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Submission date: 03-May-2023 10:21AM (UTC+0700)

Submission ID: 2082697640

File name: 3._Sunu_2018_J._Phys._Conf._Ser._953_012064.pdf (416.99K)

Word count: 2375

Character count: 11994

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Experimental Studies on Grooved Double Pipe Heat Exchanger with Different Groove Space

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Abstract. Experimental studies were performed on grooved double pipe heat exchanger (DPHE) with different groove space. The objective of this work is to determine optimal heat transfer parameter especially logarithmic mean temperature difference (LMTD). The document in this paper also provides the total heat observed by the cold fluid. The rectangular grooves were incised on outer surface of tube side with circumferential pattern and two different grooves space, namely 1 mm and 2 mm. The distance between grooves and the grooves high were kept constant, 8 mm and 0.3 mm respectively. The tube diameter is 20 mm and its made of aluminium. The shell is made of acrylic which has 28 mm in diameter. Water is used as the working fluid. Using counter flow scheme, the cold fluid flows in the annulus room of DPHE. The volume flowrate of hot fluid remains constant at 15 lpm. The volume flowrate of cold fluid were varied from 11 lpm to 15 lpm. Based on logarithmic mean temperature difference analysis, the LMTD of 1 mm grooves space was higher compared to that of 2 mm grooves space. The smaller grooves space has more advantage since the recirculating region are increased which essentially cause larger heat transfer enhancement.

19

1. Introduction

A heat exchanger is device for heat transfer that exchange the heat at different temperature between two working fluid [1]. One of the modesly heat exchanger is double pipe heat exchanger (DPHE). This kind of heat exchanger has many advantages such as serviceable easily, wide range temperature and pressure application. The thermal performance of the double pipe heat exchanger is the temperature driving force which can be measured from the Logarithmic Mean Temperature Difference (LMTD). One of the main conditions which affect the thermal performance is fluid flow. Much researcher has been conduct to find ways the banefull effect of controlling fluid flows in the surface area toward the heat transfer. The problem of heat transfer through the boundary layer of the fluid detrimentally affect many field in engineering such as chemical, transportation, combustion, cooling system and many others field applications. Special attention has been given to small heat exchanger but efficient in heat transfer. There are active and passive methods which are developed to increase the heat transfer [2]. Active method use external power source to enhance the heat transfer like surface vibration, and makes it suitable for limited application. Especially in passive method, surface modification has been



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developed for increasing the heat transfer and pressure drop in turbulent flow regime. This method adopting surface techniques that induced vorticities at at the secondary flow region. Grooved heat exchanger would be the best candidate for these needed. Grooves increase the surface areas, easy to install, little in space and weight.

There are many efforts in flow and heat transfer improvement through the passive method for today's technology. [3-6] investigated grooved pipe flow characteristics and their correlation on pressure drop and friction factor. To prove the phenomena behind the flow, this study completed with the simple visualization analysis. The grooves eliminate the flow oscillation and prevented the horseshoes vortex formation [7]. In this condition, the grooves were able to stop the turbulence spot formation and lead to a decay of perturbation. Research has been done on various shape of groove in order to controlling fluid flow. [8] investigated using helically corrugated tube, [9] using spirally corrugate tube, [10] investigated periodical corrugated and found the friction factor increase with the increase of Reynold Number (Re) due to cavity shape. [11] investigated the application of nanofluid greatly enhance the transfer in the presence of helically corrugated tube.[12] studied rib roughened tube and found The maximum enhancement value of 2.73 for the Nusselt Number of $p/e = 10$.

Through the years, many of investigation has done into grooved fluid flow as well as their relationship to heat transfer characteristics. [1, 2] investigated the approach temperature of grooved double pipe heat exchanger and the influence of groove toward heat transfer enhancement. [13] investigated tube bank fin with variation in fin surface geometry. Found, at lower Reynold number the annular groove fin surface not efficiently enhance heat transfer. Heat transfer performance in square channel with cylindrical-shaped grooves is analyzed by [14]. They found, the heat transfer enhancement of the grooved surface affected by the velocity magnitude in near wall region. Turbulent flow characteristics and heat transfer performance in an internally grooved tube investigated by [15]. The objective of this study is to enhance heat transfer performance by generate longitudinal swirl flows with multi vortexes without pressure drop penalty and improves temperature and velocity field synergy. In the horizontal grooved pipe with water flow inside, [16] found the thermal enhancement about 1.4 - 2.2. An investigation on heat transfer in a square duct with quadruple counter-twist tape is conducted experimentally by [17]. These vortex generators combining give an effect to the heat transfer and pressure drop.

Based on previous research, this paper present a novel application of grooves in a double pipe heat exchanger with different grooves space. The objective of this work is to enhance heat transfer performance by generating swirl flow and vortex with grooves spacing. The temperature distribution of the grooved DPHE have been presented and analyzed. Thus, this study concentrated on observing heat transfer through the grooved annulus in double pipe heat exchanger.

2. Physical Groove Description

The geometric configuration of grooved tube of double pipe heat exchanger investigated in this study are presented in Figure 1.

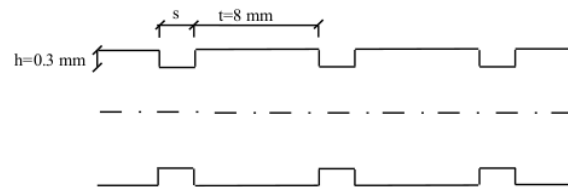


Figure 1. Schematic diagram of a tube with grooves

Groove with rectangular surface and circumferential pattern were arranged on outer surface of tube side or in the annulus room of the double pipe heat exchanger. The groove depth (h) was 0.3 mm, the

distance between groove (t) was 8 mm. The space of the groove (s) were 1 mm and 2 mm, respectively. The groove were formed by conventional etching technique. The tube diameter is 20 mm, made of aluminium. The shell diameter is 28 mm, and made of acrylic. Additional consideration concerning flow condition two extended tube with length 100 mm were connected upstream and downstream.

3. Experimental Apparatus And Method

The sketch of experimental apparatus of this study shown in figure 2.

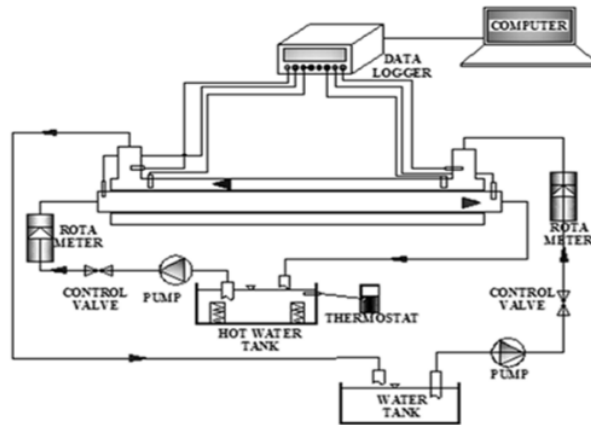


Figure 2. The schematic representation of the apparatus set-up

The double pipe heat exchanger using counter flow in flow direction so that the cold inlet side is in contact with outlet hot side and vice versa. The hot fluid flows inside the tube and the cold fluid flows outside the tube or in the annulus room of double pipe heat exchanger. Water use as a working fluid for both of hot fluid and cold fluid. The hot water temperature was 50 ± 0.5 °C and the cold water temperature was 30 ± 0.5 °C. The volume flowrate of hot fluid kept constant at 15 lpm that correlated with Reynold Number about 30904. Meanwhile the volume flowrate of cold fluid 11 lpm and it was increased up to 15 lpm which was correlated to Re about 31981 to 43610.

The length of heat exchanger test section was 500 mm. The double pipe heat exchanger were equipped with k-type thermocouple at each of fluid inlet and outlet section for temperature measurement. Thermocouples were connected to a data logger for digitalized and recorded for 600s in computer memory.

4. Result and Discussion

First step, the data temperature collected from smooth/no groove of double pipe heat exchanger. The time series data were processing to find the Logarithmic Mean Temperature Different (LMTD). All of the data were then used as a comparison to that of the grooved DPHE. Two different groove space 1 mm and 2 mm, respectively, were compared to find the most effective heat transfer parameter. Figure 3 shows the LMTD of the heat exchanger system. LMTD is the suitable form of the average temperature difference between the two working fluid and used to determining the rate of heat transfer in a heat exchanger. It is found that the LMTD increase with the increased of Reynold number. All of the grooved double pipe heat exchanger have LMTD value higher than those of the smooth DPHE. In grooved DPHE, 1 mm groove space DPHE have LMTD higher than those of 2 mm. At comparable Reynold number, the LMTD in a 1 mm groove space were enhanced about 0.04% to 1.8% compared to those of 2 mm groove space. From the fluid dynamics perspective, the narrowest gap may promote

reversed flow and thus be able to increase flow separation. This phenomenon is the driving force for increasing the LMTD.

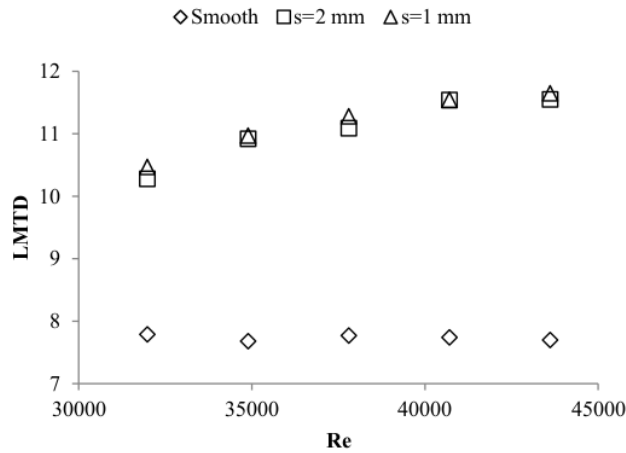


Figure 3. The LMTD variation with Reynolds Number

Figure 4 shows the total heat transfer by the cold fluid for a period of time. The heat transfer increased with the increased of Reynolds number (Re). The heat transfer by the grooved DPHE gave higher value than that of the smooth DPHE. In 1 mm groove space have higher heat transfer compare to that of 2 mm groove space about 0.7% – 3.6%. The increase of flow separation was responsible for this phenomena. Flow separation, increase the mixing process in the annulus room. This phenomenon was reduce the thermal boundary layer near the tube so that increase the heat transfer.

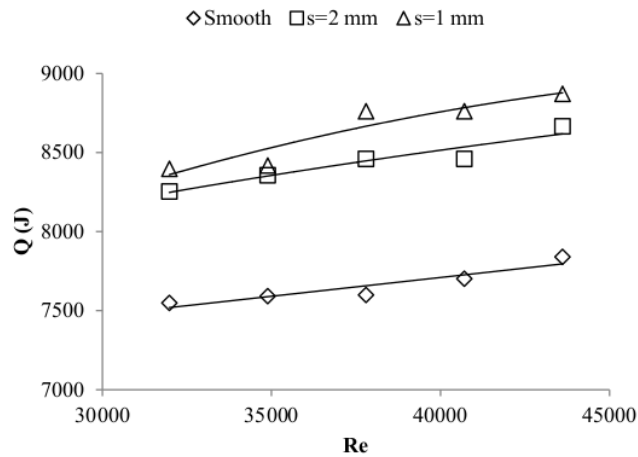


Figure 4. Heat transfer through the cold fluid

5. Conclusions

An experimental studies on grooved double pipe heat exchanger with different groove space was carried out for LMTD analysis for describing the heat transfer characteristics. The result can be summarized as,

- a) The LMTD in 1 mm groove space increased about 0.04% to 1.8% compared to those of 2 mm groove space.
- b) 1 mm groove space have higher heat transfer compare to that of 2 mm groove space about 0.7% – 3.6%

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PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6
