RESEARCH ARTICLE

Advanced Science Letters
Vol. 23, 12094–12097, 2017

Approach Temperature of Heating Process in Double Tube Heat Exchanger with Al_2O_3-Water Nanofluid

Daud Simon Anakottapary, Ahmad Wibolo, Putu Wijaya Sunu*, and I. Made Rajendra

Mechanical Engineering Department, Politeknik Negeri Bali, Jalan Kampus Bukit Jimbaran, Kuta Selatan, Badung 80364, Bali, Indonesia

The approach temperature of heating process in double tube heat exchanger with Al_2O_3-water nanofluid under turbulent flow regime have been studied. This investigation were made on the effect of 0.1% volume concentration of nanoparticles on the approach temperature decreases. In this study, the tube outside diameter is 20 mm which is made of aluminium and the shell inside diameter is 28 mm which is made of acrylic. The parallel flow used as flow pattern and Reynold Number (Re) in the annulus room were varied from 31981 to 43601 and in tube side were maintain constant at 30904. The temperature of Al_2O_3-water nanofluid (hot stream) on inlet terminals are remain constant at 45 ± 0.2 °C. Meanwhile the temperature of water cold stream 30 ± 0.5 °C. Temperature measurement conducted on each terminal of inlet and outlet heat exchanger. The experiment shows that nanoparticles induced the approach temperature. The change of approach temperature on various Re number from the Al_2O_3-water nanofluid compared to that of without Al_2O_3-water nanofluid decreased by 2.78% to 5.71%. This phenomenon indicates an increases of heat transfer process inside heat exchanger. The application of nanofluid particles enhanced the convective heat transfer passively.

Keywords: Annulus, Nanofluid, Alumina, Heat Exchanger.

1. INTRODUCTION

Thermal management of engineering system has become an interesting contemporary topics in academic and industrial society. The needs of high heat flux devices have developed in a few past decades. Many applications such as electronics, nuclear power plan, pharmaceutical process, bio technology etc. need thermal management to stretch the engineering thermal load. Various method has been done to enhance the heat transfer. Passive technique become more popular because no energy input in their application. Grooves are one of the passive methods to increase the heat surface area and very potential to improve heat transfer.[1–4]

Another way of passive technique is increasing thermal conductivity. The poor fluid thermal conductivity acts as a main obstacle to increases the energy efficiency of heat exchangers. In recent years nanofluids have been introduced as ideal candidate for enhancing thermal conductivity. The nanofluid defined as a colloidal solvent containing dispersed nanometer (1–100 nm) sized particles.[5] Oil, water etc. used as the base heat transfer fluid. Many scientists have been investigating the properties of nanofluid and it is expected to become the future generation of heat transfer technology. The investigation observing the properties of Alumina (Al_2O_3) nanofluid has been done by Ref. [6]. The addition of 0.1% concentration will raise the pH from neutral to acid (6.5 to 5) and the viscosity of nanofluid decreased with increasing sonicating time[7,8] investigated experimentally the convective heat transfer coefficient and flow characteristics for Cu-water nanofluid. The result showed that the addition of nanoparticle enhanced the heat transfer and calculate a correlation of convective heat transfer[9] investigated the thermophysical properties on heat transfer coefficient for low concentration nanofluid. The result shows that for the various thermophysical models have no significant effect on Nusselt Number (Nu).

Capability of nanofluid in heat transfer enhancement has prompted researcher to develop their concept[10] investigated the heat transfer enhancement of 1–4% of CuO, TiO_2 and Al_2O_3. The result shows heat transfer rates increase with an increase of nanofluid concentration[11] studied heat transfer of Al_2O_3-water nanofluid in developing region of pipe flow with two particle size (45 nm and 150 nm). It was observed that the nanofluid with 45 nm particle size show higher heat transfer[12,13] investigated heat transfer enhancement of Al_2O_3-water. Heat transfer of nanofluid under turbulent flow regime through groove channel[14] studied using a numerical method. Found nanofluid is

*Author to whom correspondence should be addressed.

 1936-6612/2017/23/12094/004 doi:10.1166/asl.2017.10580

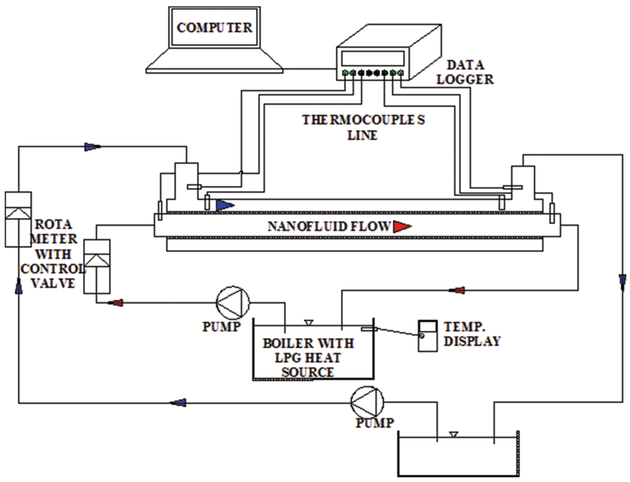

Fig. 1. Experiment apparatus set-up.

good candidate to increase heat transfer. Mostly from the references above the heat transfer enhancement were measured from Nusselt number. This experiment introduced a simply method to show the heat transfer enhancement using temperature approach of the heat exchanger.

2. EXPERIMENTAL METHOD

The sketch of the experimental apparatus for this investigation is shown in Figure 1. This investigation used parallel flow in horizontal double tube heat exchanger (DTHE). This experimental set-up consist a boiler system to maintain nanofluid temperature; two centrifugal pump (9 m head); two rotameter (0–18 lpm) with control valve to measure the flowrate; 4 thermocouples *k* type for temperature measurement. A boiler system using LPG heat source heating the nanofluid (Al_2O_3-water) and maintain at constant temperature 45 °C inside aluminium storage tank. The fluid flow through a PVC tube by centrifugal pump from the boiler/water tank to the test section at range 11–15 lpm. The total fluid inside the system is 6 l, with single nanoparticles volume concentration 0.1%. Four *k* type thermocouples placed at inlet and outlet terminal of DTHE to measure temperature accurately. A data logger digitalized signal from thermocouples before being recorded in computer. Nanofluid was prepared using mechanical mixer (magnetic stirrer) for dispersing nanoparticles.

The test section made from smooth aluminium tube with 20 mm outer diameter 50 cm long while the outer tube made from acrylic with 28 mm in diameter. The nanofluid flowing inside the inner tube meanwhile coldwater flows through the annulus room. The Reynold number (Re) of the cold fluid flows through the annulus space investigated were 31981, 34888, 37796, 40703, 43610 respectively. The hot nanofluid flowing inside the inner tube with constant at Re = 30904. For calculating the % approach temperature of nanofluid compared to that of pure water using the equation bellow:

$$\%T_{\text{app}} = \frac{\Delta T_{\text{without nanofluid}} - \Delta T_{\text{nanofluid}}}{\Delta T_{\text{wthout nanofluid}}} \times 100\% \qquad (1)$$

3. RESULTS AND DISCUSSION

Approach temperature on parallel flow of double tube heat exchanger (DTHE) refered to the outlet temperature difference of hot and cold fluid as shown in Figure 2. Figure 2 describe the temperature profile in heating process of the cold fluid. The red line denotes the hot fluid which has constant temperature at 45 °C. And the other line denote the temperature profile of each specified Re.

Figure 2 shown, that the increase of Re correlated with the increase of temperature of heating process. The higher Re, the higher momentum and heat transfer through the interchange of the fluid particle. So that the cold fluid with the highest Re (43610) has the highest temperature increase on heating process.

The nanoparticles inside nanofluids act as heat carrier between solid wall and the fluid itself. Interaction of nanoparticles and wall play an important role in convective heat transfer.

The blue line with rectangular pointed denotes the approach temperature of water without nanoparticles. Meanwhile the red rhomb pointed represented the approach temperature of Al_2O_3-water nanofluid. In each part of Figure 3, the solid line indicates the polynomial approach of the approach temperature. From Figure 3, it is found that for both water and Al_2O_3-water the decreased of approach temperature following polynomial line. At the begining of the experiment, the polynomial line has high slope. This phenomenon signifies a major change in the approach temperature. With increasing time, the line slope

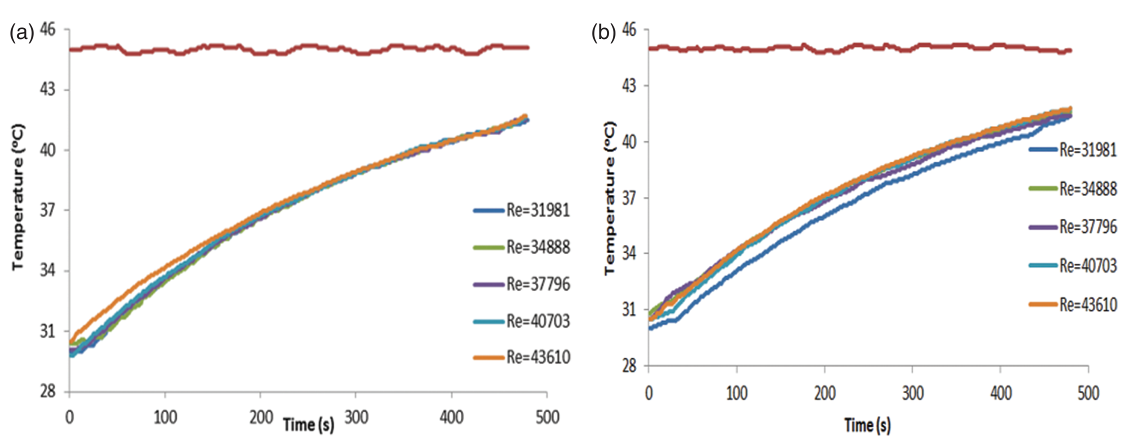

Fig. 2. Temperature profile of heating process. (a) Without nanoparticle; (b) With nanoparticle.

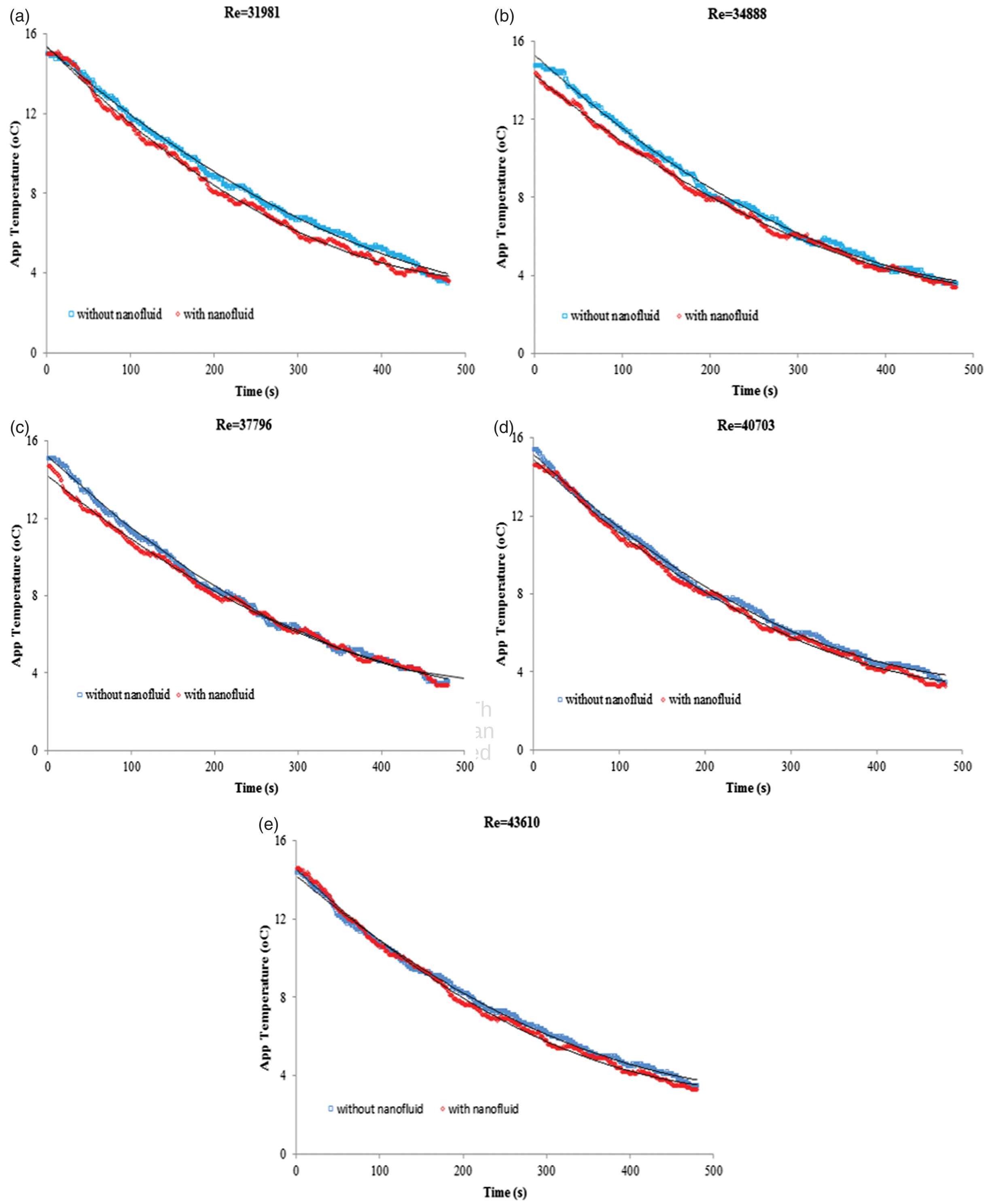

Fig. 3. Real time approach temperature on various Re.

down slowly. This indicates decreases of heat transfer. If we compared between water and Al_2O_3-water nanofluid of all Reynold number, the approach temperature Al_2O_3-water nanofluid line slightly below the pure water line. This circumstance illustrates that nanofluid improve heat transfer. The reason of increasing heat transfer of nanofluid is the increasing of thermal conductivity.

The average value of approach temperature at different Reynold number (Re) is shown in Figure 4. The percentage value shown the estimation of approach temperature decreases in DTHE according to Eq. (1). It appears that the approach temperature of double tube heat exchanger decreases with increasing in Reynold number. The decreases of approach temperature reffered the increases of heat transfer from the tube.

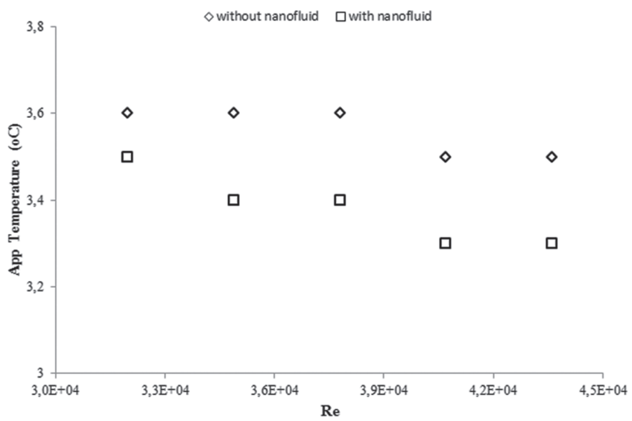

Fig. 4. Overall average approach temperature of the heating process.

4. CONCLUSIONS

The approach temperature of horizontal double tube heat exchanger with nanofluid has been experimentally investigated. The effect of Reynold number of cold fluid flowing inside annulus room has been determined and summarized as following:

(1) the approach temperature of double tube heat exchanger decreases with increasing in Reynold number;

(2) From Reynold number, the approach temperature Al_2O_3-water slightly below the pure water line about 2.78%–5.71%.

References and Notes

1. P. W. Sunu, I. N. G. Wardana, A. A.Sonief, and N. Hamidi, *Adv. Studies Theor. Phys.* 8, 643 **(2014)**.
2. P. W. Sunu, *Adv. Studies Theor. Phys.* 9, 57 **(2015)**.
3. P. W. Sunu, I. N. G. Wardana, A. A.Sonief, and N. Hamidi, *Int. J. Fluid Mech. Resch.* 42, 119 **(2015)**.
4. P. W. Sunu, D. S. Anakottapary, and W. G. Santika, Temperature approach optimization in the double pipe heat exchanger with groove, *Matec Web of Conference* **(2016)**, Vol. 58, pp. 04006.
5. S. Lee, S. U. S. Choi, S. Li, and J. A. Eastman, *Journal of Heat Transfer* 121, 280 **(1999)**.
6. M. Jeyakumar, O. Ahmed, S. Shankar, and M. Hamed, Heat transfer coefficient and viscosity of alumina-water Nanofluids, *8th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics* June–July **(2011)**.
7. Q. Li and Y. Xuan, *Science in China (Series E)* 45, 408 **(2002)**.
8. Q. Li and Y. Xuan, *ASME Journal of Heat Transfer* 125 **(2003)**.
9. W. Duangthongsuk and S. Wongwises, *International Communications in Heat and Mass Transfer* 35, 1320 **(2008)**.
10. M. K. Abdolbaqi, C. S. N. Azwadi, and R. Mamat, *Case Studies in Thermal Engineering* 3, 59 **(2014)**.
11. K. Anoop, T. Sundararajan, and S. K. Das, *Int. J. of Heat and Mass Transfer* 52, 2189 **(2009)**.
12. N. Bozorgan and M. Mafi, *Adv. Mech. Eng.* 1 **(2012)**.
13. O. S. Prajapati, *Int. J. Nanosci.* 1, 1 **(2012)**.
14. A. N. Al-Shamani, K. Sopian, H. A. Mohammed, M. Sohif, M. H. Ruslan, and M. A. Azher, *Case Studies in Thermal Engineering* 5, 48 **(2015)**.

Received: 30 August 2016. Accepted: 30 May 2017.