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Optimization and evaluation of Overall Heat Transfer Coefficient of helical coil tube heat exchanger with air injection

Muna Ali Talib[1], Ali Shaqir Baqir[1], and Ahmed Hammodi Ali [2]
1,2Engineering Technical College, Al-Furat Al-Awsat Technical University, Al-Najaf 31001, Iraq

E-mail:
munaalitalib@gmail.com , coj.alish@atu.edu.iq, ahmed.hamoodi.chm@atu.edu.iq

Abstract. Heat transfer is performed experimentally in the outer coil insulation and the externally finned coil. Experiments are performed with a total height of 50 cm and an inside diameter of 1.5 cm. A length of approx. 4 m and an inside diameter of 0.44 cm were used with with external small fins (approx. 266 fin) During the experiments, three different hot water flow rates and five different cold water flow rates were tested with a constant temperature difference (ΔT = 20 ℃). The temperature distribution along the heating equipment and the heating rate were determined and discussed. The results showed that the temperature of the projectile increased with altitude, which was positively affected by the flow of the projectile mass. The accepted value of the lateral rotational speed of the front was determined in accordance with the current operating conditions. Finally, the heat transfer rate was significantly affected by the mass rate of coil side

Keywords: heat exchanger, coil tube, air injection bubbles, and sparger.

1. Introduction

Spiral heat exchanger with spiral tube has many advantages, such as compact design (small space requirement), simple manufacture, high pressure work, high heat transfer coefficient, corresponding laminar flow or low flow conditions in the layer (ring) and cost efficiency [1, 2]; Therefore, this device is widely used in heat transfer applications. These programs include chemical reactors, evaporators, the food and nuclear industries, refrigerators, steam air conditioners, waste heat recovery, and many other

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applications [3]. To reduce the cost of materials and improve the poor performance of heating devices, researchers have proposed various methods of improving heat transfer since the 1960s. In general, these processes can be divided into two main groups, namely passive and active heat transfer processes [4]. The first uses surface or geometry changes of the flow channel by inserting attachments or additional devices such as outer surfaces, offset devices [5] and additives (Nano fluids) [6]. Active refinement techniques have complex design advantages in that they require some external flow to facilitate the desired change in fluid flow behavior and to improve heat transfer when heating. Improvements of this type include mechanical instruments, surface vibrations, liquid vibrations, liquid injection, electrostatic fields, and jet shocks [7]. Air injection, as an active method of improving heat transfer, is achieved by creating small air bubbles in the liquid or in the bottom or next to the heating wheel. The amount, shape, distribution and size of these air bubbles depends on the system with which the air is injected (diffuser). Such behavior can improve the levels of turbulence of fluids, disrupt the boundary layer of liquids around heat transfer surfaces, and consequently improve poor heat transfer performance. On this basis, Dizajietal [8] proposed injecting sub-millimeter syringes of the air bubbles of Hell. Heat exchangers to improve the operation of the heater. These researchers studied the effect of inflowing air bubbles on the number of heating units (NTUs), efficiency, and exergy losses. The flow rate of the coil (hot liquid) and the temperature difference are invariant with the flow rate. The results showed that air injection through the tray significantly improved NTU and the effectiveness of a heat exchanger. Mousavi and others. [9] investigated the effect of the inflowing air bubbles on the heat transfer function of the heat exchanger with the same test system from Dizazi et al. [8] and by changing the coil rise and the temperature difference.

The authors found that an increase in the volume of blown air adjacent to the heating layer increases the overall heat transfer coefficient to approximately 6-187%. Similarly, Panahi [10] observed that the introduction of air bubbles into the side of the heating layer of the heat roller increased the number of Nulets and its efficiency by 50–328% and 53–127%, respectively. Khorasani and Dadvand [11] investigated the effect of rational bubble injection on the work of the helicopter’s horizontal heating system. Their results showed that NTU energy and air losses have significantly improved. [12] evaluated the effects of incoming air bubbles on Nu, exergy curvature, and the efficiency of double

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vertical heating. Their results showed that the heat recovery and reduction of pipe and pipe heating pressure for Nu, Exergy and Effectiveness are closer to 57%, 30% and 45%, respectively, which is more efficient than DC air injection technique, but the pressure drop is higher. .But in general The heat transfer coefficient was improved by 131-176% with flow injection devices. Based on the second comprehensive law of thermodynamics, Solehhorasani et al. [14] analysed the thermal performance of a horizontal heat exchanger with a bubble placed in the edge of the wheel. These authors examined the effect of the air bubble fraction on the NTU and the pressure reduction. The results showed that the NTU increases by a fraction, reaches a certain value and then decreases again. In addition, the formation of entropy and pressure reduction increased with fractionation. Since all experiments are aimed at increasing the thermal efficiency of heat exchange by air blowing techniques, the cost of the additional device to be used is difficult. From this point of view, optimizing the operating conditions and determining the optimal conditions under which the air injection technique can be used effectively becomes an important question that remains unanswered. The relevant studies discussed above focus on a limited range of operating conditions that would be inconsistent for a full assessment of the impact of air injection on the thermal performance of a heating system. Therefore, there is currently a need for research to optimize the operating conditions of a vertical fuel-fired coil heater. lateral flow velocity, lateral flow velocity, initial temperature difference and fuel flow velocity were investigated experimentally.

2. Experimental setup and test procedures

Figure 1 shows a diagram of the test equipment. The test unit consists of a heating, cooling and heating unit. The heating unit that supplies the system with hot water consists of a copper boiler, a hot water tank, Variac electric heaters and a wattmeter. The refrigeration system supplies raw or cold water during the experiments, has a cold water tank and a cooling system. Finally, the heating unit consists of a cylindrical sheath of PVC, a wound copper pipe, subsequent fittings, valves and connecting parts. Table 1 summarizes the geometry of the heater. In addition, the column was insulated with 3 mm EPE foam, and a bubble spreader was placed at the bottom of the plate as shown in Figure 2. In addition, 8K thermocouples are used to measure the temperature distribution of the system. The speed of cold and

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hot water and the air flow were measured using rotometers. Air was supplied to the system via a HAILEA ACO-318 compressor. The system flow configuration was reversed, as shown in Figure 2. 3. All thermocouples were connected to the data logger PICOLOG 6 TC-08 with a resolution of 0.1 ^{0}C, which is connected directly to the computer to read the thermocouple measured values.

Experiments begin with the circulation of hot and cold water on the side of the tub and on the side of the heating layer until a stable state is obtained where the temperature measurement is made. The air is then blown directly into the side layer of the heater through a diffuser with a certain volume flow. Thermocouple readings were obtained when a new steady state was reached. This procedure was repeated for the different working conditions shown in Table (2).

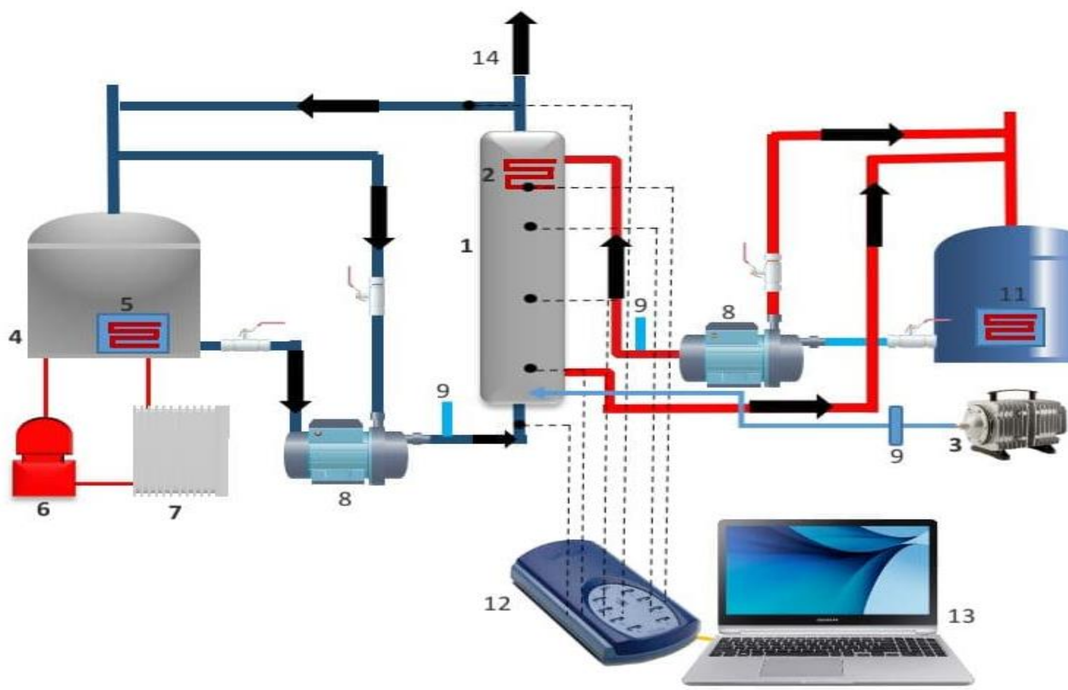

Fig. 1: A planning view of the empirical configuration: 1.Shell tube, 2. Helical coiled tube, 3. Aquarium air compressor, 4.cold water tank, 5.evaporator, 6. Compressor, 7.condensor, 8. Water pump, 9. rotameter, 10.hot water tank, 11. Electric heater, 12. Data logger 13. PC, 14. Air vent

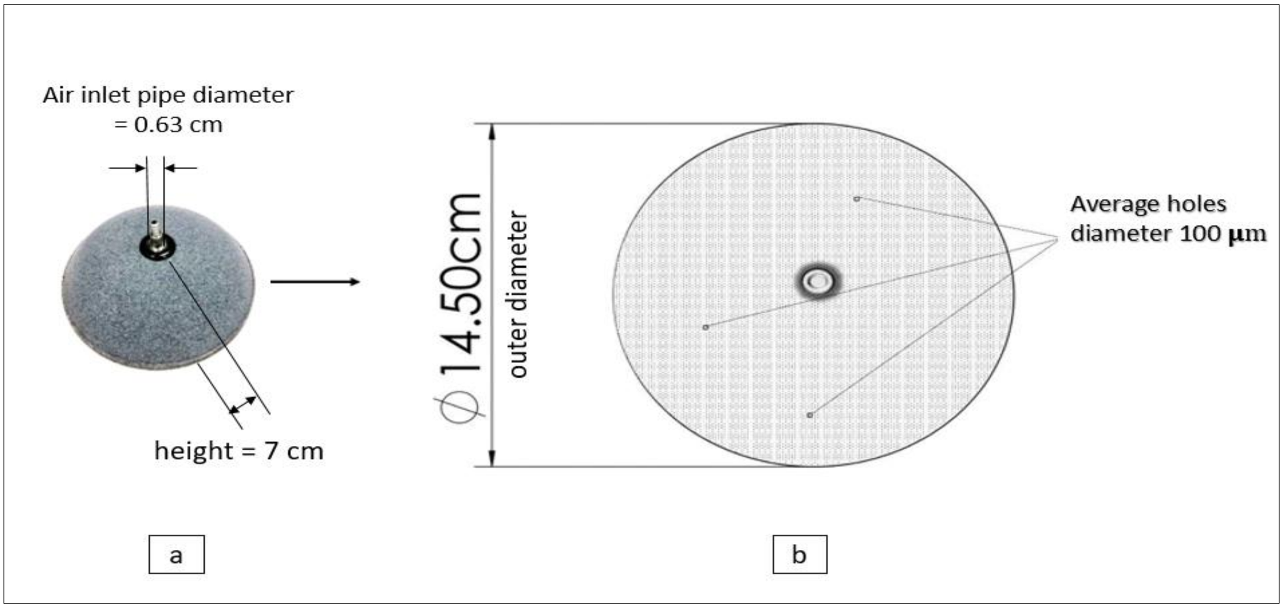

Fig. 2: Sparger specification: (a) over view, (b) planning view

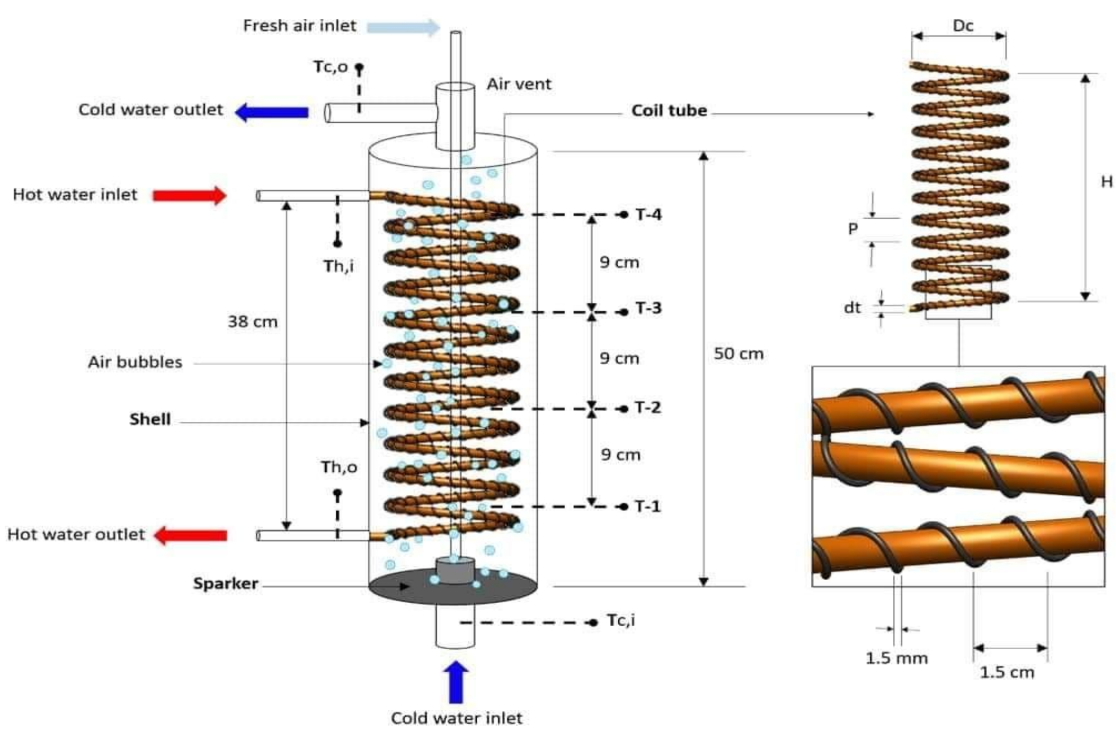

Fig. 3: Diagram of the experimental part.

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Table 1. Summary of heat exchanger geometry

Tube	Di	H	Dc	N	t	L	di	P
Shell	152.4	500	-	-	3	-	-	-
Coiled tube	-	380	114	11	1.6	3939 (bco)	4.4	30

Table 2. different operational condition

shell and coiled tube inlet temperature (C°)	The coil-side water flow rate of the coil (LPM)	The water flow rate on the side of the shell (LPM)	Airflow rate (LPM)
T coil = 37 ^{0} C T shell = 17 ^{0} C	1	2,4,6,8,10	0,2,4,6
	1.5	2,4,6,8,10	0,2,4,6
	2	2,4,6,8,10	0,2,4,6

3. Results and discussion

In the present experimental work, the enhancement of heat exchangers' improve the Overall Heat Transfer Coefficient of heat exchanger as a result of injecting air bubbles in the shell side of a counter-current vertical helical coil heat exchanger is conducted. For an efficient heat transfer process, Qs = 10 LPM ,coil side flow rate =(1, 1.5and2) LPM , temperature difference= T(20°C) and air injection flow rate=Q LPM (0, 2, 4 and6) air are tested. Air injection, especially into the shell side of the helical coil heat exchanger , can significantly improve the heat transfer process by heating [8-10]. Therefore, this method should lead to a reduction in the size of the heater, the required pumping capacity and heating costs. However, additional devices, such as a compressor and air injection system, require additional costs. Therefore, it is important and useful to determine the optimal conditions in which the air injection technique contributes to the maximum in the heat transfer process.

when the fluid flows in a curved tubes (coil tube), centrifugal force is induced due to tube curvature which produce a secondary flow, A secondary flow has a significant ability to improve

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the heat transfer rate, where the fluid in the middle of the curved tube moving centrifugally (outwards), and near the wall inwards. As well as, due to the density difference between the air bubbles and water in the shell, the bubbles are driven vertically through the bulk of water under the effect of buoyancy forces. The overall heat transfer coefficient (U) increases significantly when air bubbles are injected into the shell tube. Both techniques were used in the present study in order to enhance overall heat transfer coefficient

First important indicator about the efficient of the thermal process under different operational conditions is overall heat transfer coefficient (U) which investigated and in the present study. Overall heat transfer coefficient can be calculated from the following equation.

$$U = \frac{q}{A_s \,.\, \Delta T_{lmtd}} \quad \text{---} \quad (1)$$

Where $q, A_s and\ \Delta T_{LMTD}$ represent the heat transfer rate, surface area of heat transfer and the log-mean temperature difference. So, the heat transfer rate (q) can be calculated from energy balance, as following:

$$q = \dot{m}_h C_{p,h}\left(T_{h,i} - T_{h,o}\right) = \dot{m}_c C_{p,c}\left(T_{c,o} - T_{c,i}\right) \quad \text{----------------------------} \quad (2)$$

The heat transfer rate was evaluated based on the assumption of that all heat transfer from the coil side completely absorbed by the water in the shell side.

The log-mean temperature difference can be evaluated from equation below:

$$\Delta T_{lmtd} = \frac{(T_{h,i}-T_{c,o})-(T_{h,o}-T_{c,i})}{\ln\left(\frac{T_{h,i}-T_{c,o}}{T_{h,o}-T_{c,i}}\right)} \quad \text{--} \quad (3)$$

As seen in Figure.4 the variation of the overall heat transfer coefficient with coil side flow rate (1, 1.5, and 2) LPM at three different pitch size ($P = 1, 1.5, and\ 2$) cm, and three different constant air flow rates ($Q_{air} = 2, 4\ and\ 6$) LPM divided into three figures as shown below (a, b and c) and constant shell side flow rate at 10 LPM . Firstly, the air flow rate is held constant $(Q_{cair} = 2\ LPM)$ see figure.4.a. .It is obvious that the enhancement of the overall heat transfer coefficient improve significantly when hot water flow rate 1.5 LPM and pitch size 1 cm. when the air flow rate increase

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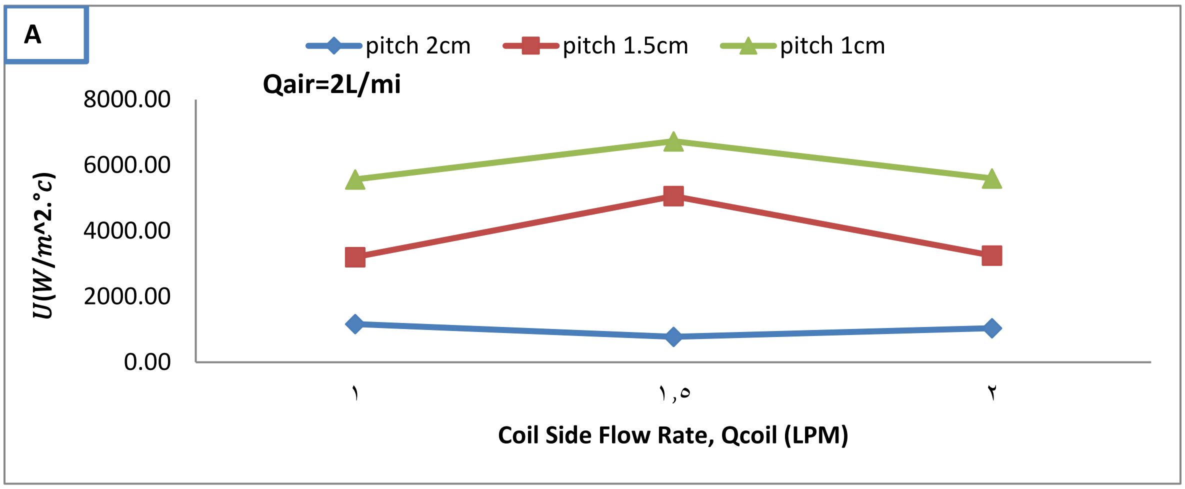
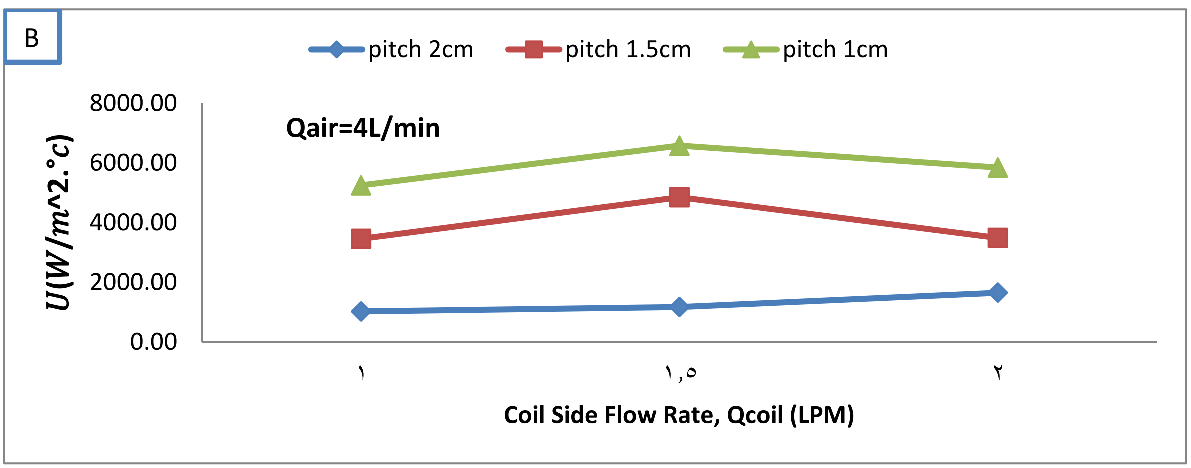
into 4 and 6 LPM, thermal performance have same enhancement be heavier at the Same operation parameter with different value of overall heat transfer coefficient.





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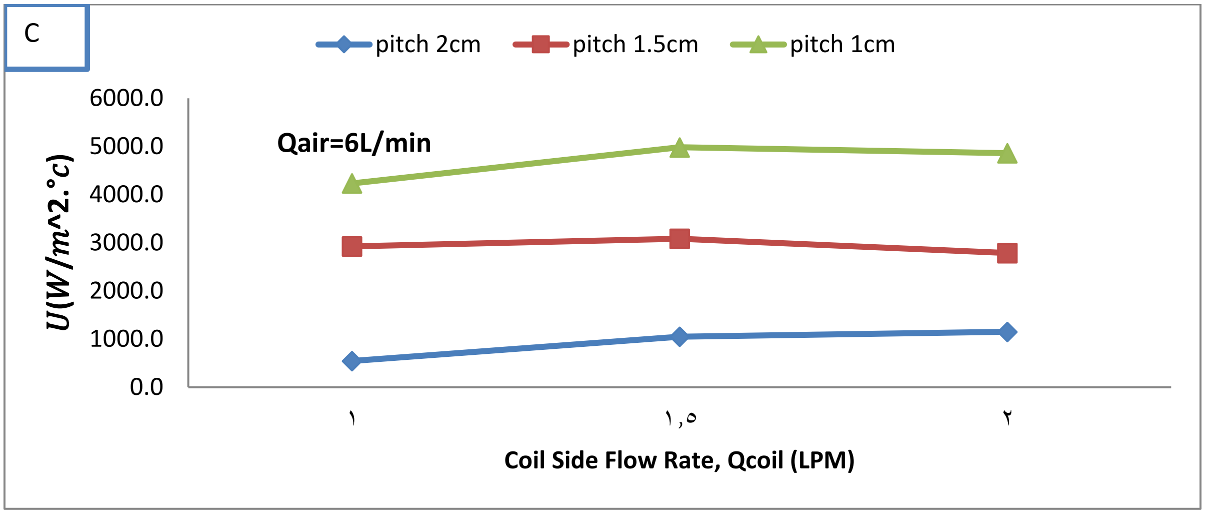

Fig.4: Variation of overall heat transfer coefficient with the coil flow rate for different air flow rates $(A)Q_{air} = 2,\ B)\ 4,\ C)\ 6\ l/min)$, three different pitch and constant shall (cold) flow rate $(Q_{cshell} = 10l/min)$

Figure 5. express the variations of enhancement ratio with same operation parameters above coil side flow rate (1, 1.5, and 2) LPM at three different pitch size ($P = 1, 1.5, and\ 2$) cm, and three different constant air flow rates ($Q_{air} = 2, 4\ and\ 6$) LPM divided into three figures as shown below (a, b and c) and constant shell side flow rate at 10 LPM. Maximum enhancement ratio was at 1 cm pitch size, 1.5 LPM hot water flow rate and 2 LPM air flow rate as a result of air injection and increasing curvature ratio due to reduce pitch size into 1 cm to improve secondary flow configuration.

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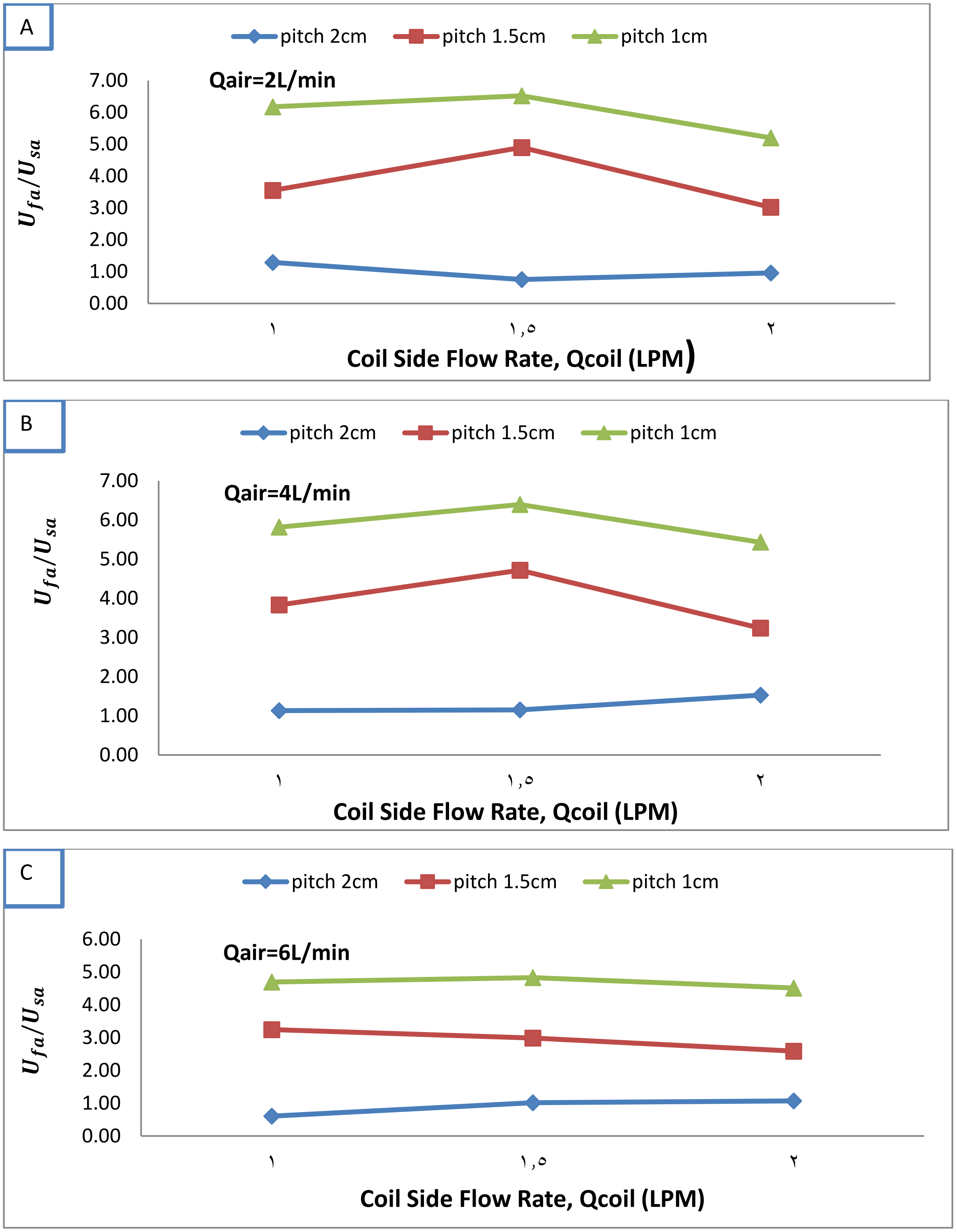

Fig.5: Variation of $\boldsymbol{U_{fa}/U_{sa}}$ with the coil flow rate for different air flow rates $(A)Q_{air} = 2,\ B)\ 4,\ C)\ 6\ l/min)$, three different pitch and constant shall (cold) flow rate ($Q_{cshell} = 10l/min$

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4. Conclusion

In this study, experiments were carried out with the effect of air injection to improve the thermal conductivity of a spiral pipe. In order to determine the optimal values of the injection air volume flow and the lateral volume flow for the overall heat transfer coefficient , various operating conditions were examined. The following conclusions can be drawn from the experimental results:

1- The overall heat transfer coefficient has been significantly improved by blowing in air in the form of small bubbles (in micrometres). It was found that the increase in the overall heat transfer coefficient increases with the speed of the injected air flow and the size of pitch for fin = 1 cm. It was also observed that the flow velocities on the shell and coil side had a positive value on the overall heat transfer coefficient, while no significant influence of the temperature differences was observed.

2- The effect of the air injection is clearer with a low flow rate on the shell side-

3- The intimate thermal mixing of the water jacket due to the air injection may be responsible for the significant improvement of the thermal efficiency of the heat exchanger.

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