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Performance assessment on double pipe heat exchanger with longitudinal groove

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Abstract. Thermal performances were performed as preliminary research on double pipe heat exchanger with low number of longitudinal groove. The objective of this work is to determine optimal heat transfer parameter especially logarithmic temperature difference (LMTD) as a time series function. The thermal analysis in this paper also provide total number of heat absorb in the cold fluid. The rectangular-longitudinal grooves were incised on outer surface of tube side with number of longitudinal grooves of 2. The grooves high and width were kept constant at 0.3 mm and 1 mm respectively. The tube made of aluminium with outer diameter is 20 mm. The shell is made of acrylic which has 26 mm in internal diameter. Water is used as the working fluid with counter flow scheme. The volume flowrate of cold fluid was varied from $18 \times 10^{-5} \text{ m}^3/\text{s}$ up to $25 \times 10^{-5} \text{ m}^3/\text{s}$ which are equal to Reynold number (Re) around 31981 to 43610. The volume flowrate of hot fluid remains constant at $25 \times 10^{-5} \text{ m}^3/\text{s}$ which is equal to (Re) around 30904. The LMTD of 2 grooves double pipe heat exchanger was better compared to that of the smooth one since the thermal sectional area are increased which essentially cause larger heat transfer.

1. Introduction

Turbulent flow over a rough surface has been a major interest topic in field of fluid mechanics and heat transfer for this recent years. Heat exchanger is a engineering equipment that integrates both field. Heat exchangers are engineering equipment that integrates and applicates both topics with the concept of maximizing heat transfer and minimizing pressure losses between two working fluid that have temperature diffrence [1]. To maximixing the heat transfer process, the force convection n¹⁸ employed inside the heat exchanger system. The use of turbulence promoters is common technique to increase the rate of heat transfer [2]. This surface engineering technique for improving the heat exchanger thermal performance is to increase the periodic disturbance along the streamwise direction by rough surface and extended surface area such as rib, groove, fin etc [3-5]. The incised groove and the groove pattern might lead to the enhancement of flow mixing and interruptions the thermal boundary layer with some compensation on pressure drop [6-8]. Enhancing the thermal performance of a heat exchanger makes



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great interest of researcher since it can enhance transfer energy, material application, cost saving, and the weight of heat exchanger itself. There are many kind of heat exchanger that applied in industrial application. Double pipe heat exchanger (DPHE) is the modest heat exchange equipment. This kind of heat exchanger has wide application for pressure ranges and have many others advantages such as wide of temperature operation and easily to service.

The heat exchanger proposed in this investigation is longitudinal-grooved double pipe heat exchanger. There are many progresses on research in fluid and heat correlation and development through the passive technique enhancement scheme. Sunu *et al.* investigated grooved pipe through the correlation on pressure drop and reveal the friction of system [1], [6-8]. The grooves installation inside the fluid system, reduce the flow oscillation and prohibited the development of horseshoes vortex [11]. In this situation, the grooves valley was capable to prevent the turbulence formation. Research on various shape grooves has been done in order to monitoring fluid flow [1], [5-8]. Investigated corrugated tube with helical shape [12], using corrugate tube with spiral form [13], investigated periodically corrugated [14].

Due to the widespread use of double pipe heat exchanger, their efficient design and optimization have been analyzed from some parameters, such as logarithmic mean temperature difference (LMTD). The thermal performance and the thermal driving force of the double pipe heat can be measured from the LMTD value [9,10]. The relationships between the effectiveness of heat exchanger system and the thermal resistance are developed by [15]. Exergetic analysis that focuses on an investigation using exergy transfer effectiveness method for an isolated heat exchanger by Wu *et al.* [16]. San *et al.* optimize the waste heat recovery exchanger using Second-law [17]. In this few recent years, many research has done to observed the effect of grooved on fluid flow as well as their relationship to enhance the heat transfer. Sunu *et al.* explored the temperature approach of grooved heat exchanger and their influences toward the friction and heat transfer parameter [5, 6]. Zhi *et al.* considered a sequence of tube fin with various fin surface geometry [18]. At low Re, the annulus groove fin surface was not efficient for enhance the heat transfer. Heat transfer parameters in square channel equipped by cylindrical-shaped grooves is investigated by Liu *et al.* [19].

The objectives of this study were design, build, and instrument the grooved double pipe heat exchangers, the grooves incised in annulus longitudinally; experimentally evaluate the LMTD characteristics of a double pipe heat exchangers for counterflow configurations; compare the experimental results between groove and smooth of double pipe heat exchangers.

Based on previous computation and experimental research above, this paper presents an original analysis of longitudinal grooves application in a double pipe heat exchanger with two number of groove under various volume flowrate based on the time series of temperature distribution of LMTD.

2. Research setup

The sketch of dimensions parameters of longitudinal-grooved in this experiment are described in Figure 1.

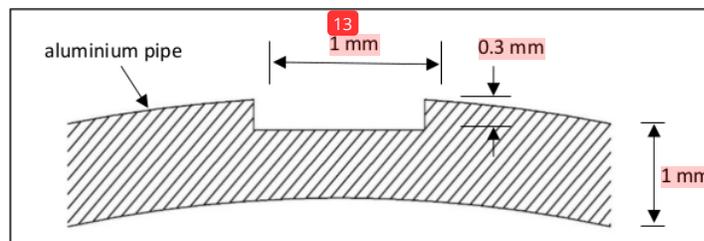


Figure 1. Physical dimension of grooves.

Grooves with rectangular cross sectional and longitudinal design were incised on the outer surface of aluminium tube which placed in the annulus of DPHE. The groove depth (h) and groove width (s) were 0.3 mm and 1 mm respectively. The total number of the grooves (n) was 2. The groove was made by traditional milling machine. The aluminium tube diameter is 19.8 mm. Meanwhile the acrylic shell diameter is 27.5 mm.

The sketch of heat exchanger apparatus investigation shown in Figure 2.

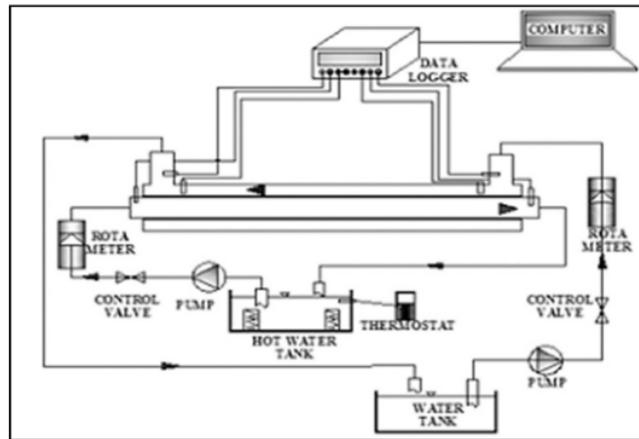


Figure 2. The experiment set-up

For the LMTD analysis, the heat transfer equation can be arranged as:

$$\dot{Q} = UA\Delta T_{LM} \quad (1)$$

where U is the overall heat transfer coefficient; A is the surface area for heat transfer; ΔT_{LM} is log-mean temperature difference inside the heat exchanger. For single-pass heat exchangers:

$$\Delta T_{LM} = \frac{\Delta T_i - \Delta T_o}{\ln(\Delta T_i / \Delta T_o)} \quad (2)$$

where ΔT_i and ΔT_o are the temperature differences between two fluids at inlet and outlet of each working fluid in the heat exchanger. For intricate flow arrangements, such as multi pass of fluid flow inside heat exchangers, the LMTD method can be extended to by introduction the correction factor. In this investigation the series of LMTD value calculated from temperature data.

This experiment using counter flow scheme. The cold fluid flows inside the annulus of heat exchanger and the hot fluid flows inside the aluminum tube. The working fluid is water for both hot and cold respectively. The hot water temperature was 50 ± 0.5 °C and the cold water temperature was 30 ± 0.5 °C. The flowrate of hot fluid constant at 25×10^{-5} m³/s with Reynold Number about 31000. Meanwhile the flowrate of cold fluid 18×10^{-5} m³/s up to 25×10^{-5} m³/s and converted to Re of smooth pipe about 33000 to 46000. The test section length was 0.5 m which equipped with four k-type thermocouples for temperature instrumentation and taken for 600 s.

3. Results and discussion

The first step, data temperature collected from smooth of double pipe heat exchanger. The time series data were processing using Equation (2) to find the logarithmic mean temperature different (LMTD). The calculation results were then used as a comparison to that of the longitudinal-grooved of double pipe heat exchanger.

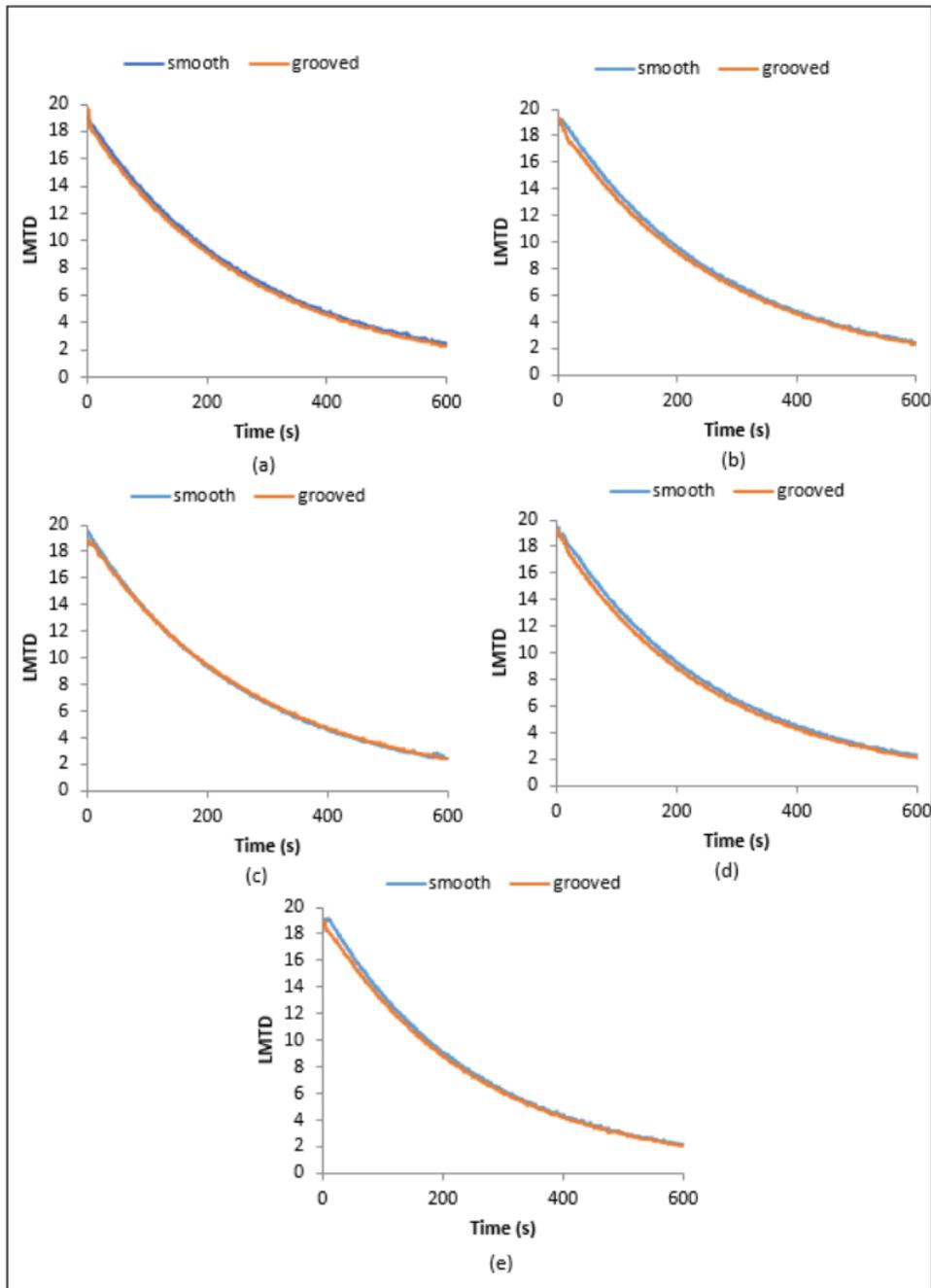


Figure 3. The time series of LMTD of DPHE on various Reynold Number: (a) Re = 31981; (b) Re = 34888; (c) Re = 37796; (d) Re = 40703; (e) Re = 43610

The time series LMTD shows in the Figure 3. LMTD method is the useful method of findings the time series average temperature difference between the hot and cold fluid. Also determining the rate of heat transfer inside a heat exchanger. As presented in Figure 3, the LMTD line approach and asymptotic to the x axis. The LMTD of heat exchanger tend to be increase with the increased of Re of cold fluid. The grooved annulus has time series LMTD value lower than the smooth one for all volume flowrate.

From the real temperature perspective, the temperature line that getting closer to the x axis mean the outlet hot fluid temperature lower and the outlet cold fluid temperature higher. The maximum LMTD of grooved heat exchanger was better until 10.76 % compare that of smooth one. This experiment data were the preliminary data of a project in heat transfer for double pipe heat exchanger incised with grooves. In this article, we endorse that the longitudinal-groove along the outer side of tube causing the approach temperature smaller.

4. Conclusions

An investigation through experimental method on double pipe heat exchanger with number of longitudinal-grooved 2 was implemented for time series LMTD analysis. Aims of this study was revealed preliminary heat transfer characteristics. It can be concluded that the longitudinal-grooved double pipe heat exchanger has better slight of time series LMTD value until 10.76%. The longitudinal-groove along the outer side of tube causing the real outlet temperature better compare to that of smooth tube.

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