Heat transfer rate of close-loop oscillating heat pipe with check valve using NiO as working fluid

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Abstract. This Research studied the heat transfer characteristics of the closed-looped oscillating heat pipe with check valves (CLOHP/CV), examining effectiveness, considering the effects of heat transfer rates and studying the internal pressure of the (CLOHP/CV). That install the fins and do not install the fins by using a heat pipe made of copper pipe, inner diameter of 5 mm, with two check valves. The evaporator section, condenser section and adiabatic section lengths were 20, 20 and 10 cm, respectively. Heat pipe had two check valves and 24 turns. Nickel oxide (NiO) was used at a working filling ratio and concentration 50% by volume and 0.14 g of the tube respectively. Hot air was at 60 70 and 80 degree Celsius, at a wind speed of 1.0 m/s. The fins were copper with radian size of 0.5 cm, and thickness of the fins was 1 mm. From the experiment, it was found that the heat flux of the CLOHP/CV heat exchanger set with the fins was the highest at 80 degree Celsius, with a value of 9,743.11 W/m². The effectiveness is 0.3 and the internal pressure is 123.59 kPa.

1. Introduction
The heat pipe is a heat exchanger that has high heat transfer ability. It is a closed-end copper tube. Inside is vacuum, which contains basic working fluid substances such as ammonia, methane, water. The working principle is that the working substance inside the pipe, when heated, will evaporate and move to the other end, while moving, it will condense and become a liquid on the surface of the pipe and will then return to the end of the heat pipe. An oscillating heat pipe (OHP) has been developed as a very effective heat transfer device with can work even if the difference in temperature between the heat sources is small. There are 3 types of closed end OHP, (1) closed-loop oscillating heat pipe (2) closed-loop oscillating heat pipe with check valves, and (3) OHP with three sections of evaporator-adiaebatic and condenser sections of heat pipe, which a closed-loop oscillating heat-pipe with check valves (CLOHP/CV). This type is a closed loop oscillating heat pipe, in which both ends of the capillary tube are connected to form a closed-loop [1-3]. Recent studies by Meena and Rittidech [4-6] aimed to design, construct and test waste heat recovery by closed-loop oscillating heat pipe with check valve from pottery kilns for energy efficiency. Meena and Saengmart [7] investigated characteristics of heat transfer rate and its effectiveness in a closed loop oscillating heat pipe with check valves (CLOHP/CV) on fins at heat mode. Assessing the heat transfer rate required focus on working fluid, evaporator temperature and air velocity, all heat exchangers used silver nano as working fluids. Meena and Ainyim [8] aimed to determine the effect of the position of fins to closed-loop oscillating heat pipe with check valves.
(CLOHP/CV) at top heat mode. Assessing the heat transfer rate required focus on evaporator temperature, air velocity, and position of fin. All heat exchangers used ethanol as working fluid.

This research aimed to study the heat transfer of CLOHP/CV and studied the thermal efficiency considering the effects of heat transfer rates and studied the internal pressure CLOHP/CV install fins and do not install fins. Using NiO as a working substance 0.14 g, test temperature 60 70 and 80 degree Celsius, at a wind speed of 1.0 meters per second. The radiuses of fins were 0.5 cm. and the thickness was 1 millimeter. This study focused on the actual thermal efficiency of the 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

\[ Q = m C_p (T_{out} - T_{in}) \]  (1)

where \( Q \) is the heat transfer rate (W), \( m \) is the mass flow rate (kg/s), \( C_p \) is the specific heat (J/kg-\(^\circ\)C), \( T_{in} \) is the inlet temperature (\(^\circ\)C) and \( T_{out} \) is the outlet temperature (\(^\circ\)C).

\[ q = \frac{Q}{A_c} \]  \( D_oL_cN \)  \[ (2) \]

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:

\[ \varepsilon = \left( \frac{Q_{act}}{Q_{max}} \right) \]  \[ (3) \]

2.2. Experimental details

Design and construction of a test machine and the construction of a CLOHP/CV heat exchanger installed with fins were as shown in figure 1. The length of the evaporator, adiabatic and condensation section of heat pipe cm and a thickness was 20, 10 and 20 cm, respectively. Cooling fins were made of copper with a size of 0.5 of 1 mm fin, the filling ratio 50% of the total volume. Heat Exchanger on fins and on fins

![Figure 1. The CLOHP/CV heat exchanger test rig.](image)

The installation of the CLOHP/CV with experimental equipment and measuring instruments is shown in the picture. The thermocouple wires (Type K thermocouple) with the tester in the evaporator
heat and condensation thermocouple wires were used to measure air temperature in the inlet-out temperature and the thermocouple wires were connected to the data logger (Agilent Technologies 34970A), to store data for analysis. The standard resolution was $6^{1/2}$ (22 bits), 0.004%. The temperature of the hot air evaporator was 60, 70 and 80 degree Celsius, controlling the wind speed of 1.0 meters per second by inverter air flow through the condenser for cooling. CLOHP/CV.

3. Results and discussion

3.1. Effect of temperature on the heat transfer rate, heat flux, thermal effectiveness and pressure of CLOHP/CV

Figure 2 shows the temperature of CLOHP/CV with and without fins affecting the heat transfer rate using NiO as a working substance, temperature control of 60, 70 and 80 degree Celsius, with constant wind speed of 1.0 meters per second. From the experiment, it was found that the best heat transfer rate of CLOHP/CV that installed the fin when maintained at 80 degree Celsius was equal to 493 W.

Figure 3 shows the temperature of CLOHP/CV with and without fins that affect the heat flux using nickel oxide as a working fluid temperature control of 60, 70 and 80 degree Celsius, with constant wind speed of 1.0 meters per second. From the experiment, it was found that the best heat flux of CLOHP/CV that installed fins when using heat at 80°C, equal to 9,743.11 W/m$^2$.

Figure 4 shows the temperature of CLOHP/CV with and without installed fins that affect the thermal effectiveness use nickel oxide as a working fluid temperature control of 60, 70 and 80 degree Celsius, with...
the same wind speed of 1.0 meters per second. From the experiment, it was found that the best thermal efficiency of the (CLOHP/CV) that installed the fin when using heat at 80°C was 0.31.

Figure 5 shows the temperature of the CLOHP/CV with and without installed fins affects the pressure using nickel oxide as a working substance, temperature control of 60 70 and 80 degree Celsius, with constant wind speed of 1.0 meters per second. From the experiment, it was found that the best pressure of CLOHP/CV that installed fins when using heat at 80 degree Celsius, equivalent to 123.59 kPa.

4. Conclusions
This paper investigated the temperature effect of (CLOHP/CV) with and without installed fins. Affecting the heat transfer rate, the thermal and pressure effectiveness of CLOHP/CV using nickel oxide as working fluid to focus on the temperature of (CLOHP/CV) with and without installed the fins. In a liquid working fluid with a filling ratio of 50% by the total volume of the evaporator temperature tube at 60 70 and 80 degree Celsius this study concluded that the heat exchanger CLOHP/CV of the heat exchanger at 80 degree Celsius and the wind speed at 1.0 meters per second Where the condenser part of the heat pipe shows the maximum heat flux and thermal efficiency.

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