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The Experimental Investigation of Double Pipe Heat Exchangers Prepared from Two Techniques

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Abstract. Heat exchangers are the equipment used in variety of industries at all levels related to heat and thermal systems. Using heat exchangers at maximum efficiency are to reduce the amount of energy lost that impacts on environment and manufacturing cost in the industry. This research focused on comparing performances of two heat exchangers; two double-pipe heat exchangers were fabricated domestically with two different welding techniques (flare and Argon welding techniques). Both heat exchangers were tested on the same experimental setup and investigated for their thermal efficiency. Their working fluid was water, hot water and cold water flowed inside the heat exchangers were arranged as parallel (co-current) and counter flow configurations. Thermal efficiency when hot water and cold water flow rates varied in the range from 0.5 to 2 liters per minute, were also investigated. The results showed that the second heat exchanger fabricated with the Argon-welding technique showed the better thermal performance than that of the first heat exchanger fabricated with the flare technique. The thermal performances of the second heat exchanger were varied from 92% to 99% while the performances of another heat exchanger were varied from 32% to 38%. Therefore, the heat exchanger manufacturing played an important role to the heat exchanger performance. The same heat exchanger design but different fabricating technique caused lost in heat transfer process which affected the thermal performance and operating cost of the industry.

1. Introduction

The double pipe heat exchanger uses various inserts inside tube so as to enhance heat transfer and hence increase heat transfer coefficient [1]. These types of heat exchangers found their applications in heat recovery processes, air conditioning and refrigeration systems, chemical reactors, and food and dairy processes [2]. The double pipe heat exchanger would normally be used for many continuous systems having small to medium headuties. The heat exchanger is a device which transferred the heat from hot medium to cold medium without mixed both of medium since both mediums are separated with a solid wall generally. There are many types of heat exchanger that used based on the application. For example, double pipe heat exchanger is used in chemical process like condensing the vapors to the liquid. When to construct this type of heat exchanger, the size of material that want to uses must be considered since it affected the overall heat transfer coefficient. For this type of heat exchanger, the outlet temperature for both hot and cold fluids that produced is estimated by using the best design of this type of heat exchanger [3].



Prabhat et al. [4] studied on a performance evaluation of counter flow heat exchanger considering for low temperature application. He found those Counter flow heat exchangers are commonly used in cryogenic systems because of their high effectiveness. They observed that losses such longitudinal conduction through wall, heat in leak from surrounding, flow misdistribution etc. They extended their study to understand quantitative effect of heat in leak and axial conduction parameters on degradation of heat exchanger performance for 300-80,000 and 80-20,000 temperature range.

Swapnil et al. [5] has discussed about fabrication and analysis of counter flow helical coil heat exchanger. The heat transfer coefficient increases with increase in Reynolds number as Nusselt number increases. Greater will be the turbulence higher will be the heat exchange. As the Dean number is increasing with increase in Reynolds number so, the heat transfer rate will also increase with the Reynolds number.

Christian et al. [6] has discussed about experimental investigation on the effect of fluid flow rate on the performance of a parallel flow heat exchanger. The effect of fluid flow rate on the performance of parallel flow heat exchangers in an extended plate with regard to thermal efficiency, overall heat transfer coefficient, convective heat transfer coefficient, flow rate, and Reynolds number. Physical characteristics and thermal performance of a real heat exchanger were studied in this work. Also the convective heat transfer coefficient increases with both Reynolds and Nusselt numbers, which increases the overall heat transfer coefficient.

Tapre et al. [7] has discussed about Review on Heat Transfer in Spiral Heat Exchanger Energy saving is major matter in our global world, and heat exchanger is very useful for energy saving. Study on the various effects of feed flow rate and the coil diameter was done and concluded that on increasing the feed flow rate the pressure drop increases and vice versa. A relation between the pressure drop and the feed flow rate for the steady state Newtonian fluid into the Archimedean spiral tubes was developed.

Magadam et.al [8] has discussed about Review of Experimental analysis of parallel and counter flow heat exchanger. In this paper, we have discussed about various literature review of various paper and we are now going to calculate LMTD by varying flow rate and temperature of hot water and cold fluid.

Hoonpong and Skullong [9] experimentally studied on heat transfer and flow friction characteristics in a solar air heater duct roughened artificially with V-shaped baffles. The absorber plate is mounted with V-baffle vortex generators to improve the performance of the solar thermal system for energy saving. The experiment in the test duct having the aspect ratio (AR) of 10 is conducted for Reynolds number (Re) based on the hydraulic duct diameter ranging from 5300 to 22,600. In the current work, V-baffles are placed on the absorber with three relative baffle heights ($R_B = b/H = 0.1, 0.2$ and 0.3) and pitches ($R_P = P/H = 0.5, 1.0$ and 1.5) at a single attack angle (β) of 60° . The experimental results reveal that the use of V-baffle vortex generators yields the considerable increase in heat transfer over the smooth duct around 2.32–4.3 times while the friction loss increases around 4.08–36.9 times. The heat transfer and the friction loss tend to rise for increasing R_B but show the reversing trend for increasing R_P . The maximum thermal performance for the V-baffle vortex generators around 1.57 is seen at $R_B = 0.2$ and $R_P = 1.0$.

Chingtuaythong and Chokphoemphun [10] experimental and numerical investigation on thermal performance in a uniform wall heat-fluxed tube inserted with 45° inclined oval–pentagon rings (OPR) for turbulent flow region using air as the working fluid. The ring parameters included three blockage ratios ($R_B = e/D = 0.05, 0.10$ and 0.15) and four pitch ratios ($R_P = P/D = 1.0, 1.25, 1.5$ and 2.0) are introduced. The results from the inserted tube are compared with those from smooth tube alone and show that the OPR can augment the heat transfer rate and friction loss around 2.25–4.86 and 14–100 times over the smooth tube, respectively, depending upon operating conditions. The maximum thermal enhancement factor for using OPR tabulators at about 1.36 is for $Re = 3900$, $R_B = 0.05$ and $R_P = 1.0$. It is worth noting that the results of numerical study are in good agreement with the experimental ones. The average deviation of both results is within $\pm 7\%$ for Nusselt number and $\pm 10\%$ for friction factor.

In this work, we focused on the performance of heat exchangers; two double pipe heat exchanger were built domestically with two different welding techniques. Both heat exchangers were tested on the same experimental set and investigated thermal efficiency. The hot water and cold water flow inside the

heat exchangers were arranged as parallel and counter flow configurations. The effects of hot water and cold water flow rates; in the range of 0.5 to 2 liters per minute.

2. Experimental Setup

2.1 Double-pipe heat exchanger

A double-pipe heat exchanger is considered as the simplest type of heat exchangers. It consists of two concentric pipes having different diameters (Fig. 1). One fluid flows through the smaller pipe while another fluid flows through the annular space between both pipes. Two flow arrangements in any double pipe heat exchangers could be parallel flow (both hot and cold fluids move in the same direction, enter and exit the heat exchanger at the same side of the heat exchanger) and the counter flow (hot and cold fluids enter and exit the heat exchanger at the opposite ends and flow in the opposite directions). In this work, the double pipe heat exchanger dimensions were as 300 mm in length, the inside-pipe diameter of 3.9 mm, the outside-pipe diameter of 15.4 mm, and 5 mm in thickness. The cold fluid or cold water flowed through the inside pipe while the hot fluid or hot water flowed simultaneously through the annular space between both pipes.

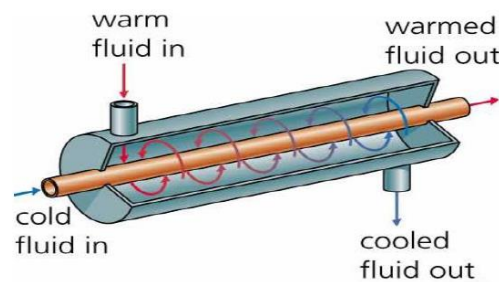


Figure 1. A double pipe heat exchanger [9].

The two double pipe heat exchanger were built domestically with two different welding techniques. Firstly, the flare technique was a process that is used to join metal with another metal by using electricity to create enough heat to melt metals. When the melted metals are cooled, their result is a binding of the metals. It is a type of welding that applies a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. We can apply alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, or slag (Fig. 2 (a)). Secondly, the argon-welding technique is a welding process that uses a non-consumable tungsten electrode to produce the weld (Fig. 2 (b)). The weld area and electrode are protected from oxidation or other atmospheric contamination by an inert gas (argon or helium).



(a) The flare technique



(b) The argon-welding technique

Figure 2. The heat exchanger fabricated with
(a) the flare technique and (b) the argon-welding technique.

2.2 Theoretical considerations

The Nusselt number is calculated as follows:

$$Nu = \frac{hD_h}{k} \quad (1)$$

Heat absorbed by hot fluid from the annulus, Q can be written by:

$$Q = \rho V A C_p (T_{out} - T_{in}) \quad (2)$$

The convection heat transfer coefficient of fluid respectively:

$$U = \frac{Q}{A_{in} \Delta T_{lm}} \quad (3)$$

Where A_i and ΔT_{lm} are heat transfer area and logarithmic mean temperature difference (LMTD).

The LMTD calculated from

$$\Delta T_{lm} = \frac{(T_{hot,in} - T_{cool,out}) - (T_{hot,out} - T_{cool,in})}{\ln[(T_{hot,in} - T_{cool,out}) - (T_{hot,out} - T_{cool,in})]} \quad (4)$$

3. Results and Discussion

The two double pipe heat exchangers were built domestically by two different welding techniques. From the fabrication results, we found splinters of the melted metal on the surface of the double pipe heat exchanger fabricated by the flare technique which implied that there were some metals were moved out of their positions. Additionally, we also found that there were leakages on this heat exchanger, as on Fig. 3, because of the flakes from the welding. While the surface of the heat exchanger fabricated by the argon-welding technique was smooth which implied that all metals were melted with each other regularly. We found that there was no leakage in this heat exchanger. Noticeably, the double pipe heat exchanger fabricated by the argon-welding technique contained the area around the joints of the copper pipe which was smoother than that of the flare technique.

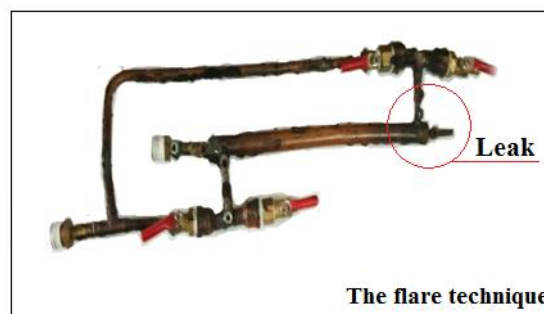


Figure 3. The fabrication result of the heat exchanger with the flare technique

Fig. 4 and 5 showed the variations of thermal effectiveness with different mass flow rates of the cold fluid for parallel and counter flows respectively. The plot clearly indicated that the effectiveness was increased with decreasing the cold-water mass flow rates for the counter flow (Fig. 4). While the plot in Fig. 5 clearly revealed that the effectiveness was decreased with increasing the cold-water mass flow rates for the counter flow. We noticed that the effectiveness of the counter flow heat exchanger was greater than that of the parallel flow heat exchanger.

Both heat exchangers were also investigated when the hot water and cold water flow rates; in the range of 0.5 to 2 liters per minute. The results showed that the second heat exchanger fabricated with the argon-welding technique showed the better thermal performance than that of the first heat exchanger fabricated with the flare technique. The thermal performances of the second heat exchanger were varied from 92% to 99% while the performances of another heat exchanger were varied from 32% to 38%. Therefore, the heat exchanger manufacturing played an important role to the heat exchanger performance. The same heat exchanger design but different fabricating technique caused lost in heat transfer process which affected the thermal performance and operating cost of the industry.

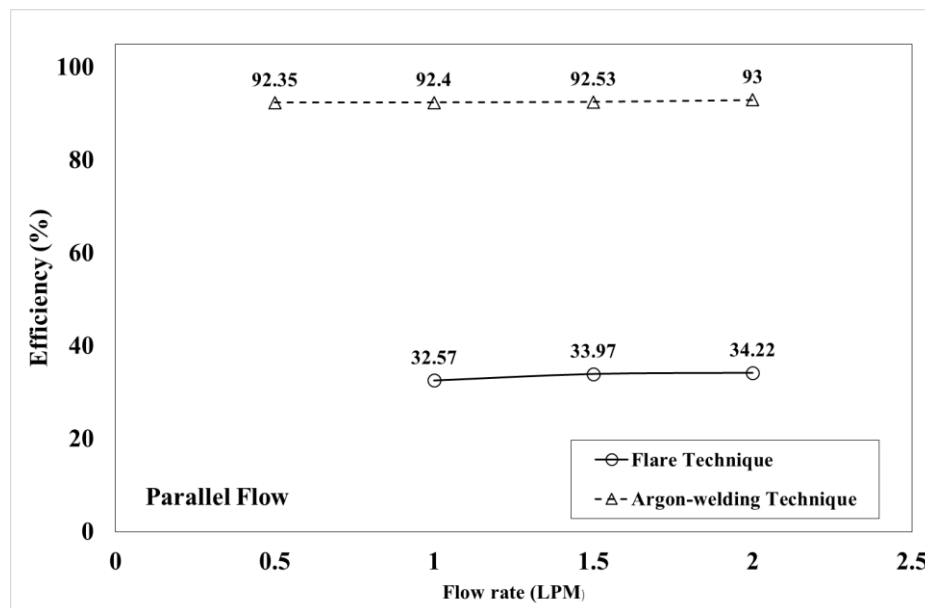


Figure 4. Efficiency of the heat exchangers were arranged as parallel flow configurations.

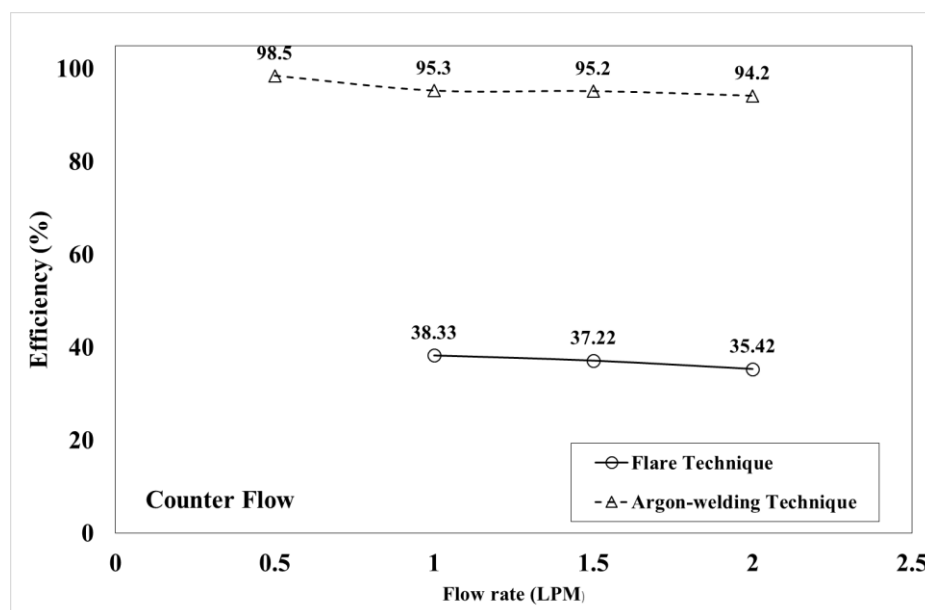


Figure 5. Efficiency of the heat exchangers were arranged as counter flow configurations.

4. Conclusions

This research focused on the performance of heat exchangers; two double pipe heat exchanger were built domestically with two different welding techniques. Both heat exchangers were tested on the same experimental set and investigated thermal efficiency. The hot water and cold water flow inside the heat exchangers were arranged as parallel and counter flow configurations. The effects of hot water and cold water flow rates; in the range of 0.5 to 2 liters per minute, were also investigated. The results showed that the second heat exchanger fabricated with the argon-welding technique showed the better thermal performance than that of the first heat exchanger fabricated with the flare technique. The thermal performances of the second heat exchanger were varied from 92% to 99% while the performances of

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