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CFD Analysis of Spirally Coiled Heat Exchanger

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ABSTRACT

Flow parameters such as pressure drop, temperature variation, heat transfer rate have been found out for spirally coiled heat exchanger. Fluid entering the heat exchanger is considering at 293K and wall is assumed to be at 320K. Mass flow rate has been varied from 0.06Kg/s, 0.08 Kg/s and 0.10 Kg/s & the diameter of coil has been considered as 6mm, 8.025mm & 10mm. Standard k-ε turbulence model has been considered for handling turbulence. Reynolds number, Euler number, temperature variation, pressure drop and heat transfer rate have been found out & compared for all the cases.

Keywords: *Spirally coil tube, temperature variation, heat transfer rate, pressure drop, k-ε model.*

I. INTRODUCTION

A heat exchanger is a device which is used to transfer heat between two fluids. Among all heat exchangers, spiral coil heat exchangers occupy the least space. Spiral coils are curved coil which have been widely used in engineering applications like space heating etc. The design of spiral coil heat exchangers is of a uniform cross-section which creates “swirling” motion within the fluid to give better heat transfer. The fluid flow is fully turbulent at a much lower velocity than in straight tube heat exchanger and fluid travels at constant velocity throughout the whole unit. Conventionally, spiral coil heat coupling mechanism is attributed to many factors such as geometrical configurations, compact size, bigger thermal conduction space, the number of loops, etc. A lot of researches have been conducted to investigate and determine the configuration and geometry of spiral coil heat exchanger to further enhance the heat transfer rate. Parameters such as the number of loops, mass flow rate, coil orientation, and coil pitch on diameter are some of the factors that influence the heat transfer rate. The main objective of this paper is to study the effect of mass flow rate and diameter of coil on the performance of heat exchanger. Non dimensional parameters such as Reynolds number and Euler number discussed also found out.

II. LITERATURE REVIEW

PaisarnNaphon experimented on horizontal spiral coil tube [1].Duc-Khuyen Nguyen and Jung-Yang San worked on a counter-current spiral heat exchanger [2]. Young-seok son Amdjee- young shin analysed on shell-and-tube heat exchangers with spiral baffle plate by using CFX [3]. Xia et. Worked on heat transfer for the smooth helical tube [4].Pongsoi and Pikulkajorn worked on spiral fin and tube heat exchangers of air side performance [5]. Bhavsar et.al experimented on the design of spiral tube heat exchanger [6]. Jayachandriah et.al proposed a theory on pressure drop in horizontal spiral coil using experimentation [7]. Seyedashraf has studied pressure drop in horizontal spiral coil heat exchanger [8]. Paisarn Naphon and Jamnean Suwagrai worked on effect of curvature ratios on the heat transfer and flow developments in the horizontal spirally coiled tubes [9].

III. GEOMETRIC MODELLING

Spiral coil heat exchanger is found out have good to heat transfer rate and occupy very less space. In present research work the numbers of turns of spiral coil heat exchanger have been taken as 3. The distance between two consecutive turn, called pitch is taken as 18 mm. The distance from centre to last turn of the spiral coil heat exchanger i.e. ($R_{max)}$ is taken as172mm. And the distance from centre to first turn of the spiral coil heat exchanger (R_{min}) is taken as 82mm. Fig 1 shows the geometry of considered spiral coil heat exchanger. Diameter of the coil has been considered as 06mm, 8.025mm &10mm and for variation mass flow rate which are taken as 0.06 Kg/s, 0.08 Kg/s & 0.10Kg/s.

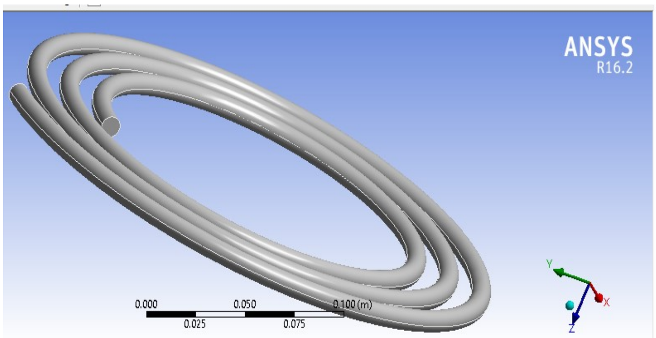

Figure 1 :3 Dimensional view of spiral coil heat exchanger

MESHING

Mesh can be hexahedral or tetrahedral depending up on requirement and available computational power. The details of mesh for all the cases are given in table1.

Table 1: Mesh details

S.No.	Tube diameter	No. of nodes	No. of elements
1	6mm	115487	89298
2	8.025mm	113535	100408
3	10mm	150195	135576

Mesh quality also affects the convergence and obtained results. Mesh quality has been kept as per the recommended values of ANSYS Fluent 16.2. Figure 2 shows the mesh of spiral coil heat exchanger of 6mm tube diameter.

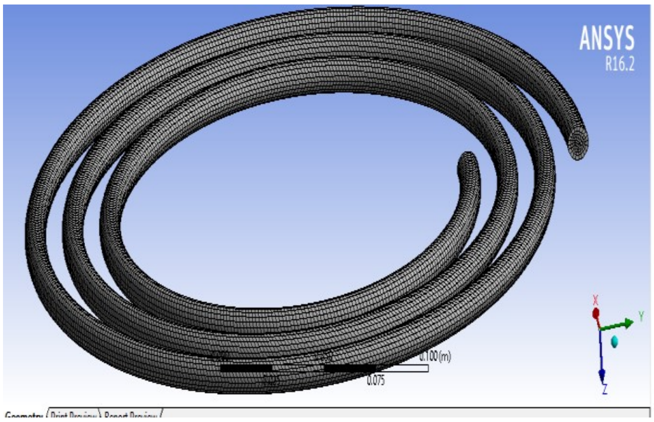

Figure 2 :3 Dimensional view of mesh of spiral coil heat exchanger

INPUT DATA, MATERIAL AND BOUNDARY CONDITIONS

Water is taken as working fluid in spiral coil heat exchanger. The inlet temperature of water is 293K and the wall temperature is taken constant as 320K. Aluminium is taken as heat exchangers, material due to its high thermal conductivity. k- ε Turbulence model has been considered for all the analysis.

FORMULAE USED

Mass flow rate:	$\dot{m}= \rho av$
Area of Coil:	$A= \frac{\pi}{4} d^2$
Reynolds Number	$Re.\ No = \frac{\rho v d}{\mu}$
Euler Number	$Eu.\ No= 2\Delta P/\rho v^2$

RESULTS AND DISCUSSION

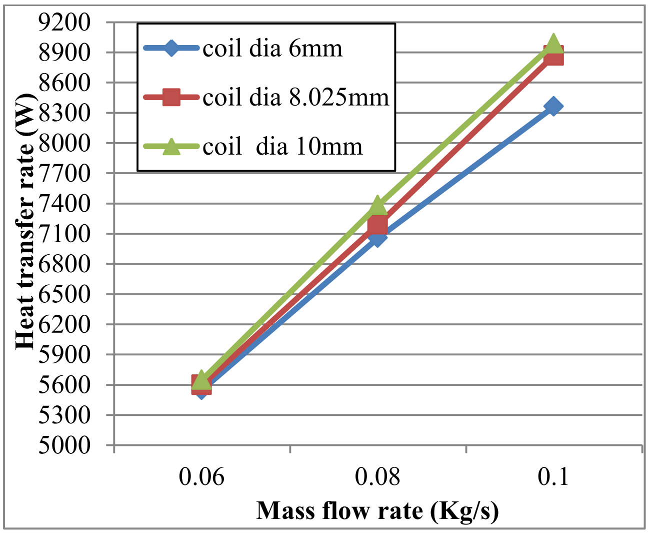

Figure 3: Variation in heat transfer rate with diameter

The heat transfer rate of a spiral coil heat exchanger depends on coil diameter. Increase in diameter causes increment in heat transfer rate. As seen in Figure 3, for spiral coil heat exchanger maximum heat transfer rate is obtained for 10mm coil diameter and minimum for 6mm diameter. Heat transfer rate is directly proportional to diameter of coil. So, highest heat transfer rate is obtained for largest diameter heat exchanger. Moreover, they both vary linearly because of increase in cross-sectional area.

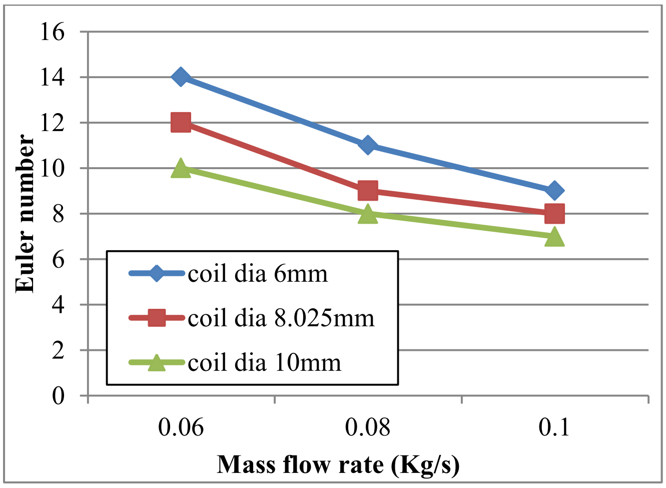

Figure 4: Variation in Euler No. for 6mm, 8.025mm & 10mm coil diameter of spiral coil heat exchanger.

Euler number is directly proportional to inlet and outlet pressure difference & inversely proportional to the velocity of working fluid. Increase in diameter of coil causes decrease in velocity of fluids, which led to decrease in Euler number at same mass flow rate. It is also seen in Figure 4 that maximum Euler number is obtained for 10mm coil diameter and minimum for 6mm diameter. Increase in mass flow rate for same coil diameter of heat exchanger results in increase in velocity of fluid. Therefore, with increase in mass flow rate, Euler number decreases.

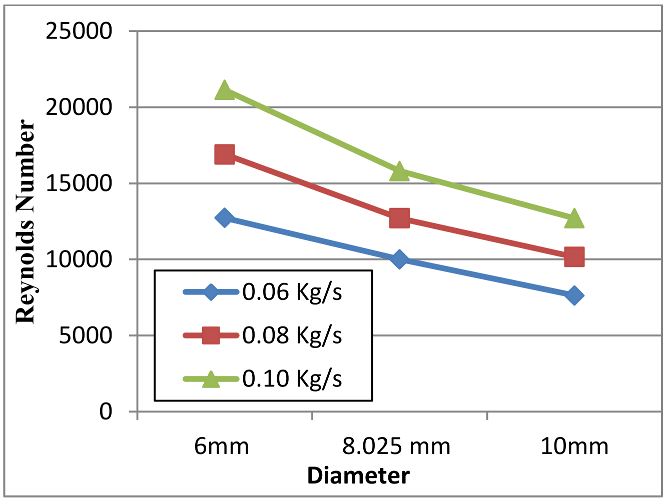

Figure 5: Variation of Reynolds No. on 6mm, 8.025mm & 10mm diameter

The Reynolds number depends on mass flow rate. Increase in mass flow rate causes increase in Reynolds number as seen in Figure 6. Maximum Reynolds number is obtained for 10mm coil diameter and minimum for 6mm coil diameter at mass flow rate of 0.10Kg/s and 0.06 Kg/s respectively.

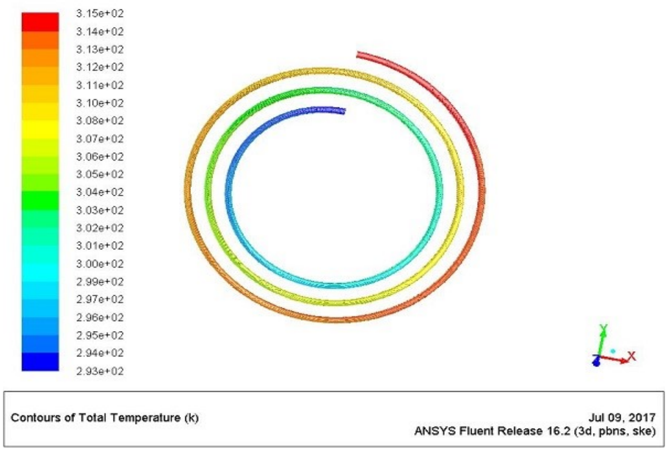

Figure 6: Variation in temperature for 6mm coil diameter at mass flow rate of 0.06 Kg/s.

As seen in Figure 6, the temperature of fluid increases gradually from inlet to outlet. Water get heated as it flows inside the coil.

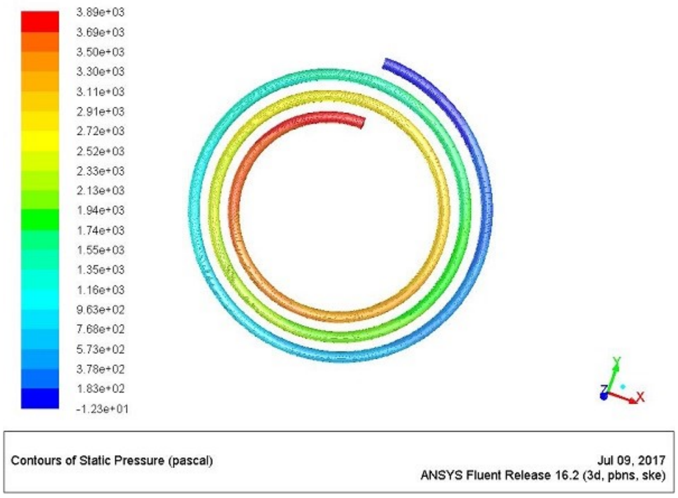

Figure 7: Variation in pressure for coil diameter 8.025 mm at 0.06 kg/sec mass flow rate

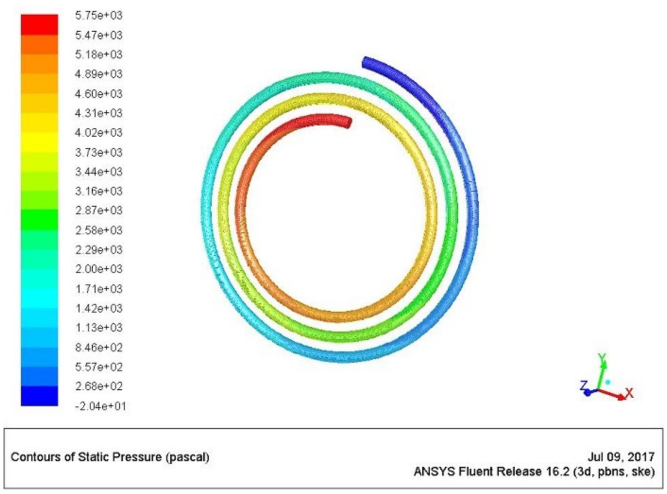

Figure 8: Variation in pressure for 10mm coil diameter at 0.06 kg/sec mass flow rate

Pressure drops evenly from inlet to outlet as seen in Figure 7 & Figure 8. Pressure drop increases with increase in diameter of coil for same mass flow rate. This also leads to increase in Euler number for same mass flow rate.

IV. CONCLUSION

Spiral coil heat exchanger is the heat exchanger, which occupies least area and have good heat transfer rate. With increase in mass flow rate, Reynolds number and heat transfer rate of spiral-coiled heat exchangers increases whereas Euler number decreases. For same mass flow rate and increase in coil diameter also, there is an increase in Reynolds number and heat transfer rate and Euler number decreases.

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