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An Experimenatl Study on Heat Transfer Behaviors of A Welded - Aluminum Minichannel Heat Exchanger

Thanhtrung Dang[1], Thanhnghia Nguyen[2] and Tronghieu Nguyen[1]
[1]Ho Chi Minh University of Technology and Education, Vietnam
[2]Quy Nhon Vocational College, Vietnam

ABSTRACT:

This paper presented an investigation for heat transfer behaviors of a welded-Aluminum minichannel heat exchanger (MNHE) using experimental method. In this study, the results show that the welding Aluminum method for MNHE is less efficiency than the bonding PMMA method at high mass flow rate of water. For water having the inlet temperature of 62 ℃ and mass flow rate of 4.1g/s, the heat transfer rate of the welded- Aluminum MNHE is 118W and the heat transfer rate of the bonded-PMMA MNHE is 132W. It is an important key to select a method for design a minichannel heat exchanger.

KEYWORDS: *Temperature, heat transfer, heat exchanger, minichannel, experimental.*

I. INTRODUCTION

Enhancing heat transfer efficiency and decreasing size are attractive investigations. Regarding to these fields, Dixit and Ghosh [1] studied the effect of heat in-leak for two stream cross flow minichannel heat exchangers with unmixed fluids. The analytical results have been used for predicting the outlet fluid temperatures. With experimental data, one of the end plates in a crossflow-type multistream, minichannel heat exchanger has been subjected to deliberate external heat input given electrically. Experimental result obtained is employed to validate the fluid exit temperatures predicted by the developed model under the same conditions of external heat ingress. The variation in the exit fluid temperatures has been recorded as a function of this external heat in-leak entering the exchanger through one of its outer surfaces. Ray et al. [2] investigated nanofluids performance in a compact minichannel plate heat exchanger. Three nanofluids (comprising of aluminum oxide, copper oxide and silicon dioxide nanoparticles in ethylene glycol and water mixture) have been studied theoretically to compare their performance in a compact minichannel plate heat exchanger. Comparisons have been made on the basis of three important parameters; equal mass flow rate, equal heat transfer rate and equal pumping power. The results show that for a dilute particle volumetric concentration of 1%, all the nanofluids show improvements in their performance over the base fluid. From experiments on a 0.5% aluminum oxide nanofluid, preliminary correlations for the Nusselt number and the friction factor for nanofluid flow in a plate heat exchanger has been derived. This apparatus will be useful to test different kinds of nanofluids. Effect of inlet configuration on the refrigerant distribution in a parallel flow minichannel heat exchanger was studied by Kim et al. [3]. The refrigerant R-134a flow distribution was experimentally investigated for a round header/ten flat tube test section simulating a brazed aluminum heat exchanger. Three different inlet configurations (parallel, normal, vertical) were studied. It is shown that normal and vertical inlet yielded similar flow distribution. The flow distribution was the worst for the parallel inlet configuration. Dixit and Ghosh [4] reviewed micro- and mini-channel heat sinks and heat exchangers for single phase fluids. Miniature heat exchangers have the potential to provide energy efficient systems. In addition, their characteristics of compactness, small size and lesser weight have attracted widespread applications. Literatures related co-current, counter-current and cross-current micro- and mini-channel heat exchangers have been discussed. Sohel et al. [5] studied heat transfer enhancement of a minichannel heat sink using Al_2O_3–H_2O nanofluid. The thermal performances of a minichannel heat sink are experimentally investigated for cooling of electronics using nanofluid coolant instead of pure water. The Al_2O_3–H_2O nanofluid including the volume fraction ranging from 0.10 to 0.25 vol.% was used as a coolant. The experimental results showed the higher (up to 18%) improvement of the thermal performances using nanofluid instead of pure distilled water. Peyghambarzadeh et al. [6] experimentally studied overall heat transfer coefficient in the application of dilute nanofluids in the car radiator. Nanofluids showed greater heat transfer performance comparing with water. Increasing liquid and air Re increases the overall heat transfer coefficient. Increasing the inlet liquid temperature decreases the overall heat transfer coefficient. Nieh et al. [7] employed oxide nano-coolant in air-cooled radiator for heat dissipation.

They produced the Al_2O_3 and TiO_2 nano-coolant by the two-step synthesis method. The heat dissipation capacity and the efficiency factor of the nano-coolant are higher than ethylene glycol. The results showed that the enhanced ratio of the pressure drop and pumping power is not obvious. Dang et al. [8, 9] studied the minichannel heat exchangers to replace for a scooter radiator using experimental method. The results of this study show that minichannel heat exchangers have higher heat transfer rate than that obtained from scooter radiator, but the size of minichannel heat exchangers is about 64% (with three passes) and about 55.7% (with five passes) the size of scooter radiator. However, in [1-7], authors did not study effect of pass number of the heat exchangers on heat transfer behaviors; in [8,9], authors did not use heat exchangers with welding Aluminum instead of bonding PMMA (Polymethymethacrylate) on minichannels. From the relevant literatures above, it is important to study a minichannel heat exchanger with welding Aluminum on minichannels. In the following section, the heat transfer characteristics of the welded Aluminum minichannel heat exchanger (MNHE) will be compared with those of the bonded PMMA MNHE in [9]. All dimensions of two heat exchangers are the same.

II. METHODOLOGY

To design and fabricate the welded-Aluminum MNHE, the governing equations are mentioned [8-10]. The energy balance equation for this minichannel heat exchanger is expressed by:

$$m_w c_w (T_{w,i} - T_{w,o}) = m_a c_a (T_{a,o} - T_{a,i}) \quad (1)$$

Where m is mass flow rate (subscripts w and a stand for water and air sides, respectively), c is specific heat, $T_{w,i}$, $T_{w,o}$, $T_{a,i}$, and $T_{a,o}$ are inlet and outlet temperatures of water and air sides, respectively.
The maximum heat transfer rate, Q_{max} is evaluated by

$$Q_{max} = (mc)_{min} (T_{w,i} - T_{a,i}) \quad (2)$$

The effectiveness (NTU method) is determined by

$$\varepsilon = \frac{Q}{Q_{max}} \quad (3)$$

Heat flux is calculated by

$$q = \frac{Q}{A} \quad (4)$$

Or $q = k\Delta T_{lm}$ (5)

Where Q is heat transfer rate, q is heat flux, A is heat transfer area, k is overall heat transfer coefficient, and ΔT_{lm} is log mean temperature difference.
The log mean temperature difference is calculated by:

$$\Delta T_{lm} = \frac{\Delta T_{max} - \Delta T_{min}}{\ln \frac{\Delta T_{max}}{\Delta T_{min}}} \quad (6)$$

A welded-Aluminum MNHE was designed, based on the above equations. All dimensions of this heat exchanger are the same with the minichannel heat exchanger in [9]. Model (including 48 channels for the water side with the length of 110 mm) is divided into five passes. The channels have a rectangular cross-section, with the width of 1 mm and the depth of 1 mm, the distance between two channels is 1mm. The separating walls have the width of 2 mm. The manifolds of MNHE are rectangular in shape, with the width of 10 mm and the depth of 1 mm. Air side has 54 fins; the cross-section is rectangular, with the depth of 10 mm and the length of 140 mm. The distance between two fins is 1 mm and the thickness of fin is 1 mm. All dimensions are shown in Fig.1.

To seal this MNHE, five Aluminum plates were welded on the five fluid passes of substrate by welding precise technology. After welding, the heat exchanger was filed to get as a smooth plate.

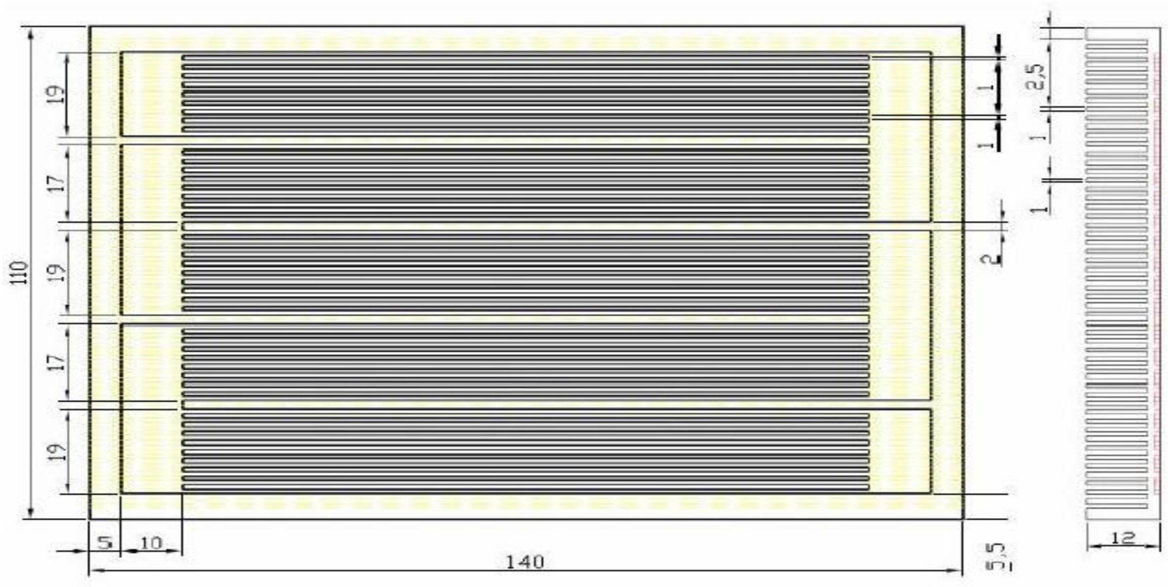

Fig.1. Dimensions of the model

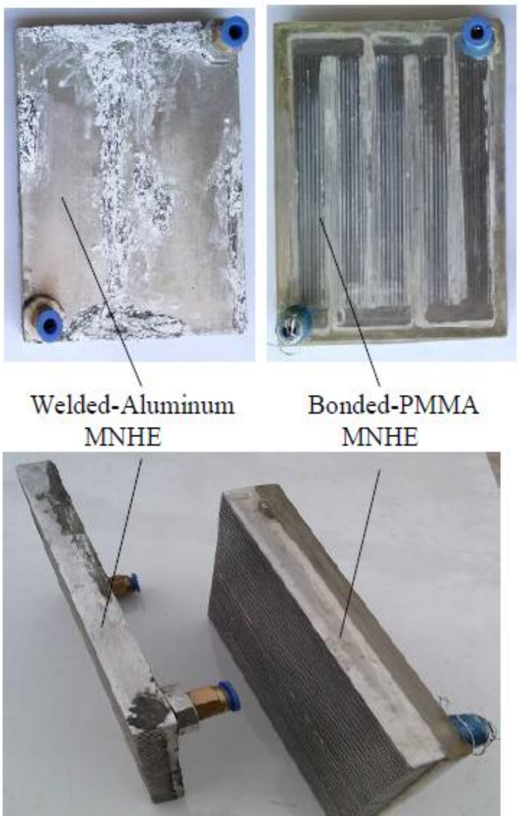

Fig.2. Bonded-PMMA MNHE and welded–Aluminum MNHE

A comparison between the bonded-PMMA MNHE and the welded-Aluminum MNHE is shown in Fig. 2. The onded-PMMA MNHE is the heat exchanger which mentioned in [9]. With the bonded-PMMA MNHE, a layer of PMMA was bonded on the fluid side of substrate by UV light process

Experimental setup

The experimental system consists of the test sample (the Bonded-PMMA MNHE or the Welded-Aluminum NHE), syringe system, and overall testing loop, as shown in Fig.3. Experiment data obtained from the two heat exchangers are under the constant room temperature condition of 30°C.

Table 1. Accuracies and ranges of testing apparatuses

Testing apparatus	Accuracy	Range
Thermocouples	± 0.1 °C	0 ~100 °C
Precision balance	± 0.0015 g	0.0000 ~ 210g
Anemometer	± 3 %	0 ~ 45 m/s

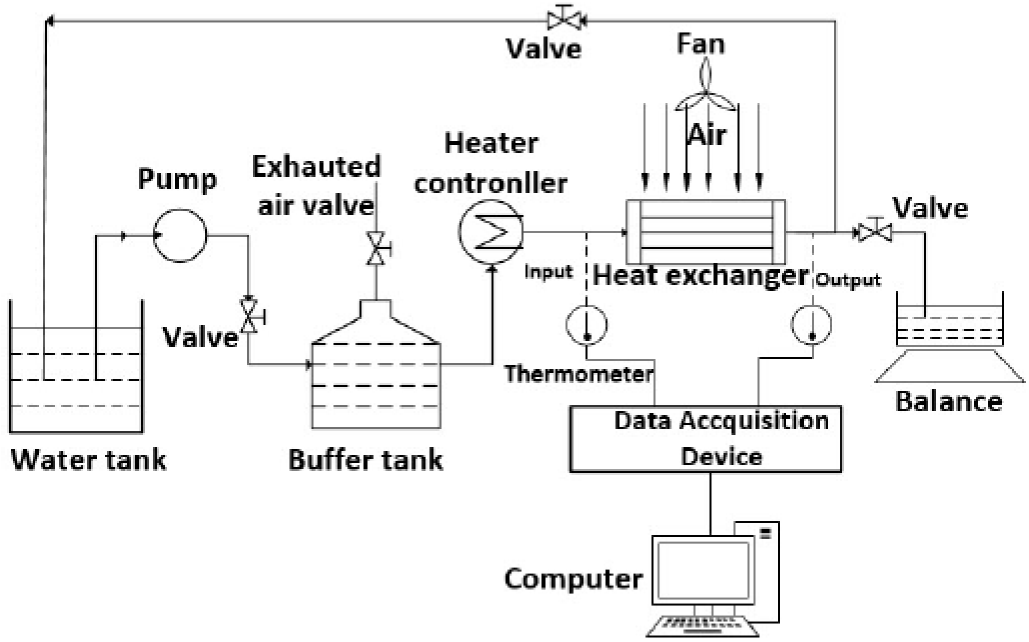

Fig.3. Schematic diagram of the test loop

Accuracies and ranges of testing apparatuses are listed in Table 1. A picture of test loop is shown in Fig. 4. Equipments used for the experiments are listed as follows [8, 9]: - Thermocouples, Model PT-100, made by Omega - Pump, VSP-1200, made by Tokyo Rikakikai - Heater, Model AXW-8, made by Medilab-nemometer, AVM-03, made by Prova - Micro electronic balance, Model TP - 214, made by Denver.

Fig.4. Photo of the test loop

III. RESULTS AND DISCUSSION

The study was done in the case of varying the mass flow rate of water.

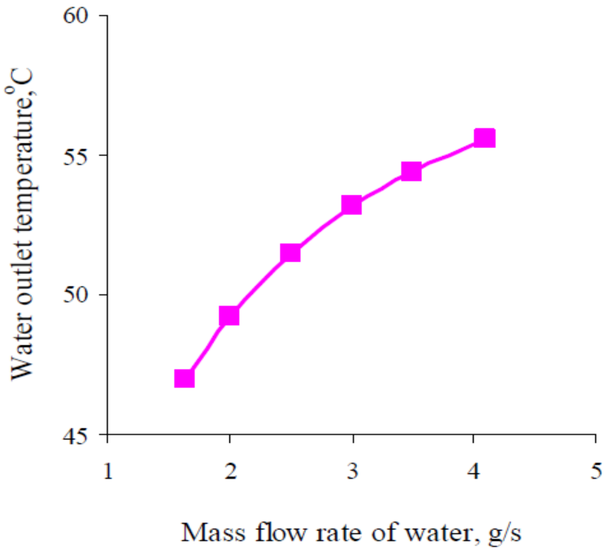

Fig.5. Water outlet temperature versus mass flow rate of water

The experimental data obtained under the ambient temperature of 30°C; the air velocity was fixed at 2 m/s; the mass flow rate of water was varying from 1.64 to 4.1g/s, and the water inlet temperature was fixed at 62°C. The experimental conditions in this study are the same conditions in [9].

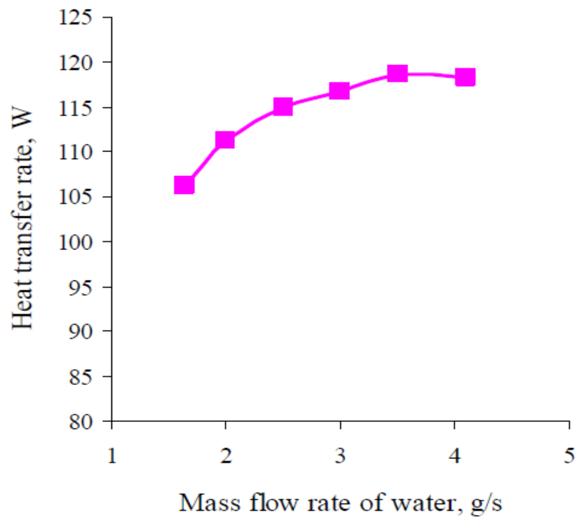

Fig.6. Heat transfer versus mass flow rate of water

When the mass flow rate of water increases, the water outlet temperature increases, it leads to the water temperature difference decreases. Figure 5 shows a relationship between the water outlet temperature and the mass flow rate of water. Because that the mass flow rate term increases more strongly than the temperature difference term, so the heat transfer rate of the heat exchanger increases as rising mass flow rate of water, as shown in Fig. 6. However, when the mass flow rate of water is over 3g/s, the heat transfer rate of the heat exchanger slowly increases. It is explained that at low mass flow rate of water, the force of water is weak, the welded-Aluminum plates and the separating walls of channels do not have gaps. But at high mass flow rate of water, the force of water is strong, the welded- Aluminum plates and the separating walls of channels have gaps, water runs for both the minichannels and gaps between the welded- Aluminum plates and the separating walls of channels. So the fluid flow is not minichanel heat transfer state. Comparisons between the welded-Aluminum MNHE and the bonded-PMMA MNHE are shown in Fig. 7 and Fig. 8. All conditions for these comparisons are the same. It is observed that as the mass flow rate is lower than 3g/s, the heat transfer rate obtained from the welded-Aluminum MNHE is higher than that obtained from the bonded-PMMA MNHE. It means that the welded-Aluminum MNHE was reinforced heat transfer by the welded- Aluminum plate which the thermal conductivity of Aluminum is higher than PMMA. For the welded-Aluminum MNHE, the heat transfer rate of 111W was achieved for water having the inlet temperature of 62°C and mass flow rate of 2g/s. For the bonded-PMMA MNHE, the heat transfer rate of 103W was achieved for water having the inlet temperature of 62°C and mass flow rate of 2g/s. However, when the mass flow rate is over 3g/s, the heat transfer rate obtained from the welded-Aluminum MNHE is lower than that obtained from the bonded-PMMA MNHE. It is due to Aluminum is flexible, so water flows for both the minichannels and the gaps between the welded- Aluminum plates and the separating walls of channels. With the bonded-PMMA MNHE, the thickness of PMMA is 10mm, it is strong enough, so it has not have the gaps between the PMMA plate and the separating walls of channels. For the welded-Aluminum MNHE, the heat transfer rate of 118W was achieved for water having the inlet temperature of 62°C and mass flow rate of 4.1g/s. For the bonded PMMA MNHE, the heat transfer rate of 132W was achieved for water having the inlet temperature of 62°C and mass flow rate of 4.1g/s.

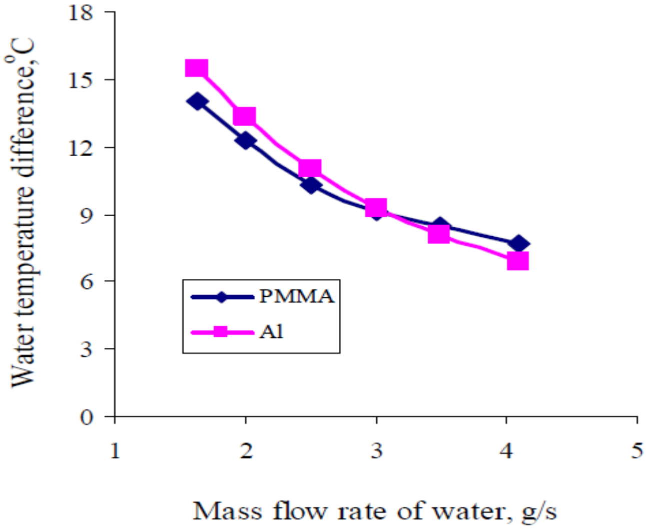

Fig.7. Comparison between the welded-Aluminum MNHE and the bonded-PMMA MNHE for the water temperature difference

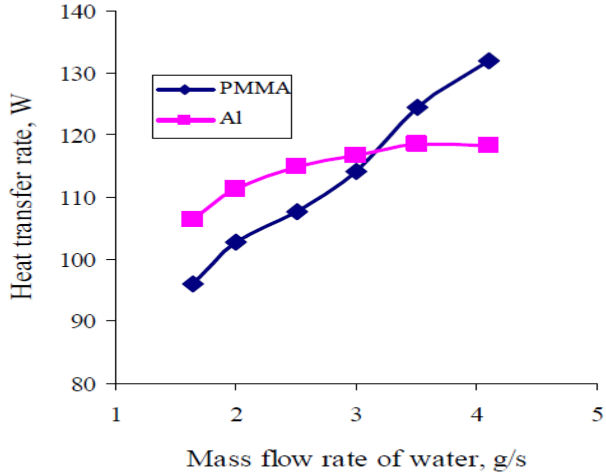

Fig.8. Comparison between the welded-Aluminum MNHE and the bonded-PMMA MNHE for heat transfer rate

From Figs. 5-8, it is indicated that at low mass flow rate of water, the heat transfer rate of the welded-Aluminum NHE is higher than the heat transfer rate of the bonded-PMMA MNHE. However, at high mass flow rate of water, the heat transfer rate of the welded- Aluminum MNHE is lower than the heat transfer rate of the bonded-PMMA MNHE. In this study, these results show that the welding Aluminum method for MNHE is less efficiency than the bonding PMMA method; it is an important key to select a method for design a minichannel heat exchanger.

IV. CONCLUSION

An investigation for a welded-Aluminum MNHE has done by experimental method. This heat exchanger has also compared with the bonded-PMMA MNHE. For water having the inlet temperature of 62°C and mass flow rate of 2g/s, the heat transfer rate of the welded-Aluminum MNHE is 111W and the heat transfer rate of the bonded-PMMA MNHE is 103W. For water having the inlet temperature of 62°C and mass flow rate of 4.1g/s, the heat transfer rate of the welded-Aluminum MNHE is 118W and the heat transfer rate of the bonded-PMMA MNHE is 132W. In this study, the welding Aluminum method for MNHE is less efficiency than the bonding PMMA method. It is an important key to select a method for design a minichannel heat exchanger.

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