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Research Article

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Experimental investigation of heat transfer inside coiled heat exchanger with variable straight-section lengths

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Abstract This paper presented the heat transfer inside the coiled heat exchanger with variable straight-section lengths experimentally. The study carried out at Reynolds number inside tube is varied from 1500 to 4500. Three cross sections of coil are considered, straight, low to high, and high to low. The inner diameter of tube and the total length are constant of 7 mm, and 350 cm respectively. Experimental results showed that, the heat transfer increase with the increase in a Reynolds number. On the other hand the experimental illustrated that the Nusselt number is not more influence with variable cross section of coil. Where the Nusselt number in low to high coil is improved by 7.56 % and 4.32 % compared with high to low and straight coils respectively.

Keywords Nusset Number, Variable coil, Coil heat exchanger

1. Introduction

It has been more study investigated the heat transfer rate inside the indirect channels such as helical, spiral, or serpentine tubes as a passive heat transfer enhancement technique are higher when compared to the straight ones [1]. The centrifugal forces made in an indirect channel give rise to rotating flows, swirl flow and secondary flow patterns. So, addition axial direction, the heat transfer takes place by diffusion and convection in the radial direction [2]. In addition, the attendance of secondary convective transport significantly improves the heat transfer rate per unit length of the indirect channels compared to straight ones [1]. This causes a compact structure in the practical applications such as power generation, nuclear industry, process plants, heat recovery systems, air conditioning, refrigeration, food and petrochemical industries [2, 3]. Heat exchangers are mechanical devices which used to transfer a thermal energy, also called enthalpy, through thermal contact between two or more fluids, between a solid surface and a fluid, or between solid particulates and fluid, at different temperatures [1, 5]. In addition, no external heat or work interactions required in heat exchangers which are commonly used in heating or cooling specific fluid stream. Also, heat exchangers are used in condensation and evaporation of single or multi-component fluid streams [2,4].

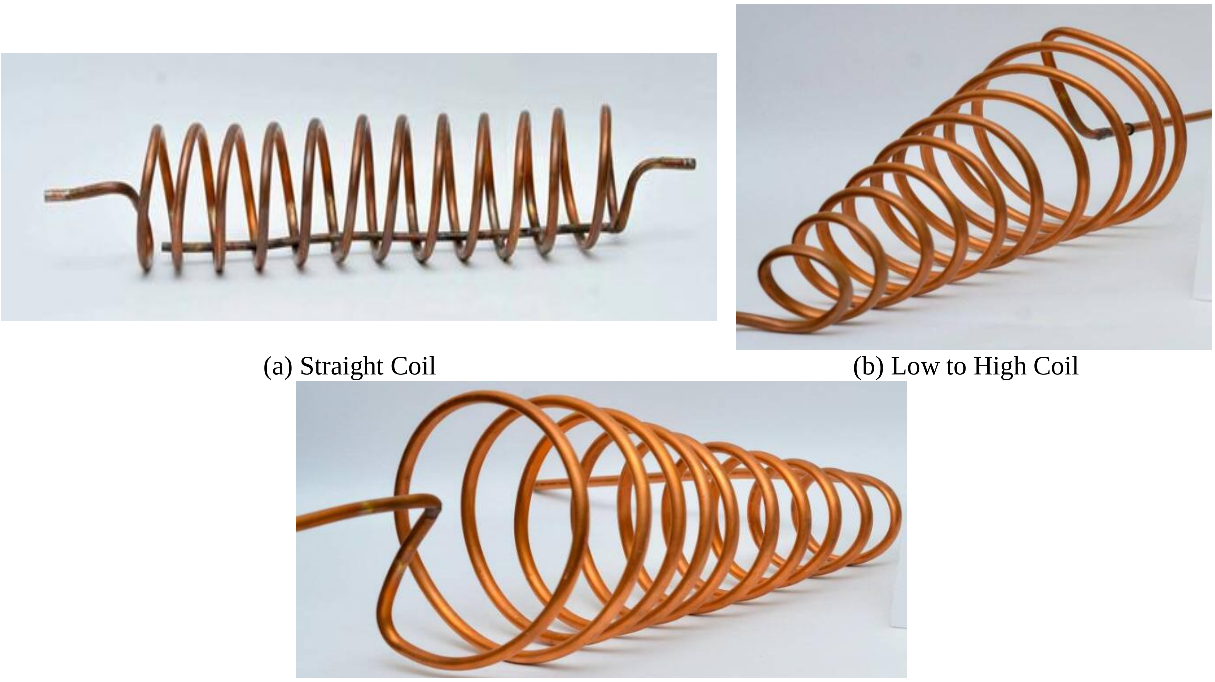
General examples of heat exchangers are shell and tube exchangers, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers. Although, sensible heat exchanger will have no phase change occurrence in any of processed fluid [5]. Furthermore, some exchangers such as Electric heaters and nuclear fuel elements could contain internal thermal energy sources. Particular kinds of heaters such as Boilers, fired heaters, and fluidized-bed exchangers engage chemical interaction and combustion inside the exchanger [6]. The numerous studies have indicated that helically coiled tubes are superior to straight tubes when employed in heat transfer applications [7]. Salimpour [8] studying experimentally the Nusselt number of shell and helically coiled tube heat exchangers for different coil pitches for parallel and counter-flow configuration in which a hot water flows inside the tube-side and the cold water flowing in the shell side.

The secondary developed in the curved helical coiled tubes due to centrifugal force observed in the fluid flowing, enhances the heat transfer in coiled tube heat exchanger. The intensity of secondary's [10, 11] established in the tube is the function of inner tube diameter (d) and coil diameter (D). For the smaller coil and inner tube diameter the intensity of secondary established is higher. This increase in intensity of secondary allows proper mixing ofthe fluid, which enhances heat transfer coefficient for the same flow rate. Increase in tube and coil diameter decreases the secondary developed which decreases Nusselt number [12]. Hussein et al. [13], investigated experimentally the thermal performance of shell and coiled tube heat exchanger in the vertical position compared with the horizontal position.

This paper carried out to investigate the effect of variable of cross section of coil heat exchanger on heat transfer. Three cross section of coil are considered, straight, low to high, and high to low coil. The Reynolds number or all three cross section of 350 cm with constant inner diameter of 7 mm.

2. Experimental set-up

The variables coil are shown in Fig. 1, the experimental includes two lop, one is cooling lop; in this lop the cooling flow (water) through the shell with constant Reynolds number of 2000. The second one is heating lop, which through inner the coil with different Reynolds number varied from 1500 to 40000. The inner dimeter of 7 mm and the total length of the three coils is 350 cm. the coil length is 80 cm for case of low to high and high to low. For case of straight coil the length is 50 cm as shown in Fig. 2.



(a) Straight Coil (b) Low to High Coil

(c) High to Low Coil

Figure 1: Photo of differences cross section coils

Figure 2: Photo of Shell and Finned Tube Heat Exchanger

3. Data Reduction

The log mean temperature difference (LMTD) could be written for a parallel flow or counter flow arrangement. The LMTD has the form:

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{1n\frac{\Delta T_2}{\Delta T_1}} \quad (1)$$

The heat transfer rate for a cross flow heat exchanger described as:

$$Q = F\ UA\Delta TLMT\ D \quad (2)$$

According to the counter flow heat exchanger arrangement the factor F is a correction factor, and the log mean temperature difference. In LMTD both inlet and outlet temperatures are identified. While this is not the case, the explanation of heat exchanger trouble becomes to some extent tedious. An alternate method based upon heat exchanger efficiency is more suitable for this type of analysis. If $\Delta T1 = \Delta T2 = \Delta T$, then the expression for the LMTD reduces simply to ΔT.

By heat balance,

$$Q = Q_c \quad (3)$$

The convection heat transfer can be calculating by the flowing equations;

$$Q_c = hA_s\ (T_m - T_s) \quad (4)$$

The Nusselt number, Nu could be calculi from the following equation;

$$Nu = h.d/k \quad (5)$$

4. Results and Discussion

4.1. Heat Transfer Rate

The heat transfer rate which was calculated from equation No. 2 is showed in Fig. 3. This figure shows the heat transfer rate distribution with Reynolds number at different coils. It observed that the heat transfer increase with increase of Reynolds number for three coils. On the hand the heat transfer for low to high coil is higher than other coils. For high Reynolds number the value of heat transfer for low to high coil is 5.14 kW, while this value reduces to 4.35 kW and 4.25 kW for high to low and straight coils respectively. For case of low Reynolds number (Re = 1500) the value of heat transfer for low to high is 1.6 kW. While the value of heat transfer for high to low and straight coils are 1.45 kW and 1.35 kW respectively.

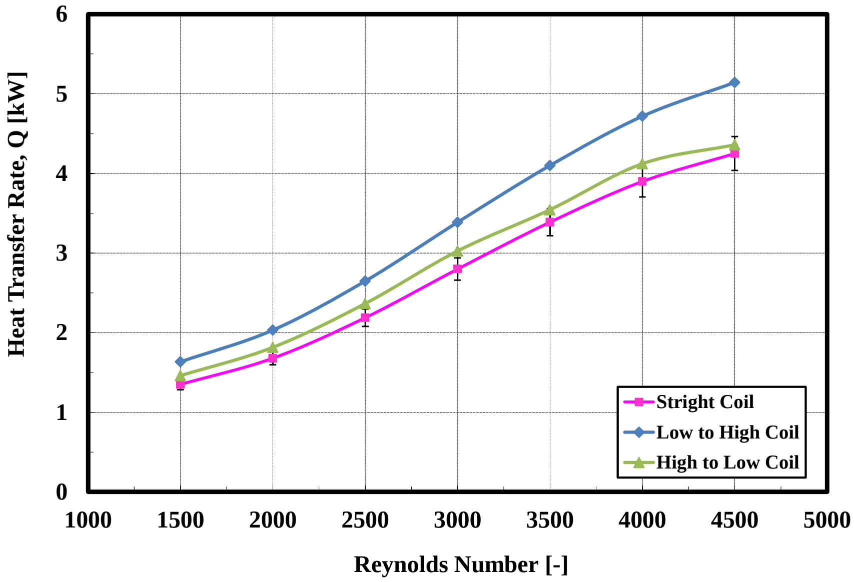


Figure 3: Heat Transfer Rate Distribution with Reynolds number for Three Different Coils

4.2. Nusselt number

Fig. 4 shows the Nusselt umber distribution with Reynolds number for straight coil. It observed that the Nusselt number increase with increase of Reynolds number. On the other hand the Nusselt number increasing slowly in Reynolds number region from 1500 to 3000, and then increasing gradually with increase of Reynolds number

(Re > 3000). This result due to the first region is laminar regen and then with increase of Reynolds number the flow entering in turbulent region. Therefor the turbulent insanity increase then heat transfer enhancement.

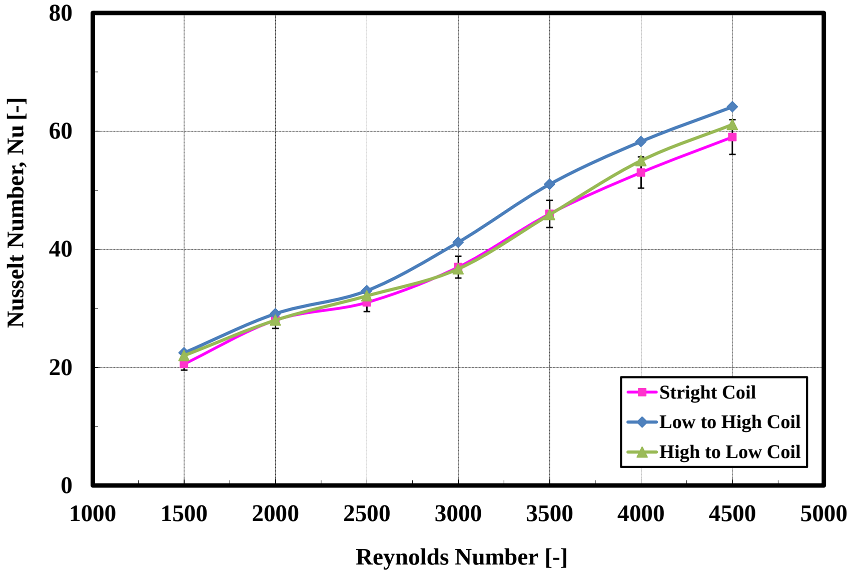


Figure 4: Nusselt number distribution with Reynolds number for Low to High Coil

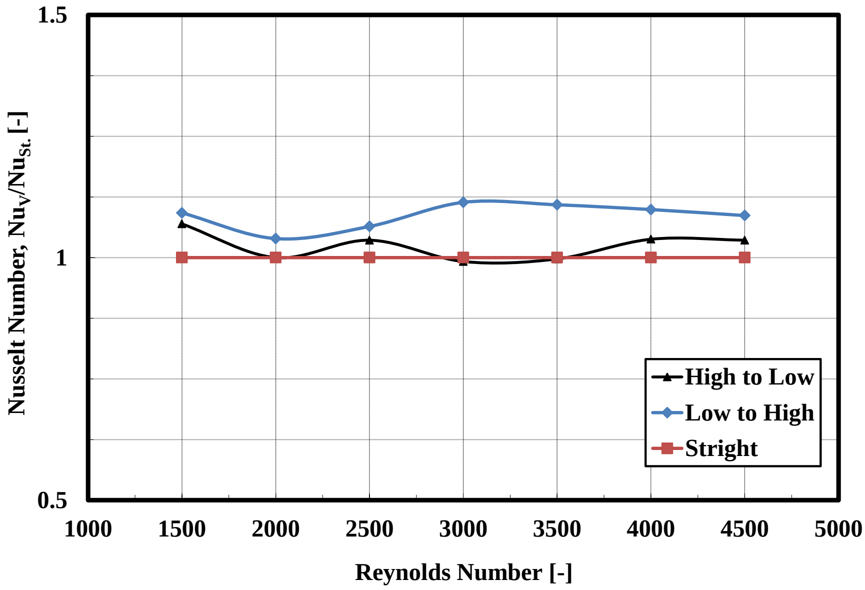


Figure 5: Evaluation of Nusselt number distribution with Reynolds number at three Coils

The Nusselt number for low to high coil is greater than other coils. Where, the Nusselt number for low to high coil is improved by 9.19 % and 2.13 % compared with high to low and straight coils at low Reynolds number (Re = 1500) respectively as shown in Fig. 4. While for high Reynolds number (RE = 4500) this improvement increase to 11.4 % and 8.8 % for high to low and straight coils respectively. This result may be the centrifugal force is strong in low to high coils. Therefore, the heat transfer increases than other coils.

4.3. Evolution of Heat Transfer

To evaluation the heat transfer, the Nusselt number ratio is considered through this study. Where the Nusselt number ratio could be calculated by the following equation;

$Nu_v = Nu/Nu_{St}$ (6)

Fig. 5 shows the Nusselt number evolution distribution with Reynolds number for to coils low to high and high to low. When the value of Nusselt number evolution over the unity that means the Nusselt number is improved through the coil. This figure shows the coil of low to high is better than other coil especially high Reynolds number (Re > 3000). Where the value of Nusselt number evaluation is improved by 10 % compared with high to low coil.

5. Conclusions

Experiments were performed to investigate the Nusselt number flowing in shell and coil tube heat exchanger. The Reynolds number is barred from 1500 to 4500. The conclusion from this study could be summarized by the flowing:

1 – Heat transfer and Nusselt number is influence by Reynolds number. Where both of heat transfer and Nusselt number are increases with increase Reynolds number.

2 - Nusselt number is enhancement by using the low to high coil by 9.19 and 8.8 % compared by other coils at low Reynolds number.

3- The experimental results showed that the Nusselt number evaluation is higher at low to high coil.

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