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The Effect of Using Compound Techniques (Passive and Active) on the Double Pipe Heat Exchanger Performance

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Abstract

This experimental study explores the effect of using compound technique (passive techniques (packing the shell side with small cylindrical aluminium pieces) and active techniques (air injection or bubble generation) were securitized. It is conducted for both configurations (parallel and counter) flow with applying both techniques (compound) at the same conditions in a double pipe heat exchanger. The main objective of this study is to indicate the effect of employing the two techniques simultaneously and compare the outcomes without and with the passive (packing) method under the same conditions. The heat transfer of heat exchanger in terms of cost and size has been. For this purpose, the test rig is prepared by designing and making a suitable heat exchanger equipped with flow meters and thermocouples for measuring flow rates and temperatures (T_{in} and T_{out}) of both fluids (hot and cold). The hot fluid is heated in a small tank by electrical heater with temperature controller from (TEquipment). The results show that the performance parameters of the heat exchanger enhanced about (15%) for case of applying the both techniques together and (25) % for case of using active method only.

Keywords: Active techniques; Passive techniques, Heat Transfer Enhancement; Heat exchangers.

1. Introduction

The Numerous techniques of heat transfer via heat exchanger are utilized. These techniques can be categorized into three types: compound, active and passive techniques. In the compound method (techniques) two or more than one heat transfer enhancement techniques (active and/or passive) can be utilized synchronously in order to yield an enhancement that is higher than that obtained when utilizing the techniques disjointedly (reference).

In the passive techniques, this improvement of enhancement can be achieved without any extra flow energy. While in the active methods, the improvement can be obtained with adding flow energy. All the heat exchangers have been used and applied in a wide range of applications for heating or cooling fluids as an essential requirement of the industrial stages such as refinery of oil, medical, chemistry, power generation, I.C. engines and food industries. The heat can be transferred from one fluid (hot) to other fluid (cold) without mixing. The simplest and common type of this device is the double pipe heat exchanger which can be used by applying either parallel flow configuration or counter flow configuration.

Great efforts have been exerted by researchers and engineers to improve the performance and efficiency of heat exchanger with reducing size and costs. As mentioned above, there are different techniques have been used such as passive techniques (in which no external force was used such as nano-fluids [1,2],

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packing with materials [3], fines [4], propellers [5], helical coils [6] and internal springs [7]). Moreover, the active techniques (in which the external power was required) have been used such as bubbles generation [8,9], pipe rotation [10], electrodynamics and jet [11], spray, surface vibration and fluid vibration [12], bubble generation has a significant impact on the heat exchanger performance enhancement [13], Using Helical Coiled Wire Inserts [14].

The purpose behind of carrying out this research work is to show the effect of using both techniques concurrently and comparing the results with and without passive (packing) method at the same conditions. Due to the dearth in the literature related to this research and the importance of this device and wide use in applications this subject was selected as a research work and the experiments were performed in Kirkuk technical college laboratories in winter 2018.

2. Materials and Methods

2.1. Theoretical Analysis

The heat transfer rate can be calculated by using the following relations [15]:

$Q_h = \dot{m}_h CP_h (T_{hi} - T_{ho})$

or $Q_c = \dot{m}_c CP_c (T_{co} - T_{ci})$ (1)

and $Q_{ave} = (Q_h - Q_c)/2$ (2)

Where;

$\dot{m}_h$= mass flow rate of hot fluid

$\dot{m}_c$ = mass flow rate of hot fluid

Cp_h, Cp_c= specific heat of hot and cold fluids respectively.

and $T_{h,}$=hot fluid temperature

T_c = the cold fluid temperature.

The subscripts (i) and (o) represent the inlet and outlet hot and cold temperature respectively.

The overall heat transfer coefficient can be calculated experimentally from:[16]

$U_{exp} = Q_{ave}/A\Delta T_{LMTD}$ (3)

Where A is the surface area of the tube and for parallel flow

$\Delta T_{LMTD} = [(T_{h,out} - T_{c,out}) - (T_{h,in} - T_{c,in})] / [Ln(T_{h,out} - T_{c,out})/(T_{h,in} - T_{c,in})]$ (4)

for counter flow

$\Delta T_{LMTD} = [(T_{h,in} - T_{c,out}) - (T_{h,out} - T_{c,in})] / [Ln(T_{h,in} - T_{c,out})/(T_{h,out} - T_{c,in})]$ (5)

Effectiveness – NTU method is the versatile and powerful method for designing and analyzing the heat exchangers and can be calculated by: [15,16&17]

Effectiveness=ε= (actual heat transfer rate)/(max. possible heat transfer rate) (6)

and maximum possible heat transfer rate

$Q = (\dot{m}C)_{min} (T_{h,in} - T_{c,in})$ (7)

where $(\dot{m}C)_{min}$= the lesser value of $(\dot{m}_h Cp_h)$ or $(\dot{m}_c Cp_c)$

NTU= (number of transfer units) is indicative of the size of the heat exchanger and it is evaluated by:

$NTU = AU/(\dot{m}C)$ (8)

Where;

A is the heat transfer area (m^2) and U is the overall heat transfer coefficient ($W/m^2\,^\circ C$).

2.2. Experimental Procedure and Instrumentation

The first step of this research was to design and make a double pipe heat exchanger as demonstrated in Table1. (It shows the technical specification of the heat exchanger). The second step was preparing and selecting packing materials (Aluminum) which reveals the packing method (random). The test rig entails of a small boiler with a mass flow rate and temperature (hot fluid and cold fluid) indicators and controllers (the system that used in this work was from TEquepment), a thick layer of glass wool was utilized for insulating the shell (*outer tube*) to prevent and reduce the heat loss to the surrounding. The system was accomplished by providing and connecting an air compressor with air flow rate indicator and controller. The air is injected through a (5 mm) plastic tube with holes of (0.8mm) inside the shell (at the lower side in order to utilization of buoyancy force of bubbles formed inside the shell of the heat exchanger), along the tube as in figure 1. In all experiments performed in this work the hot water temperature and mass flow rate are kept constant at (61.1 ^oC) and (0.0233 kg/sec) respectively, while the cold-water mass flow rate is also kept equal to hot fluid mass flow rate (0.0233 kg/sec) during all steps of the experiments.

Fig. 1. Test rig

Table 1: Technical specification of the heat exchanger

Apparatus	Length
Heat Exchanger Length	60Cm
Shell Diameter (plastic)	14Cm
Tube Diameter (Cupper)	2.85Cm
Tube Thickness	0.0125Cm
Air Injection Tube (plastic) Diameter	0.5 Cm
Holes of Air Injection in plastic Tube	0.8mm

3. Results and discussion

Figure 2 denote the relationship between air injection rate and actual heat transfer rate in the double pipe heat exchanger for both configurations (counter flow and parallel flow). Each figure illustrates the heat exchange performance for both cases one without packing and the other with packing. It can be seen vividly that the actual heat transfer rate at zero injection rate of air is greater with packing case. As increasing the flow rate of air increases the actual heat transfer rate in both cases (with and without) packing. Additionally, the heat exchange is greater than case of using (packing with bubble generation) that in case of no packing (bubbling generation only). This is because the packing materials may reduce the effect of air bubbles to do this work efficiently (reduce the agitation and turbulence). As a final point both techniques (passive and active) increase the heat transfer rate about (15%) for packing case with air injection and (25 %) for air injection case with no packing.

Figure 4 exemplify the relationship between air injection rate and overall Heat Transfer Coefficient rate in the double pipe heat exchanger for both configurations (counter flow and parallel flow), each figure demonstrates the amount of enhancement in overall heat transfer coefficient for both cases, one without packing and the other with packing.

It is observed that the actual heat transfer rate at zero injection rate of air is greater with packing case while increasing the flow rate of air increases the actual heat transfer rate in both cases (with and without) packing, and in case of no packing (bubbling generation only) the heat exchange is greater than the case of using (packing with bubble generation) because the packing materials may decrease the effect of air bubbles to do his work efficiently (reduce the agitation and turbulence). Lastly both techniques (passive and active) upsurge the heat transfer rate about (15%) for packing case with air injection and (25 %) for air injection case with no packing.

Figure 5 represent the relationship between air injection rate and effectiveness of the double pipe heat exchanger (both configurations). It is perceived that increasing the injection rate of air increases the effectiveness about (18%) for the case in which the packing is presented and about (23%) for counter flow and (21%) for parallel flow in case of air injection only. It is also noticeable that in case of zero air injection the packing effect clearly enhanced the effectiveness parameter about (7%).

Figures 5 represent the relationship between air injection rate and Number of Transfer Unit (NTU) for the double pipe heat exchanger (both configurations). It is observed that increasing the air injection rate (active techniques) increases the NTU parameter for both cases and in case of using the two techniques (active and passive) together at the same time the parameter (NTU) records (9%) less than case in which active technique was used only. This phenomenon maybe due to obstruction or prevention of the bubbles by the packing materials which keep the bubbles away from reaching to the closer tubes layer which is the important layer for heat exchanging and converting the flow regimes from laminar to turbulent.

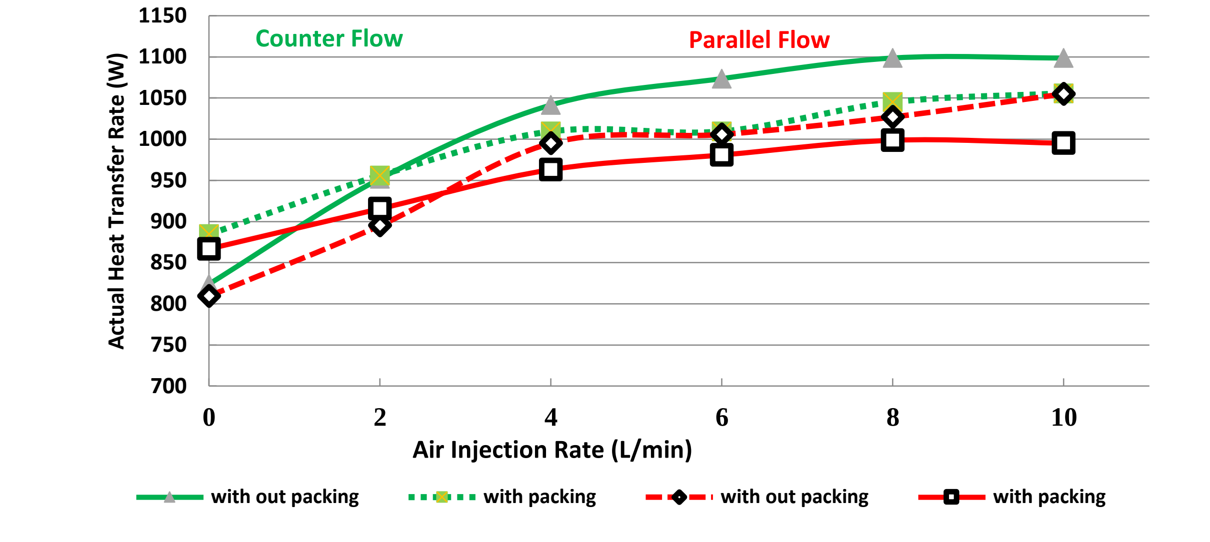

Fig. 2. The relationship between air flow rate and actual heat transfer rate

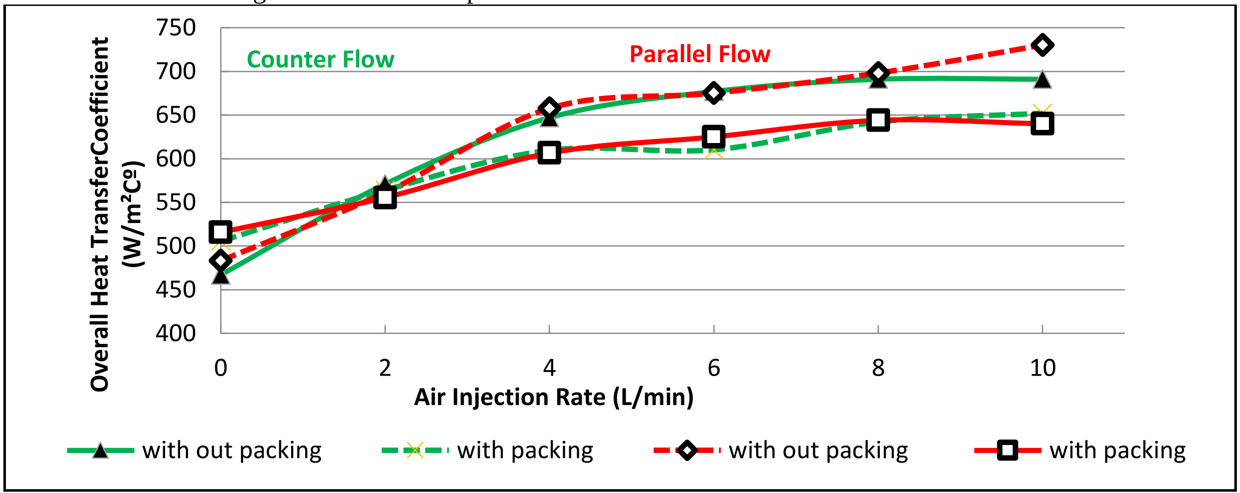

Fig. 3. The relationship between air flow rate and overall heat transfer coefficient

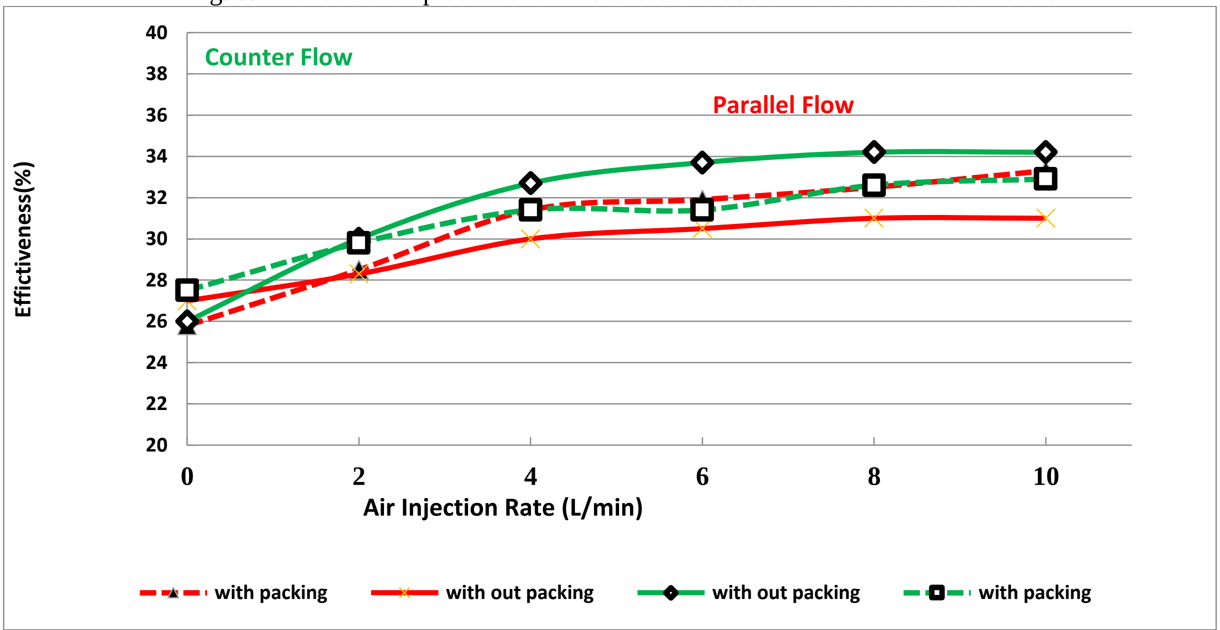

Fig. 4. The relationship between air flow rate and effectiveness

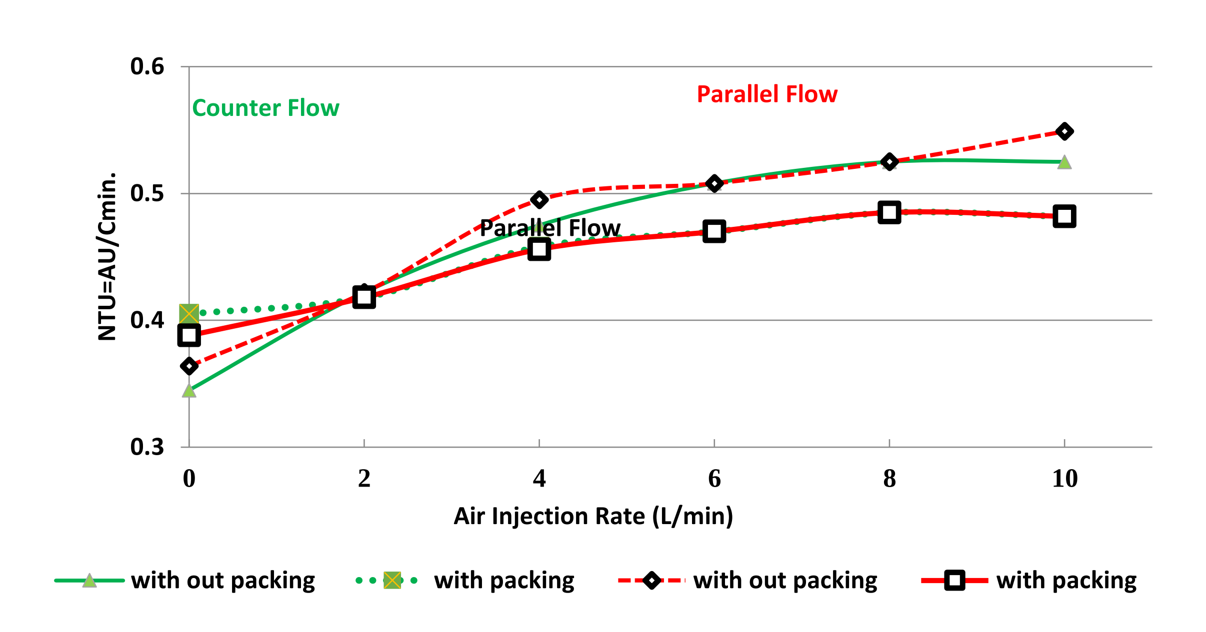

Fig. 5. The relationship between air flow rate and number of transfer units

4. Conclusion

The current experiment study discovered the effect of using compound technique (passive and active techniques) at the same conditions in a double pipe heat exchanger. The outcomes unveiled that the performance parameters of the heat exchanger enhanced about (15 %) for case of applying the both techniques concurrently and (25 %) for case of performing active method only. The main outcomes of the present study can be summed up as follows:

The active techniques require external power for operation and have power cost, using both techniques (active and passive) together may cause performance reducing. The improvement of the heat exchanger performance and bring this purpose into the perfect application is a timeline issue and need more research to be done. Enhancement of heat transfer is considerably observed for active techniques and the enhancement in active method is obviously greater than passive method but the power cost is also greater.

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