Effect of Position of Heat Mode to Heat Transfer of a Closed-Loop Oscillating Heat Pipe with Check Valves on fins

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Abstract. This research aimed to determine the effect of position of heat mode to closed-loop oscillating heat pipe with check valves (CLOHP/CV) on fins. To check on heat transfer rate needed to focus on evaporator temperature, air velocity, and position of heat mode. All heat exchangers used ethanol as working fluid with the filling ratio of 50% by total volume of tube, evaporator temperature at 60, 70, and 80 degrees Celsius, and air velocity at 0.5, 1.0, and 1.5 meter per second, size of fin was 0.5 centimetre. All heat exchangers used different positions at evaporator section and condenser section of heat pipe. The CLOHP/CV was made from copper capillary tube of (inner diameter: 5 mm), 24 turns 2 check valves. The length of evaporator and condenser and adiabatic section is 20, 20, and 10 centimetre respectively. From the experiment it's was found that the heat exchanger of bottom heat mode had a temperature of 80 degrees Celsius and air velocity of 1.5 m/s with heat flux and thermal effectiveness the highest.

1. Introduction

The energy use increases, while the volume of energy is limited. Therefore, energy utilization efficiency is a fundamental principle of the conservation of energy. The use of power should be energy-efficient. One type of device that can be applied in the energy utilization is heat exchange devices. This research proposes the use of a heat pipe heat exchanger for energy save; the heat exchange has a better heat transfer. It can transfer heat when the source receives heat and cools it a little, the cost is low and the maintenance is easy [1].An operating heat pipe may be divided into three sections, evaporator, adiabatic and condenser sections [2]. Energy is added into the evaporator section where the working fluid reaches its boiling temperature and begins to boil. The buoyant vapor of the working fluid rises through the adiabatic section to the condenser, where it condenses. The condensate then drains back into the evaporator section and the check valve is used to control the flow of liquid within the pipe to flow in one direction, resulting in higher heat transfer performance. This process of evaporation and condensation of the working fluid repeats itself continuously: as long as heat is supplied to the evaporator and an opportunity for its removal from the condenser exists. Many researchers have studied these factors [3–9]. The main factors that affect the thermal performance of a closed- loop oscillating heat pipe with check valves (CLOHP/CV) are the inclination angle, operating temperature and pressure, filling ratio, aspect ratio and working fluid. Murshed et al. [10] studied the fluid. The factors affecting the thermal conductivity include the particle volume fraction, particle size, interfacial layer and temperature [11].

Thus, in this study investigated characteristics which were heat transfer rate and its effectiveness of heat pipe heat exchangers, closed-loop oscillating heat pipe with check valves (CLOHP/CV) on fins at heat mode. To check on heat transfer rate needed to focus on position of fins, evaporator temperature, air velocity. All heat exchangers used ethanol as working fluids. The radiuses and thickness of fins was 0.5cm. and 1 mm. However, in response to the lack of detailed data, this study focuses on determine the effect of position of heat mode to closed-loop oscillating heat pipe with check valves (CLOHP/CV).

2. Theoretical consideration and Experimental details

2.1 Heat transfer characteristics of the CLOHP/CV

Determination of the heat transfer to the condenser section is calculated by the calorific method. By measuring temperature of the inlet and outlet of the heating fluid, the condenser values can be calculated using the following equation:

$$Q = \dot{m} C_p (T_{out} - T_{in}) \quad (1)$$

Where Q is the heat transfer rate (W), $\dot{m}$ is the mass flow rate (kg/s), C_p is the specific heat (J/kg-ºC), T_{in} is the inlet temperature (ºC) and T_{out} is the outlet temperature (ºC).

$$q = \frac{Q}{A_c} = \frac{Q}{\pi D_o L_c N} \quad (2)$$

Where q is the heat flux (W/m^2), D_o is the outside diameter of the tube (mm), L_c is the length of condenser section (mm) and N is the number of rods in the heat pipe condenser section.

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

2.2 Experimental details

Design and construction of the test rig and construction of the CLOHP/CV. The length of evaporator, adiabatic and condensate section was 20, 10 and 20 cm respectively. Installation of the trial CLOHP/CV with experimental equipment and instrumentation is shown in Figure 1. There were 17 measurement points from the inlet temperature to the output. The instruments were thermocouples (type K) at the air inlet and outlet of the heat source and at the air inlet and outlet of the trial evaporator section and condenser section. The thermocouples were plugged into the data Logger (Agilent Technologies 34970A). The 34970A Features $6^{1/2}$ digits (22 bits) of resolution, 0.004% basic dcV accuracy for data to be analyzed in the next step. As shown in Fig. 1. Which heating by voltage regulator to heater which is attached in the evaporator section and controlled temperature hot air of evaporator section was 60, 70 and 80 (ºC). Use blower is controlled the heating loop by use inverter (Siemens siamics g110, output frequency 0 Hz-650 Hz and Cos $\varphi \geq 0.95$) to controller the speed reaches steady state condition. The cool air is region the condenser section of CLOHP/CV. This controlled the velocity as 0.5, 1.0 and 1.5 m/s by use inverter. The cool air is allowed to flow through the condenser to cooling the CLOHP/CV. Air inlet and outlet temperatures is the condenser zone are measured.

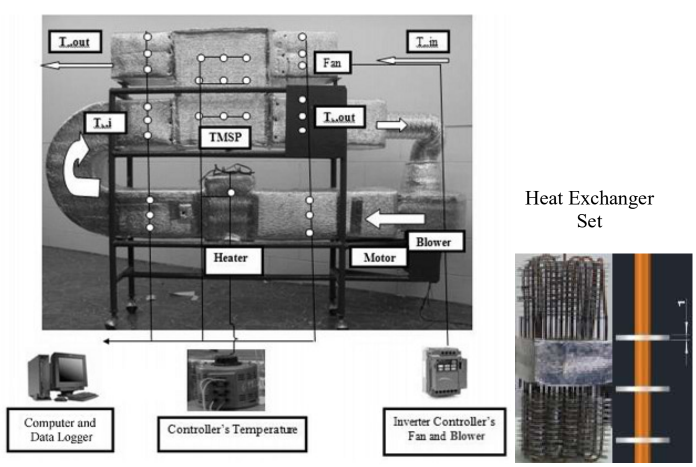

Figure 1. The CLOHP/CV heat exchanger test rig.

3. Results and discussions

3.1. Effect of velocity to the heat flux and the effectiveness of CLOHP/CV on fins

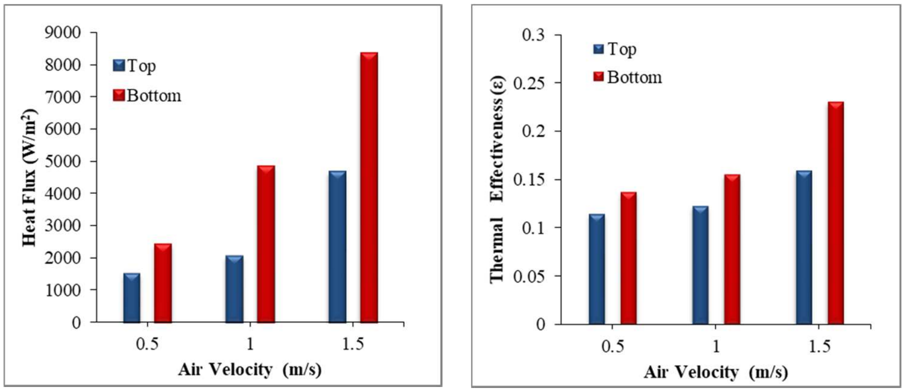

Figure 2. Effect of velocity to the heat flux and the thermal effectiveness of CLOHP/CV

A figure 2. Shows the effect of velocity to the heat flux and the thermal effectiveness of CLOHP/CV on fins. The air velocity at 0.5, 1.0 and 1.5 meter per second that performance heat transfer of the heat exchangers installed fins, given heating on bottom and top heat mode. From the experiment it's was found that the heat flux of heat exchangers, when using radial fin 0.5 cm, air velocity at bottom heat mode of heat pipe at 1.5 meter per second, temperature at 80 degree Celsius, and ethanol as working fluid, heat flux and thermal effectiveness exhibited 8,358.85 W/m2 and 0.23 respectively

Therefore, the heat pipe CLOHP/CV of heat exchangers installed 0.5 cm, given heating on bottom heat mode, using ethanol as working fluid, temperature at 80 degree Celsius, and air velocity at 1.5 m/s at condensed part, exhibited the maximum of the heat flux and the thermal effectiveness of CLOHP/CV

3.2 Effect of operating temperature to the heat flux and thermal effectiveness of CLOHP/CV on fins

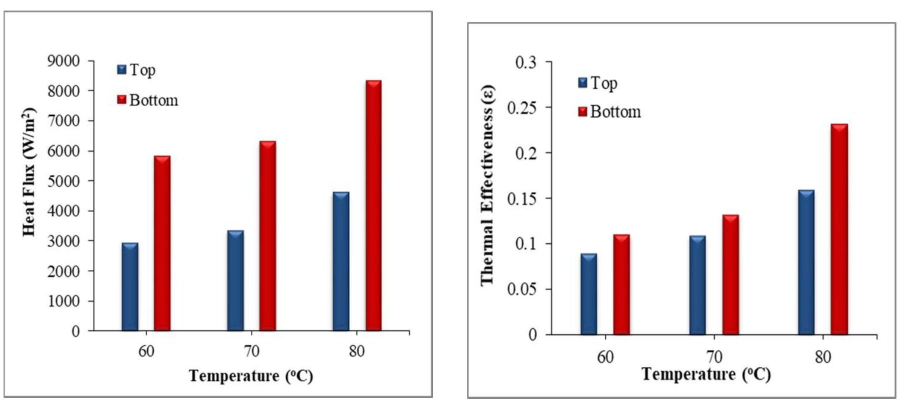

Figure 3. Effect of operating temperature to the heat flux and thermal effectiveness of CLOHP/CV

A figure 2. Shows the effect of the temperature to the heat flux and the thermal effectiveness of CLOHP/CV on fins. The air velocity at 1.5 meter per second that performance heat transfer of the heat exchangers installed fins of given heating on bottom and top heat mode were the best. From the experiment it's was found that the heat flux and thermal effectiveness of heat exchangers, when using radial fin 0.5 cm, hot air at evaporator section of heat pipe at 60, 70 and 80 degree Celsius, and ethanol as working fluid, heat flux and thermal effectiveness exhibited 8,358.85 W/m^2 and 0.23 respectively.

Therefore, the heat pipe CLOHP/CV of heat exchangers installed 0.5 cm. radial fins of given heating on bottom heat mode, using ethanol as working fluid, temperature at 80 degree Celsius, and the temperature at condensed part, exhibited the maximum of the heat flux and the thermal effectiveness of CLOHP/CV on fins.

4. Conclusions

This paper deals with the heat transfer characteristic of closed-loop oscillating heat pipe with check valves (CLOHP/CV) on fins at different heat mode. To check on heat transfer rate needed to focus on working fluid, evaporator temperature and air velocity. All heat exchanger used ethanol as working fluid with the filling ratio of 50% by total volume of the tube, evaporator temperature at 60, 70 and 80 degree Celsius, and air velocity at 0.5, 1.0 and 1.5 meter per second. The CLOHP/CV was made from 24 turns of copper capillary tube (inner diameter: 5 mm) with 2 check valves. From this study can be summarized the heat pipe CLOHP/CV of heat exchangers installed 0.5 cm. given heating on bottom heat mode, using ethanol as working fluid, temperature at 80 degree Celsius, and air velocity at 1.5 m/s at condensed part, exhibited the maximum of the heat flux and the thermal effectiveness of CLOHP/CV on fins.

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References

[1] H. Akachi, F. Polasek, P. Stulc, Pulsating heat pipe (1996) Proceeding of the 5th International Heat pipe Symposium, Australia 208-217

[2] Miyasaki Y, Polsek F, and Akachi H (2000) Oscillating heat pipe with check valves. In Proceeding of the 6th International Heat pipe Symposium 389-393

[3] Rittidech S, and others (2007) Heat-transfer characteristic of closed-loop oscillating heat-pipe with check valves. Applied Energy 84:565-577

[4] P. Meena, S. Rittidech, N. Poomsa-ad (2007) Application of Closed-Loop Oscillating Heat Pipe with Check Valves (CLOHP/CV) air-preheater for reduce relative-humidity in drying systems, Applied Energy 84:553-564

[5] Li. Zhang, Wenjuan Du., Jianhua Wu., et al (2012) Fluid flow characteristics for shell side of double-pipe heat exchanger with helical fins and pin fins, Int. J. Experimental Thermal and Fluid Science 36:30-43

[6] Thirapat Kuvannarat , Chi-Chuan Wang, Somchai Wongwises (2006) Effect of fin thickness on the air-side performance of wavy fin-and-tube heat exchangers under dehumidifying conditions, Int. J. Heat Mass Transfer 49:2587-2596.

[7] Mooyeon Lee, Taehyung Kang, Yongchan Kim (2010) Air-side heat transfer characteristic of spiral-type circular fin-tube heat exchangers, Int. J. refrigeration 33:313-320.

[8] A. Nuntaphan, S. Vithayasai, N. Vorayos, T. Kiatsiriroat (2010) Use of oscillating heat pipe technique as extended surface in wire-on-tube heat exchanger for heat transfer enhancement, International Communications in Heat and Mass Transfer.37:287-292

[9] Choi, U.S.U., 1995. Enhancing thermal conductivity of fluids with nanoparticles, developments and applications of non-Newtonian flows. FED. 231/MD 66:99-105

[10] Yu W., France DM, Choi SUS, Routbort JL (2007) Review and assessment of nano particles technology for transportation and other application. Energy system Division, April

[11] Thiraphat Kuvannarat, Chi-Chuan Wang, Somchai Wongwises (2006) Effect of fin thickness on the air-side performance of wavy fin-and-tube heat exchangers under dehumidifying conditions, Int. J. Heat Mass Transfer 49:2587-2596