ICRMESE – 2020 **ISSN: 2008-8019**

Special Issue on Proceedings of International Virtual Conference, Recent Materials for, Engineering Applications and Sustainable Environment, December 2020. International Journal of Aquatic Science, Volume 11, Issue 1, 2020.

SIMULATION OF TUBE IN TUBE HELICAL HEAT EXCHANGER

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Abstract: In the present work attempts were made to investigate the hydrodynamics and heat transfer characteristics of tube-in-tube helical heat exchanger. The steady state simulation was carried out in counter current mode operation with hot fluid in the tube side and cold fluid in the annulus area. A commercial Computational Fluid Dynamics package was used to predict the flow and thermal development in tube-in-tube helical heat exchanger. CFD simulations are carried out in tube in tube helical coils by varying different geometric parameters such as helical tube pitch.

Introduction

Flow and heat transfer in helical pipes with circular or rectangular cross-section has been a topic of important fundamental engineering interests during the past decades. Berger et al. (1983) and Shah and Joshi (1987) have presented extensive reviews of fluid flow and heat transfer in helical pipes. The modification of the flow in the helically coiled tubes is due to the centrifugal forces (Dean roll cells, 1927, 1928). The curvature of the tube produces a secondary flow field with a circulatory motion, which pushing the fluid particles toward the core region of the tube. Thus the application of curved tubes in heat exchange process can be highly beneficial in comparison with the straight tube. These applications can arise in the food processing industry for heating and cooling of highly viscous liquid food, such as pastes, or for products that are sensitive to high shear stresses. There is considerable amount of work reported in the literature on heat transfer in coiled tubes. However, practically very little attention has been paid to study the outer heat transfer coefficient in coiled tubes.

There are few references that discuss the design procedure for coil-in-shell heat exchangers (e.g., Prabhanjan et al., 2002; **Figure:**ueiredo and Raimundo, 1996; Haraburda, 1995; Prasad et al., 1989; Patil et al., 1982). In these studies helically coiled tubes were approximated as a bank of straight tubes for calculating outer heat transfer coefficients. There is poor circulation observed in shell regions near the coil in the coil-in-shell heat exchangers. This problem could be avoided by using a coil-in-coil tube con**Figure:**uration.

A tube-intube helical heat exchanger requires the knowledge of the heat transfer rates for the two flowing fluids, i.e., the flow in the helical tube as well as in the helical annulus. Karahalios (1990) and Petrakis and Karahalios (1996, 1997, 1999) reported the fluid flow and heat transfer in a curved pipe with a solid core. They showed that the size of the core affect the flow in the annulus with flows approaching parabolic for large cores (1999).

Karahalios (1990) studied the heat transfer in a curved annulus with a constant temperature gradient on both the outer and inner walls of the annulus as the thermal boundary conditions. All the above reported studies for helical coils were confined with one of two major boundary conditions, constant wall heat flux or constant wall temperature (Shah and Joshi, 1987;

Nandakumar and Masaliyah, 1986; Janssen and Hoogendoorn, 1978; Kalb and Seader, 1974). However in industrial applications of heat exchangers where one is interested in fluid-to-fluid heat exchanger the use of constant wall temperature or constant wall flux conditions does not appear to be physically realistic. This complicates the design of coil-in-coil heat exchangers, where either the heating or cooling is supplied by a secondary fluid, with the two fluids separated by the wall of the coil.

Garimella et al. (1988) reported average heat transfer coefficients for laminar and transition flow regimes for forced convection heat transfer in coiled annular ducts. Two different coil diameters and two annulus radius ratios of test sections were used in their experiments. They found that the heat transfer coefficients obtained from the coiled annular ducts were higher than those obtained from a straight annulus, especially in the laminar region.

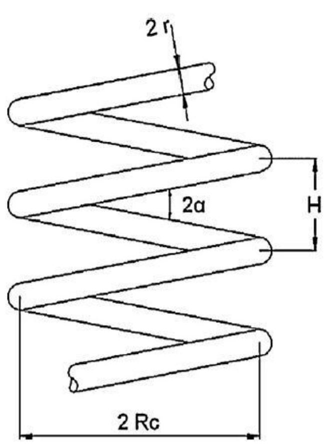

Figure : 1 Geometry of helical tube

The above **Figure:** 1 is the geometry of the simple helical tube.

Table 1: Geometry of helical tube in tube heat exchanger

Parameters	Inner tube (Hot)	Outer tube (Cold)
Outer diameter (m)	0.0254	.0508
Coil diameter (m)	0.762	0.762
Length (m)	9.5839	9.5939
Pitch (m)	0.1, 0.2 and 0.3	0.1, 0.2 and 0.3
Number of turns	4	4
Material of construction	Aluminium	Aluminium
Fluid	Engine oil	Water
Mass flow rate (Kg/s)	0.0563	0.6297

Modeling and simulation

The geometries of the heat exchanger were created in GAMBIT 2.4.6 and imported into a commercial CFD package (FLUENT 6.3.26) as per the given dimensions. The number of turns will vary as the helical coil pitch will change from 0.1 m to 0.2 m and 0.2 m to 0.3 m keeping the length of the tube constant i.e. without changing the length of the tube. Therefore the number of turns is calculated by using general formulas of helical tube. The outer tube was set with adiabatic boundary conditions. The inner tube was set to allow the hot engine oil and the outer tube (Annular side) was set to allow cold water with constant properties. The flow conditions are given to be steady and laminar. The inlet temperatures in the inner tube were 25^{0}C, the inlet temperature to the annulus would be 60^{0}C, respectively. This allowed the differences between heating and cooling to be studied in both the

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Inner tube and the annulus. The flow type is counter current flow.

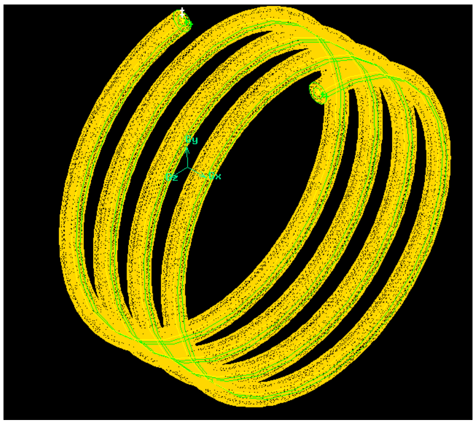

Figure: 2 Grid systems for tube-in-tube heat exchanger

Figure: 2 shows the tetrahedral meshing of the helical tube in tube heat exchanger.

Result and discussion

The outlet temperature of cold and hot fluid was found out from the simulation and also the rate of heat transfer and the pressure drop as shown in the Table 2.

Table 2: Output Temperature

Pitch (m)	Helix Angle (Degree)	Output Fluid Temperature (K)	
		Cold	Hot
0.1	2.3920	298.40	323.00
0.2	4.7757	298.33	324.65
0.3	7.1430	298.38	323.30

Table 2 shows the output temperature results of simulation in which we are getting a higher reduction of temperature in hot fluid as compared to the cold fluid because of the higher mass flow rate of colder fluid compare to hot fluid.

Table 3: Inlet and outlet Pressure of hot and cold fluid

Hot Fluid Pressure (Pa)		Cold Fluid Pressure (Pa)	
In	Out	In	Out
75075.97	39.62	291.07	0.2375
68071.84	42.43	297.42	0.2881
77231.95	42.98	304.57	0.5849

Table 3 shows the pressure difference between the inlet and outlet of the Hot fluid. The pressure difference between the inlet and outlet of hot fluid is too high because of the high temperature reduction as compared to the cold fluid.

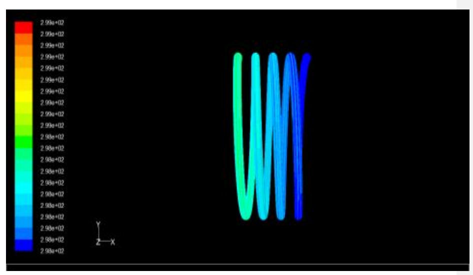

Figure: 3 Contour of temperature for cold fluid

As shown in the **Figure:** 3 the temperature of cold fluid from the inlet to outlet is increasing i.e. from right end to left end.

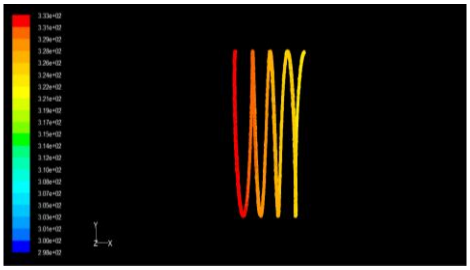

Figure: 4 Contour of temperature for hot fluid

Figure:. 4 shows the contours of temperature for hot fluid in which the temperature reduces from left end to right i.e. from inlet to outlet.

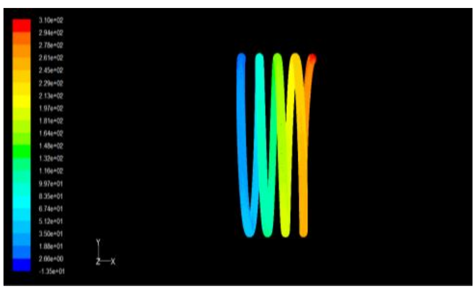

Figure: 6 Contour of pressure for cold fluid

We can see from **Figure** 6 that the change in pressure is not that much as compared to the pressure contours of the hot fluid as shown in **Figure** 7.

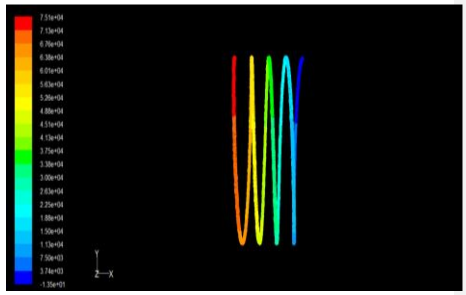

Figure: 7 Contour of pressure for hot fluid

Conclusion

A number of numerical experiments have been carried out to study influence of coil parameters, viz., pitch circle diameter, coil pitch and pipe diameter on heat transfer. The coil pitch is found to have significance only in the developing section of heat transfer. In this we found that by using helical tube in tube heat exchanger by reducing the coil pitch we can get a better heat transfer. There is a higher temperature difference in tube having low pitch as compared to the higher pitch in first and second reading but again the temperature difference reduced.

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