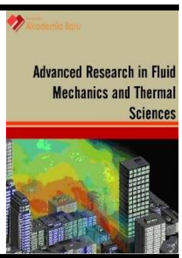
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Experimental Study for Heat Pipe Applications on Low Enthalpy Geothermal Energy Utilization for Agricultural Products Dryers

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ARTICLE INFO

Article history:
Received 23 November 2018
Received in revised form 12 February 2019
Accepted 3 March 2019
Available online 11 April 2019

Keywords:
Heat Pipe, HPHE, Low Enthalpy Geothermal, Hot Spring, Dryer

ABSTRACT

The utilization of geothermal energy needs to be improved to support energy diversification and sustainable environmental development. Applying heat pipes as a heat transfer device, will overcome several obstacles to increase the use of geothermal energy, especially low enthalpy geothermal energy. The objective of this study is to investigate the thermal performance of heat pipe usage for heat distribution from low enthalpy geothermal fluids to agricultural dryers. Geothermal fluid simulator (hot water) uses water that is heated by 9000 Watts heater and is flowed by a pump. The heat pipe has a length of 700 mm OD 10 mm, while the heat pipe filling ratio is 50 %. In this experiment, the number of heat pipe used are 42 pieces. The condenser uses a total of 181 fins with a size of 76 x 345 mm. Fin from aluminum material with 0.105 mm thickness is used in this experiment. The result show that the heat pipe could be carried out as a Heat Pipe Heat Exchanger (HPHE) in applications of low enthalpy geothermal heat. The value of HPHE effectiveness increases as the increase of hot water temperature on the side of the inlet evaporator and tends to decrease as the air velocity increases. The biggest HPHE effectiveness value is 61,427 %.

1. Introduction

Fossil energy needs to be reduced with energy diversification by utilizing the dominant energy in a location [1]. Indonesia has a big geothermal energy potential which is about 29.000 MW and spreads over 312 locations from the island of Sumatra to the islands of Maluku [2]. This large energy potential needs to be utilized for energy diversification purposes. The types of geothermal reservoirs in Indonesia are often found in shallow depths [3-5]. The most easily seen and common type is hotspring [6].

The utilization of geothermal energy needs to be improved to support energy diversification and sustainable environmental development. One of the utilization is for the dryer of agricultural products in the geothermal area [7,8]. Moisture for several agriculture products in the highlands and

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heat sources for drying can be seen in Table 1. The use of solar energy for dryers will depend on the weather and can only be done during the day. The issue is that Indonesian tea as an export commodity was rejected on the European market, because the use of firewood as a source of drying energy causes tea to be contaminated with harmful compounds from firewood smoke [9]. Drying with geothermal energy is not affected by the weather and can reduce the use of firewood as is currently being done. This will be a large potential income for the region because dried plants will increase commodity prices [5].

Table 1
Moisture content of various agricultural product [10-12]

Product	Moisture content		Max Allowable Temp. (°C)	Drying	
	Initial (%)	Final (%)		Source Energy	Time (h)
Cauliflower	80	6	65	solar	
Carrot	70	5	65	solar	
Cabbage	80	4	55	solar	
Potatoes	75	7	75	solar	
Chillies	80	5	65	solar	48
Apples	80	24	70	solar	
Tomatoes	96	10	60	solar	
Ginger	80	10		solar	168
Tea	80	3			
- 'Teh Hijau'					
- 'Teh Hitam'			Withering = 35 - 90	solar & firewood	
- 'Teh Oolong'			Drying 1st = 93 - 130		
- 'Teh Putih'			Drying 2nd = ≤ 330		
- 'Teh Wangi'					
Spinach	80	10		solar	
Coffee	65	11		solar	288

A common way to utilize the low enthalpy geothermal energy is by withdrawing it, thus it requires a pump or elevation so that it can flow. However, it has corrosive properties and has high silica content, so it takes an effort to protect geothermal fluid production pipes with high operational costs. Other constraints should also be addressed, such as residual water treatment, scaling and chemical deposition phenomena [13-15].

To reduce risks on the utilization of low enthalpy geothermal energy, the application of heat pipe to take energy without the need for withdrawal of geothermal fluid is one solution and can reduce the constraints mentioned above. Reliably, the use of heat pipes as a heat distributor has been widely used for cooling in batteries, nuclear, electric motors and rooms [16-18]. Kerrigan, *et al.,* [11] conducted a study used radiator with heat pipe for the utilization of low enthalpi geothermal energy, which obtained the results that radiators used heat pipe had twice the power density and reduce thermal mass compared to conventional radiator panels. In a similar study, by modifying the amount of heat pipe and the amount of fin used, the power density increased almost threefold and significantly reduced the thermal mass[19]. The use of heat pipes for ice melting and snow applications utilizing heat from within the earth has also been done [20].

Because Indonesia has large potential of geothermal energy sources, heat pipe applications for geothermal energy utilization without withdrawal of the geothermal fluid is very attractive and has never been done before. Thus, the purpose of this study is to perform experimental tests of low enthalpy geothermal energy utilization using heat pipes as conduits of heat for drying agricultural products around the hot spring resources. The investigation of the heat pipe performance for the heat transfer or heat pipe heat exchanger (HPHE) of low enthalpy geothermal fluid has a temperature between 60-80 °C to be used as a dryer of the agriculture product, carried out by varying velocity of air, geothermal fluid flow rate and it's temperature.

2. Methodology

2.1 Heat Pipe Heat Exchanger Design

The heat exchanger in this study uses a modification of the multi-fin heat HPHE in the previous study [21]. A module of the heat pipe heat exchanger is equipped with tubular heat pipes in a staggered arrangement. The modification is done by changing the condenser and evaporator area. The length of the condenser was changed to 35 cm from the previous 25.5 cm, while the length of the adiabatic side was changed to 10 cm from the previous 22 cm. Figure 1 shows the modified HPHE used in this study.

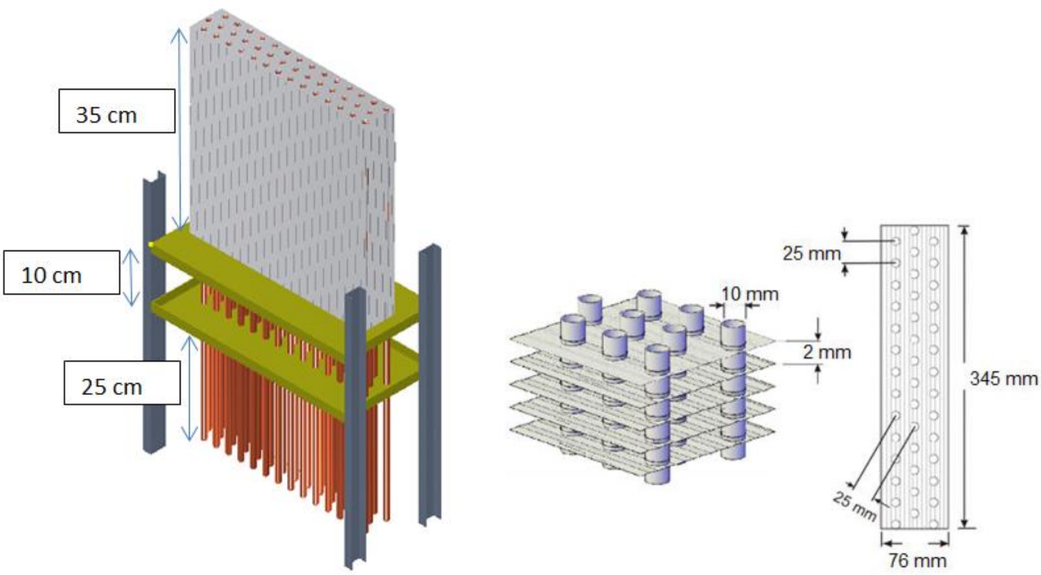

Fig. 1. The Dimension of HPHE and fin

The heat pipe length is 700 mm OD 10 mm, while the heat pipe filling ratio is 50%. The number of heat pipes in this experiment is 42 pcs. In the condenser section, the heat pipe was added to the fin with a size of 76 x 345 mm and was made with 0.105 mm-thick alumunium with a total of 181 pcs to optimize heat transfer to the air [22].

2.2 Experimental Setup

The experimental setup and placement of the measuring instrument in this experiment can be seen in Figure 2 and the experimental rig in the laboratory can be seen in Figure 3. The geothermal fluid simulators are made by heating water with a heater capacity of 9000 W in certain tanks in accordance with geothermal temperatures found in locations in Indonesia, then simulating the flow of hot water by using pump flow as in Figure 1. The pump used is CNP pump type CDLF2-11 which is connected to the FM50 TECO type inverter to adjust the motor pump rotation or hot water flow. The magnitude of the hot water flow is measured by a Dwyer UV-C112-SHD flow meter and adjusted to the large flow of hot water in several geothermal sources in Indonesia [4].

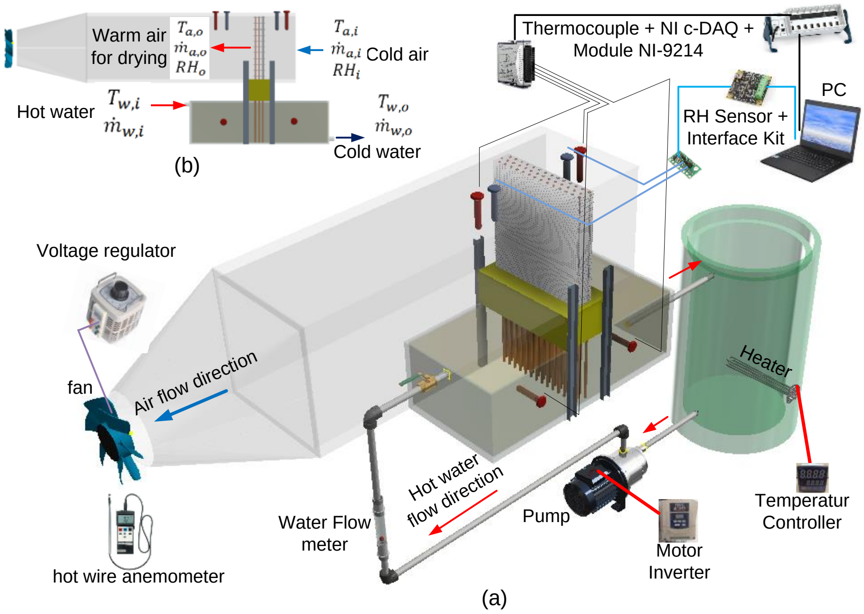

Fig. 2. Experimental setup (a) the process scheme; (b) the placement of the measuring instrument

Fig. 3. Experimental rig at the laboratory

A unit of CKE type CDI-200 fan is used to suck hot air from the HPHE which is connected directly to the hot water. To change the size of the suction air, the fan is connected to the Delta VFD022S21D inverter. The air flow measurement uses a hot wire Lutron AM-4204 anemometer. Sensor relative humidity (RH) type THD-D Autonics is installed in the direction of flow before and after air passes through the HPHE. Whereas the fluid temperature measurement, as shown in Figure 2(b), uses a K type thermocouple with an accuracy of ± 0.1 ° C. The measurement results in the form of temperature and RH data will be recorded and stored using the National Instrument data acquisition system temperature module which is linked to the virtual VIEW Lab instrument program.

2.3 Experimental Design

Experiments were carried out by varying the hot water flow rate 8.5, 12.5, 18 lpm (liter per minute), respectively. The hot water temperature varying by adjusting the controller with predetermined suggestions of obtained 60, 70, 80 °C until the steady conditions. And, air velocities are adjusted according to the size determined as part of the independent variables, 0.4,1.2, and 1.7 m/s. For the value of its effectiveness, can be used the equation 1 to 4:

$$Q_{act} = \dot{m}_c C_{pc}\left(T_{c,out} - T_{c,in}\right) \tag{1}$$

$$Q_{max} = \dot{m}_c C_{pc}\left(T_{e,in} - T_{c,in}\right) \tag{2}$$

$$Effectiveness\ (\varepsilon) = \frac{Q_{act}}{Q_{max}} \tag{3}$$

$$Effectiveness\ (\varepsilon) = \frac{(T_{c,out} - T_{c,in})}{(T_{e,in} - T_{c,in})} \tag{4}$$

3. Results

3.1. Effect of variation in hot water flow and air velocity

Experiments are carried out after the set-up of the testing tool is completed. The test is carried out by varying the temperature of the incoming hot water, the large flow of hot water, and the air flow. Figure 4 is a profile of 5 (five) temperatures recorded. Based on Figure 4, the temperature of the hot water reached a steady state after 5500 seconds. The variation of the test is taken, approximately, every 20 minutes for each variation. In every increase in air velocity, there is a decrease in the temperature of the hot water coming out of the heat pipe system. This shows that, by increasing the air stream velocity, more energy can be recovered from the hot water. However, on the contrary, with the increase in air gusts, the temperature of the air coming out of the composition of the heat pipe and fin will decrease. This is because the air contact time with HPHE is less, so the time to take the heat is also reduced[23]. So the air temperatur after passing through the HPHE also decrease. The temperature profile generated in this study is similar to previous studies [21,24].

Figure 5 shows the relative humidity values in the air in and out of the HPHE system. It can be seen that air humidity decreases with increasing air temperature after passing through the heat pipe system. The relative humidity of the outgoing air system of HPHE is also influenced by the humidity of the air entering the heat pipe system. The relative humidity of the air entering the HPHE depends on the relative humidity of the ambient air around the testing facility. Airflow with relatively high humidity when entering an HPHE condenser will result in a smaller temperature decrease. Heat absorption (sensible) results in a decrease in temperature in the air flow out of the condenser. A lower temperature decrease is affected by an increase in the condenser inlet temperature and a lower air intake speed. Higher airspeeds in the inlet will reduce the duration of heat transfer and as a result, the amount of heat absorbed will decrease [23,25]. This is because the mass convection coefficient is the function of the Reynold number and the relative humidity [26].

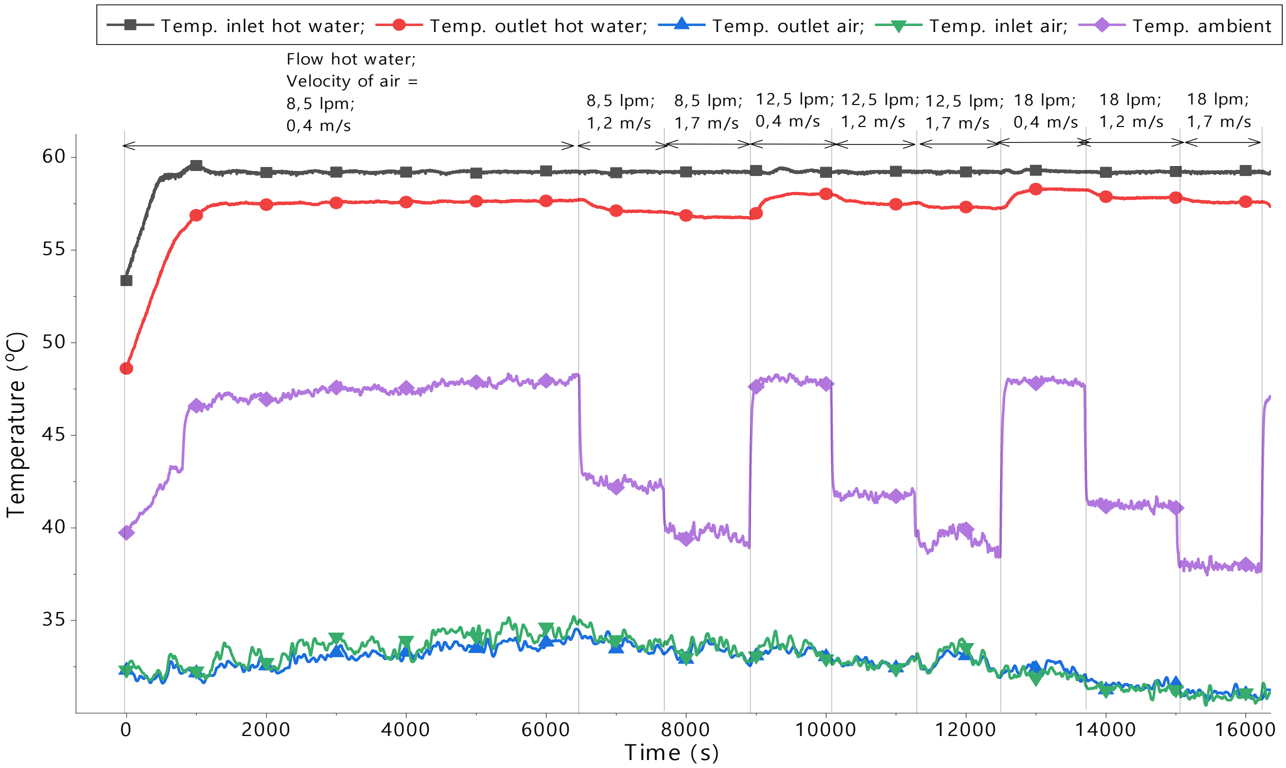

Fig. 4. Temperature profiles for various flow hot water and air flow velocity in hot water inlet temperature 60 °C

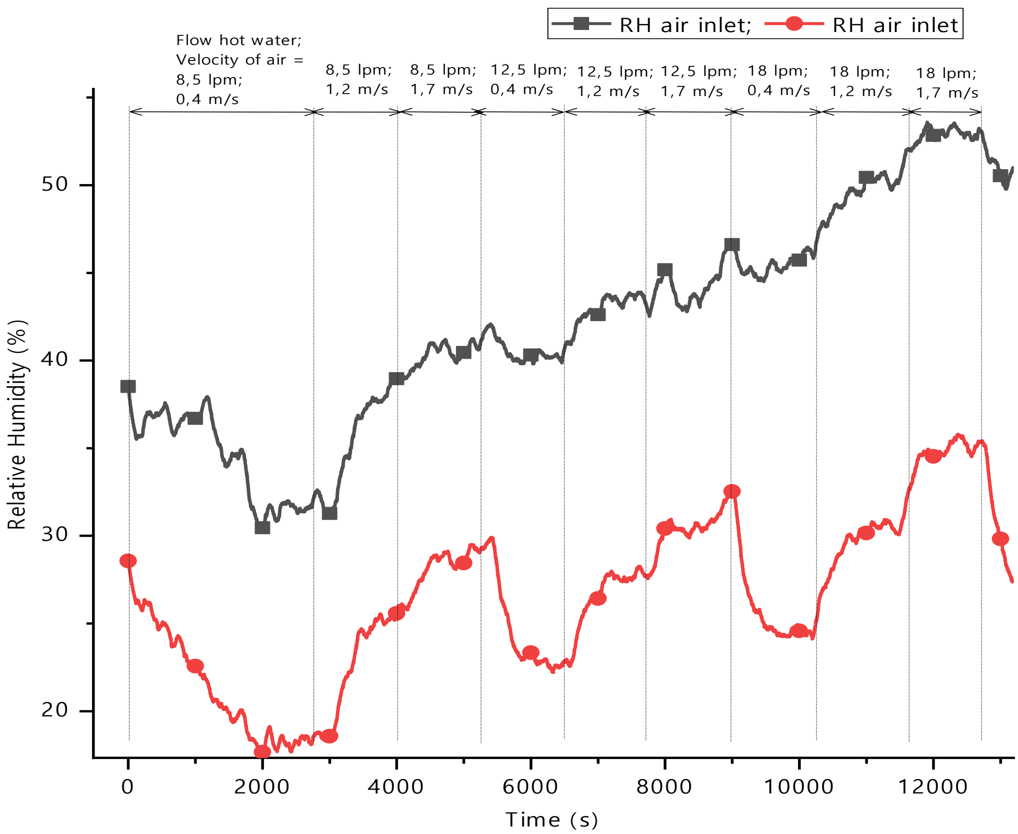

Fig. 5. Profiles for relative humidity of various flow hot water and air flow velocity in hot water inlet temperature 60 °C

The relative humidity of the heat pipe system for this dryer application is a parameter considered during testing [27]. Therefore, the results of the comparison between the relative humidity of the air out of the heat pipe system and the ambient air will be a reference in selecting the right commodity to be dried using this system and will determine how long the commodity can be dried according to the expected drought value with the system. The effect of humidity produced, commodities to be dried, and the length of drying time using this system will be carried out in subsequent studies.

3.2 HPHE Performance

It can be seen from Figure 6, from the 27 variations of testing that have been done, the largest effectiveness of the HPHE occurs in variations in testing at 80 °C hot water temperature with flow 18 lpm and air velocity 0.4 m/s. Whereas for the smallest effectiveness occurs in the variation of testing in the testing of hot water temperature of 60 °C with a flow of 12.5 lpm and the air velocity of 1.7 m/s.

The higher the temperature of hot water flowing, the higher the heat capacity that can be transferred by the heat pipe system. This is due to the influence of the latent heat of the working fluid in the heat pipe, where with the temperature getting hotter, the latent heat will be smaller. The efficiency of the heat pipe will also be better if it works at high temperatures, therefore the greater the heat given at the side of the evaporator, the greater the heat released on the side of the condenser. The greater the air velocity on the condenser side will affect the contact time between air and fin in each heat pipe arrangement so that the small air velocity causes the effectiveness of a larger heat pipe system. The characteristic pattern of effectiveness value is consistent with the results of research conducted by Nandy Putra *et al.,* [24].

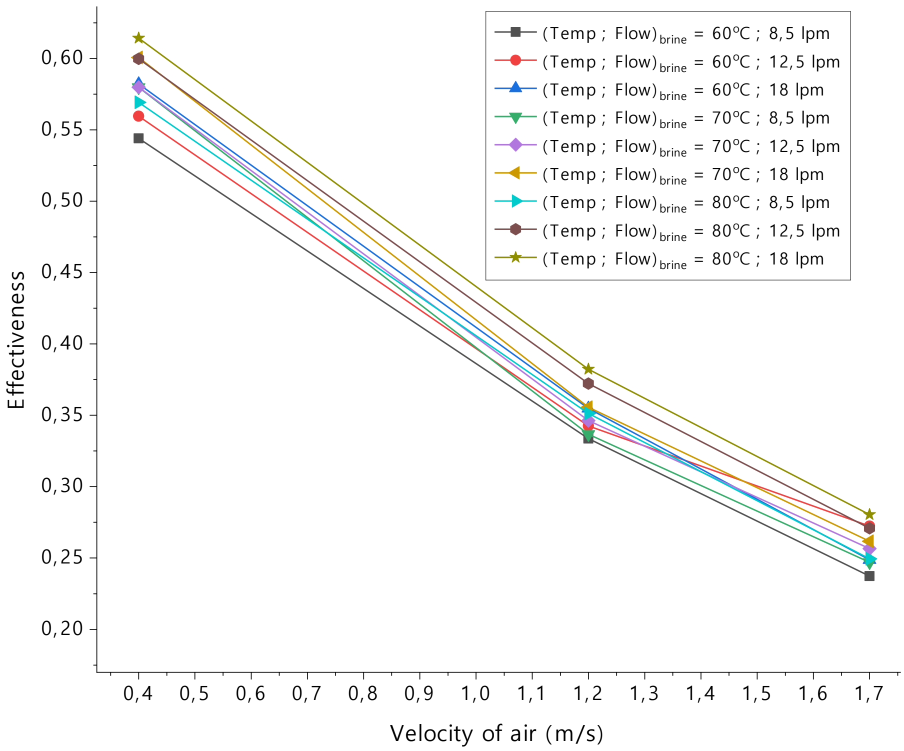

Fig. 6. Effectiveness of each test

Figure 7 shows the difference in air temperature before passing and after passing through the condenser (ΔTc = Tc, i - Tc, o). It can be seen that the increase in the temperature of the hot water used and the decrease in air velocity passing through the HPHE in this test will increase the value of ΔTc which will be useful as a reference for the purpose of drying in subsequent studies.

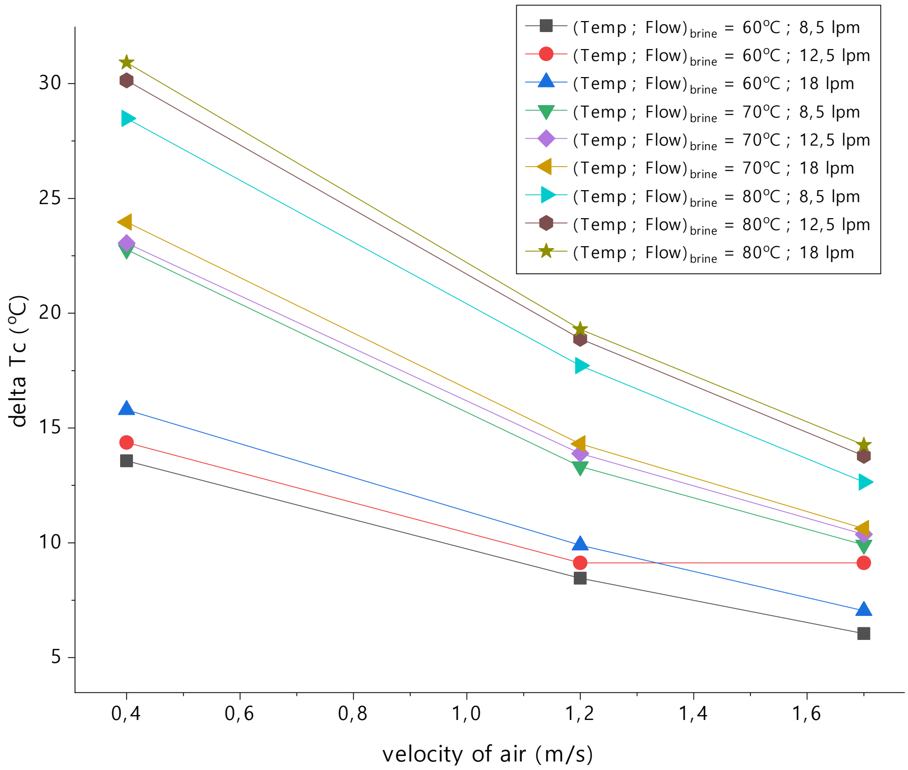

Fig. 7. The magnitude of the ΔTc for each variation of the test

4. Conclusions

The value of HPHE effectiveness increases with the increase of hot water temperature on the side of the inlet evaporator and tends to decrease when the air velocity increases. The biggest HPHE effectiveness value is 61.427 %. This value is obtained when using a variety of tests, namely the temperature and flow of hot water entering the evaporator side is 80°C and 18 lpm with suction airspeed of 0.4 m/s. Meanwhile, the smallest effectiveness of the HPHE was 23.727 % and was obtained when using a variety of tests, namely the temperature and flow of hot water entering the evaporator side was 60°C and 12.5 lpm with a suction airspeed of 1.7 m / s. The variation of the test on the greatest effectiveness value also resulted in the highest temperature difference between the incoming and outgoing air of HPHE, namely △Tc = 30.91 °C, where this value will be a parameter in determining the length of drying time to be carried out in future research**.** According to Table 1, the used low enthalpy geothermal energy as a source of drying energy with heat pipe can be applied for agriculture product dryers.

Acknowledgement
The author would like to thank Directorate of Research and Community Engagements Universitas Indonesia (DRPM UI) for funding this research through the PITTA 2018 scheme with contract number 2452/UN2.R3.1/HKP.5.00/2018 and the ESDM Ministry for the scholarship awarded to the third author.

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