

Fig.2 Spiral coil

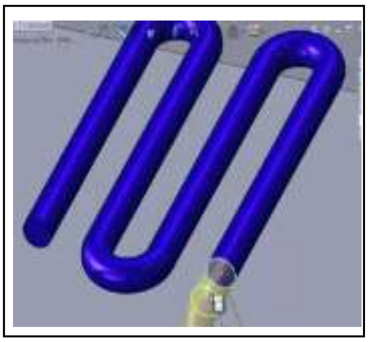

Fig.3U-Tube coil

Fig 1 shows Helical coil heat exchanger .These have been used in the nuclear industry as a method for exchanging heat in a sodium system for large liquid metal fast breeder reactors since the early 1970s, using an HCHE device invented by Charles E. Boardman and John H. Germer. There are several simple methods for designing HCHE for all types of manufacturing industries. Fig 2 shows spiral coil heat exchanger. A modification to the perpendicular flow of the typical HCHE involves the replacement of shell with another coiled tube, allowing the fluid to flow which requires the use of different design calculations. These are the Spiral Heat Exchangers (SHE), which may refer to a helical (coiled) tube configuration more generally. Fig 3 shows U-tube coil heat exchanger. It is a kind of tube and shell heat exchanger, belongs to the petroleum and chemical equipments. This kind of heat exchanger is named after the 'U' shape tube.

II. OBJECTIVE

Objectives of our study and research are:

1. To design U-tube, Helical and Spiral coil of same length and construction of required models.
2. To fabricate required experimental setup.
3. To test experimental setup under isothermal conditions for same configurations.
4. To determine mass flow rate by using rotameter.
5. To plot the graph between Nu and Re based on the result.
6. To plot the graph between overall heat transfers coefficient versus flow rate etc.

III. EXPERIMENTAL WORK

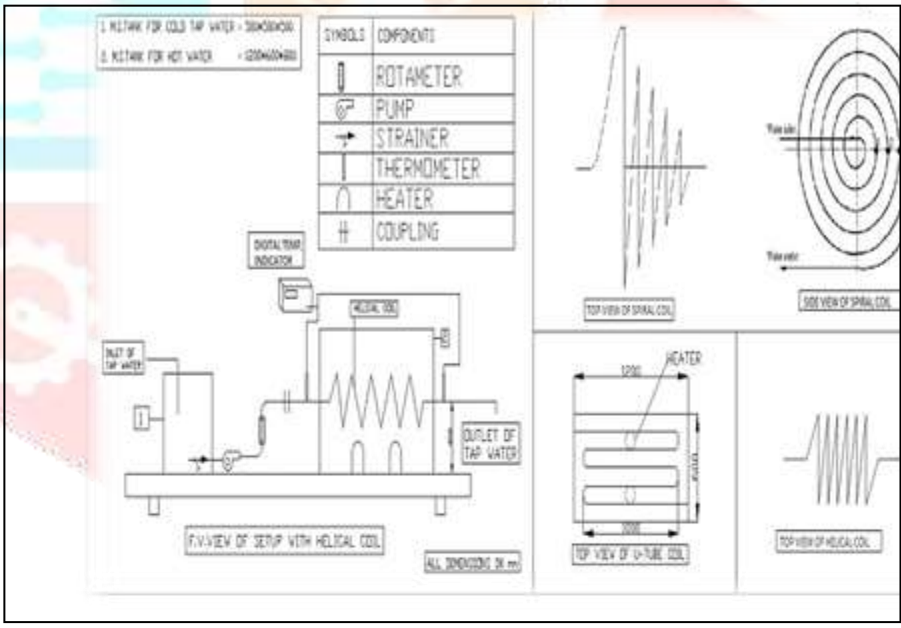

Fig. 4 Two Dimensional view

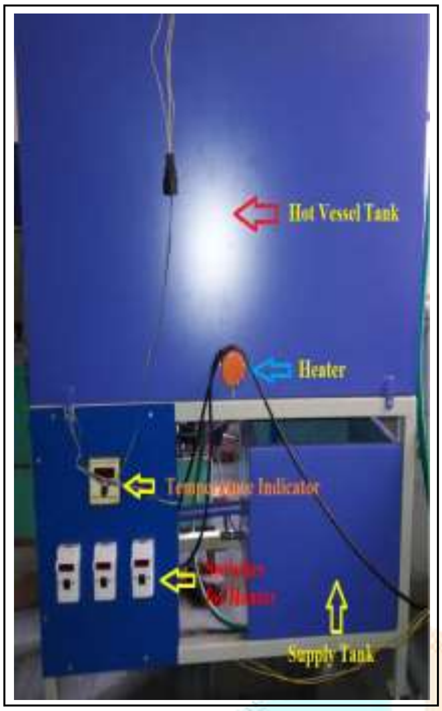

Fig 5 Front View

Fig 6 Side View

Fig 7 Three Dimensional View

Fig (5, 6, 7) different views of experimental setup. The experiment is to compare the overall heat transfer coefficient between the U-tube, helical coil and spiral coil. All three coils are made up of mild steel material and each of length 5.2 meter. An insulated hot water vessel of size 1200*600*800 mm with 4 mm thickness was used to house the coil. Three electrical heaters of 5 KW and two of 3 KW are fixed at the bottom. At the start of process both the heaters are ON to get the required temperature and after that 5 KW heater is switch ON and OFF alternatively to maintain the constant temperature of fluid. A box of 500*500*500 mm is used to store the cold water. Thermocouples are attached to measure the wall temperature of coils at different location along length of coil. Digital temperature indicator was used to record all these thermocouple temperature. The experiment is conducted for turbulent flow and water as fluid. The test fluid was pumped through coil using 1Hp centrifugal pump at room temperature. The flow rate of test fluid was measured by rotameter of capacity 200 – 2000 LPH.. The experiment is conducted for a single coil at a time. The heat transfer coefficient for every coil is then calculated and it is compare to get the result. Followings are the dimensions of the coil used-

(a) U-tube coil: Length = 5.2 m,
No. of turns = 5,
Inlet and outlet of U-tube are on opposite side of the reservoir.

(b) Helical coil: Length = 5.2 m,
No. of turns = 9,
Coil diameter = 180 mm,
Pitch = 110 mm

(c)Spiral coil: - Table 1 shows diameter range of spiral coil.

TURNS	DIAMETER (mm)
1	500
2	400
3	300
4	250
5	200

IV. METHODOLOGY

Thermo- physical properties of the water inside the coils were evaluated at an average bulk temperature. Heat Loss from the hot water in the vessel to the cold water passing through the coil is given as:

$$Q = mC_P\Delta T$$ Equation (1)

$$h_o = \frac{Q}{A_o\,\Delta T_o}$$ Equation (2)........To calculate outer heat transfer coefficient

Where A_o is the overall surface area of the coil and ΔT_o is the temperature difference between the water in the vessel and the bulk.

$$h_i = \frac{Q}{A_i\Delta T_i}$$ Equation (3).......To calculate inner heat transfer coefficient

Where A_i the overall is surface area of the coil and ΔT_i is the temperature difference between average temperature (avg. of thermocouple) and bulk temperature.

By using the above equation overall heat transfer coefficient can be calculated as:

$$\frac{1}{U_o} = \frac{1}{h_i} + \frac{1}{h_o}$$ Equation (4)

V. OBSERVATIONS

Following are observations after calculations where,

U_o is Overall heat transfer coefficient,

Nu is Nusselt number, Re is Reynolds number.

Flow rate	Re	Nu (U-Tube)	Nu (helical)	Nu (spiral)	Uo W/m^2◦C (U-Tube)	Uo W/m^2◦C (Helical)	Uo W/m^2◦C (Spiral)
100	2969.8	48.87	71.26	80.2	289.66	323.53	368.53
150	4430.5	81.48	92.25	102.3	379.95	440.6	521.84
175	5095.4	87.53	112.33	121.58	440.32	495.66	565.55
200	5760.3	96.19	125.9	139.98	504.08	530.16	612.87
225	6513.7	109.86	131.56	164.35	527.55	569.99	645.86
250	7275	124.12	137.58	179.51	543.13	605.06	696.57

275	7889.1	131.59	153.58	188.65	549.56	618.55	712.86
300	8477.2	137.11	167.06	198.48	555.95	639.21	729.36
325	8913	156.77	183.86	205.86	570.82	653.45	756.11
350	9938	186.15	204.87	216.89	594.07	637.93	785.27
375	10200	193.58	211.45	236.59	609.56	687.42	787.45
400	11243	210.05	218.58	251.21	627.95	716.14	790.97
AVG		130.27	150.856	173.8	516.05	576.475	664.436

Table 2

VI. RESULTS & DISCUSSIONS

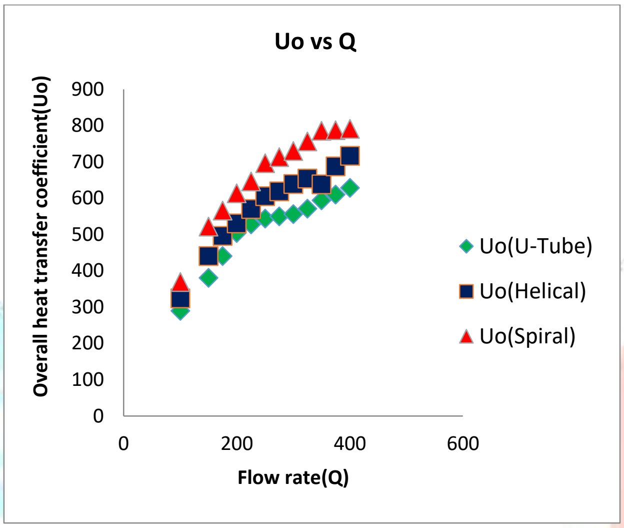

Fig 7

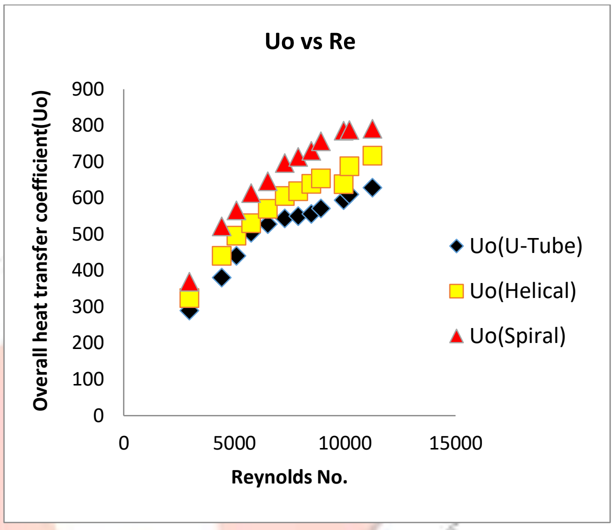

Fig 8

Fig 7 shows graph between overall heat transfer coefficients on y-axis vs. flow rate on x-axis for all three geometries. From graph it is observed that as flow rate increases the overall heat transfer coefficient also increases and it is observed that value of overall heat transfer coefficient is more for spiral coil under same experimental condition and same length of coil. It is followed by helical coil and minimum for u-tube coil.

Graph with Fig 8 shows variation of Overall heat transfer coefficient. Verses Reynolds No. The comparison for all three geometry of overall heat transfer coefficient is shown and it is more in spiral coil less in helical coil and least in u-tube coil.

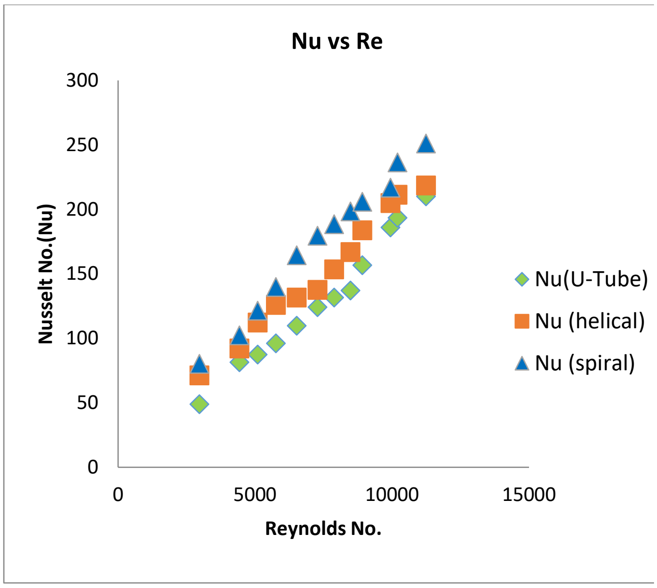

Fig 9

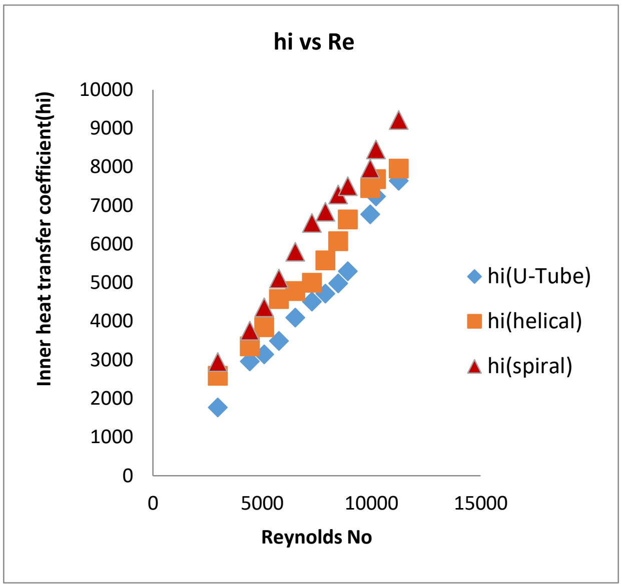

Fig **10**

Figure 9 shows variation of Nusselt No. versus Reynolds No. From graph it is observed that as the Reynolds no. increases Nusselt no increases. Nusselt No is calculated on basis of inner heat transfer coefficient.

Figure 10 shows variation of Inner heat transfer coefficient. Verses Reynolds No. Inner heat transfer coefficient is calculated from equation no (3).Its value varies up to 10000 W/m2 °C.

VII. CONCLUSION

•The overall conclusions related to the comparative analysis between spiral, helical and U-tube coil is presented.

• From comparative experimental study for spiral, helical and U-tube coil it is found that the inner Nusselt No, Convective heat transfer coefficient and Overall heat transfer coefficient are higher in case of spiral coil than Helical coil than U-tube coil for same length of the coils under isothermal conditions.

• Hence it is concluded that heat transfer is more in spiral coil than remaining two coils for same length and working condition.

• Average percentage increase in heat transfer for Spiral coil with respect to U-Tube coil is 28.75%.

• Average percentage increase in heat transfer for Spiral coil with respect to helical coil is 15.25%.

• For same heat transfer spiral coil is compact so it requires less space in comparison with other two coils and it also reduces cost while manufacturing.

VIII. ACKNOWLEDGEMENT

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IX. REFERENCES

[1] S.S. Pawar , Vivek K. Sunnapwar, "*Experimental studies on heat transfer to Newtonian and non-Newtonian fluids in helical coils with laminar and turbulent flow"* Experimental Thermal and Fluid Science 44 (2013) 792–804.

[2] S.S. Pawar, Pritam Shetty,Ancila John, Sairaj Pawar, Pravin Jagtap, "*Experimental Study for comparison of overall heat transfer co-efficient in helical coils of fixed length using water*" Volume 4, Issue 2: Page No.161-166, March-April 2015.

[3] M. Balachandran (2015) "*Experimental and CFD Study of A Helical Coil Heat Exchanger Using Water As Fluid*", International Journal of Mechanical and Production Engineering (IJMPE) , pp. 87-91, Volume-3, Issue-5.

[4] Dange H. M, Shinde Digvijay D, "Heat *Transfer Analysis of a Cone Shaped Helical Coil Heat Exchanger".*

[5] S. S. Pawar," *Comparison of Experimental Overall Heat Transfer Coefficient in Helical Coils Of Fixed Length",* Volume -3, Issue-7 (2015).

[6] B. Jayachandraiah , H.S.S.K. Praveen, "*Evaluation of Thermal Performance of Cone Shaped Helical Coil Heat Exchanger by using cfd Analysis",* Volume 1, Issue 7 (2016).