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Numerical Study of the Heat Transfer Behavior in Helical Microcoil Tube

Adnan H Rasheed[1], Hajar B Alias[1,*] and Sami D Salman[2]
[1]Chemical Engineering Department, Faculty ofEnergyand Chemical Engineering, UniversitiTeknologi Malaysia, Johor, Malaysia
[2]Al- Khwarizmi College of Engineering, University of Baghdad, Baghdad, Iraq

E-mail: r-hajar@utm.my

Abstract. This work introduces a numerical study of the convective heat transfer of helical micro coils tube heat exchanger coil. It tested for both circle and elliptical geometry with 18 mm pitch and diameter of copper pipes. It is very difficult and time-consuming if these analyses could be carried out experimentally. Water is used as a working fluid by using 80°C for hot water and 25°C for cold water. The Reynolds number selected in the range of 200 to 1800 for hot water, while specified 5000 for cold water. ANSYS-FLUENT 18.0 has been used to investigate the heat transfer behavior. In computational fluid dynamics (CFD), the partial differential equations was represented by using the finite volume method (FVM) in the form of algebraic equations and the Navier-Stokes equations were solved by using a numerical procedure which is the Semi Implicit Method for Pressure-Linked Equations (SIMPLE) algorithm. The elementary results observed a proportionality relationship between the heat transfer and the Reynolds number raised values. Also, the circular configuration present maximum heat transfer performance and the maximum values are 5.6, 3.42 for Thermal performance factor and Nuselte number respectively at Reynolds number 1800.

1. Introduction

In recent years, there has been an increasing amount of literature on energy conservation has become a pressing issue, therefore much attention has been devoted to researchers to solve this issue by finding new techniques to enhancement the thermal performance of heat transfer equipment. In General, there are three types of techniques Passive, Active and Compound. Active Techniques more complex than Passive Technique due to the Active Techniques require some external power while the Passive Technique do not need, for achieve augmentation of heat transfer by these techniques must using coiled tubes, swirl flow devices and fluid additives (Nanofluids) for Passive Technique which was used in this study and injection, suction, jet impingement for Active Technique [1-4]. Previous research findings that The big size and high cost of equipment heat transfer system like heat exchanger lead to use the of enhancement techniques [5], and also theheat transfer coefficient of laminar flow is generally low in plain tubes due to the viscous and thermal boundary layers. Thus. Several studies have found that the helical coils have better heat transfer rates than a straight tube [6-17]. The rapid developments of microelectromechanical systems (MEMS) and micrototal analysis system led to researchers have studied the effect of the characteristics of flow and heat transfer in microchannels (MC) and microtubes (MT). Salman et al [18] two-dimensional microtube with laminar flow of the convective heat transfer was numerically investigated. The results have shown that for all cases there is a positive relationship between the Nesselte number and the volume fraction but it is a negative relationship with nanoparticles diameter. Ebrahimi et al [19] numerically investigated on heat transfer using microchannel heat sink (MCHS) with longitudinal vortex generators (LVGs) and nanofluid the results show that decrease the amount of irreversibility in MCHS with longitudinal vortex generators by utilizing nanofluids as the base liquid. Dondapati et al [20] a computational study on pressure drop and heat transfer of micro heat exchangers the results show that the decrease in pressures drop with the suspension of CuO nanoparticle is low. However, to the best of authors knowledge, no report has been found so far numerical and experimental studies of the convective heat transfer of using circle or elliptical helical microtube heat exchanger,the major focus of this research is to study the heat transfer and fluid flow characteristics induced by technique using novel configurations of circular or elliptical helical microtube inserts In order to improve heat transfer coefficient, reduce the size of heat exchanger for specified heat duty and reduce the pumping power cost.

2. Materials and Method

2.1. *Physical Model*

Circle and elliptical helical microtube are one of Passive Techniques in general the model and grid of these techniques created by using ANSYS-FLUENT 18.0 with 500 mm for length and 18mm for the pitch , diameter and 28 turns was fitted in copper tube heat exchanger, the length of tube heat exchanger 500 mm, 25.4 mm, 23.26 mm are the outer diameter (Do) and inner diameter (Di) respectively for tube heat exchanger, (Dc) and (Pc) represented to the coil diameter and pitch respectively as shown in figure 1 . Although available different types of meshing elements for volume mashing in ANSYS-FLUENT 18. 0 but the tetrahedrons method with element of Quad/Tri is selected to mesh due to was suitable for irregular configurations as shows in figure 2, In addition table 1 are listed the geometric parameters, this study using the water as working fluid.

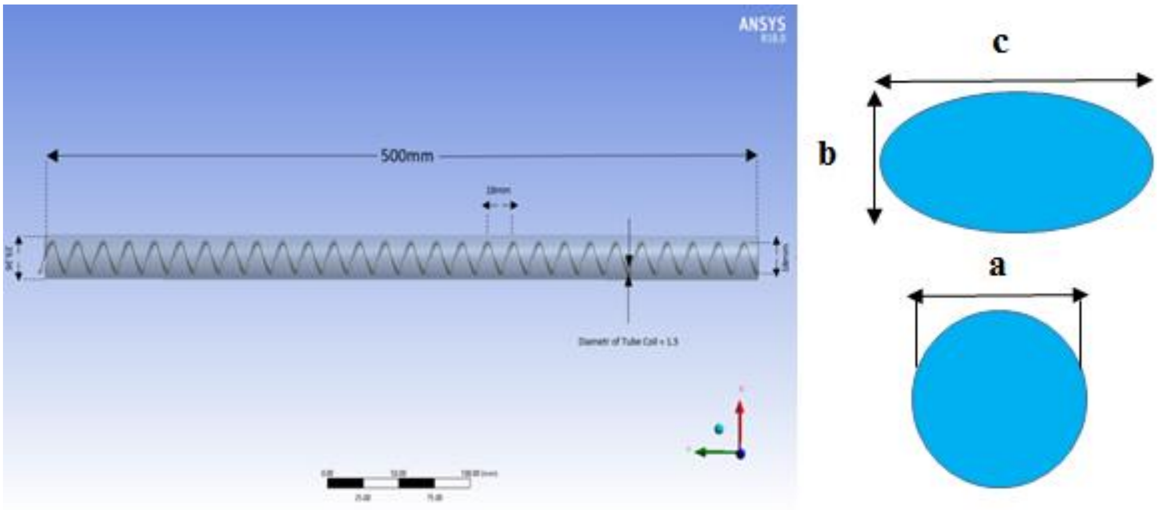

Figure 1.Geometry and studied sections.

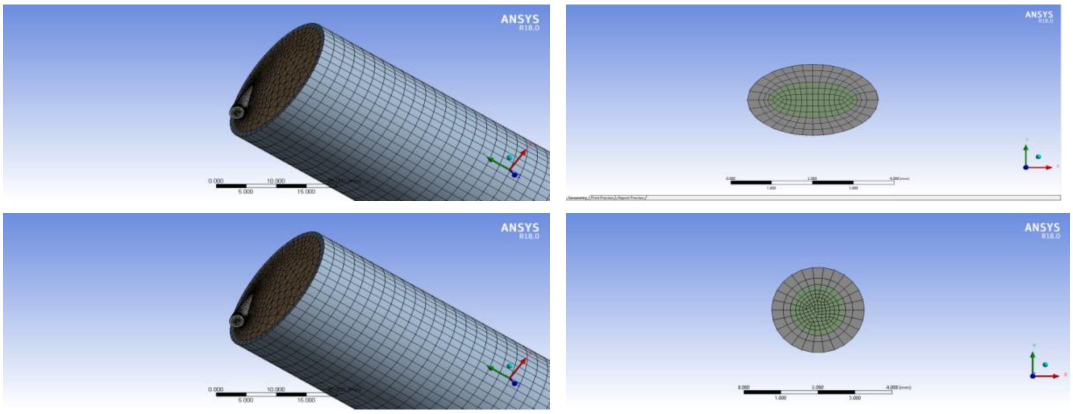

Figure 2. Meshing of Geometry and studied sections.

Table 1. Geometric parameters.

Geometry parameter	a	b	c
Value (mm)	1.5	1.022	2.2

2.2. Governing Equation and Boundary Condition
This study is carried out with three dimensional geometry at incompressible laminar flow, Study state, Single phase. It is assumed that the wall of the shell is thermal isolation and the fluid in the outlet set free and the relative pressure was zero Pa, viscous dissipation are not consideration, the governing equations as follows [21-23]:

For Continuity: $\nabla . V = 0$ (1)

For Momentum: $\rho(V .\nabla)V = -\nabla p+\mu\nabla 2 V$ (2)

For Energy: $\rho c_p(V .\nabla) = k \nabla^2 T$ (3)

The flow at the inlet of the copper shell and tube is fully developed with temperature 25 °C and 80 °C respectively. The flow in the shell is constant at Reynolds number 5000 and the flow in the tube is variation from (Re = 200 to 1800).

3. Main Results
One of the main factors of passive Techniques that use to decide the heat transfer performance is the cross-sectional tube geometry because these techniques utilize surface or geometric amendments to the channel of flow to improve the thermal performance of heat transfer equipment's. This research tests the impact of both circle and elliptical helical microtube heat exchanger to heat transfer characteristics with base working fluid is water. Figure. 3 shows average Nusselt number(Nu) for different helical microtube at various Reynolds number where Nusselt number is a non-dimensional parameter that provides a measure of the ratio of convective to conductive heat transfer at the wall which good convective heat transfer achieved with high value of a Nusselt no. From the results, it is seen that the Nusselt number increases with the rise of Reynolds number for all cases but circle helical microtube has higher value of Nusselt number than the elliptical helical microtube This can be explained by a stronger secondary flow that generated by curvature of circle helical microtubule than elliptical helical microtubule.

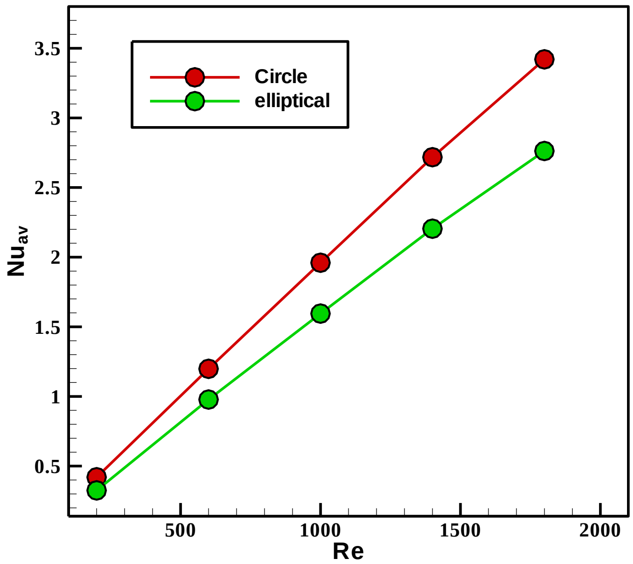

Figure 3. Average Nusselt number for different helical microtube at Various Re.

The variations of skin friction coefficient with Reynolds number for circle and elliptical helical microtube is presented in Figure 4. From this figure, as we can see that the skin friction factor decreases with the rise of the Reynolds number and the maximum value of the skin friction coefficient can be achieved by using the elliptical helical microtubule. In other words, the larger flow resistance was found by using the elliptical. Furthermore, this is since lower pressure drop in larger hydraulic diameter corresponds to the lower inlet velocity transferred into the helical microtube[24].

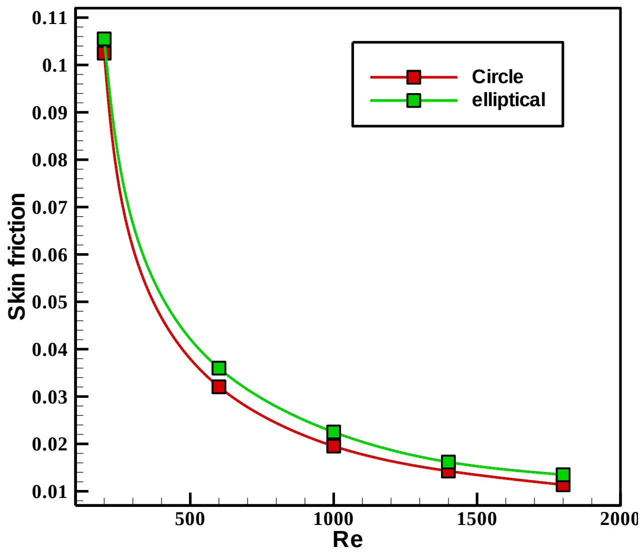

Figure 4. The skin friction with different helical microtube at Various Re.

Finally for all sections tested, figure 5. Display the Thermal performance factor for different types of helical microtube with different Reynolds number, it was found with increase the Reynolds number the value of thermal performance factor also increase and circle helical microtubule has higher value to the others.

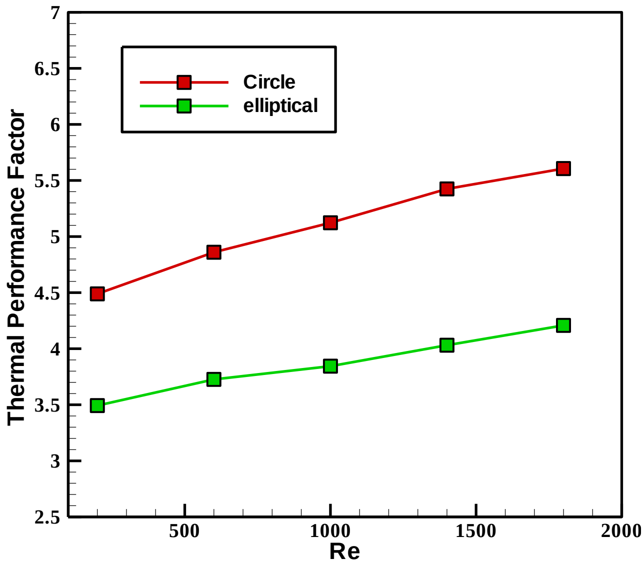

Figure 5. Thermal performance factor for different helical microtube at Various Re.

4. Conclusion

The present study was designed to decide the effect of both circular and elliptical helical microtube with laminar flow of the convective heat transfer, The Nusselt number and skin friction coefficient were obtained through the numerical simulation. . The following is a summary of conclusions:

1- The Nusselt number increased with increasing Reynolds number for all sections tested
2- The skin friction factor decrease with increasing Reynolds number for all sections tested
3- The circle helical microtubule has the highest Thermal performance factor value, and the elliptical helical microtubule has the lowest Thermal performance factor

In addition to those good performances. The circle helical microtube has better heat transfer enhancement from the elliptical helical microtube which can be widely used in the micro heat exchanger. On the other hand, this study has proven that the utilization of circle helical microtube is very important in enhancing the heat transfer compared to elliptical helical microtube.The benefits of this work will lead to design an efficient micro heat exchanger with low cost and small size and compactable for many engineering applications.Based on this project, the following recommendation would be made for future work, using nanofluid instead of water as working fluid and as an additional passive technique.

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Nomenclature

MT	Microtubes	Re	Reynolds number, Re = ($\rho V D_h / \mu$)
MC	Microchannels	Dh	hydraulic diameter, (mm)
MEMS	Microelectromechanical systems	k	Thermal conductivity of the fluid
LVGs	longitudinal vortex generators	T	Temperature, K
MCHS	Microchannelheat sink		
CuO	Copper oxide		
Do	Tube outer diameter, (mm)	*Greek symbols*	
Di	Tube inner diameter, (mm)	μ	Dynamic viscosity
Dc	Coil turn diameter, mm	ρ	Density
Pc	Coil pitch, mm		
Cp	Specific heat, J/kg K		
Nu	Averaged Nusselt number = hnfD/knf	*Subscripts*	
hnf	heat transfer coefficient, (W / m2·K)	n_f	Nanofluid
P	Pressure		
V	Velocity vector		

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