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Comparisons of Heat Transfer Performance of a Closed-looped Oscillating Heat Pipe and Closed-looped Oscillating Heat Pipe with Check Valves Heat Exchangers

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Abstract: This research was to study the comparisons of heat transfer performance of closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers with R134a, Ethanol and water were used as the working fluids. A set of heat pipe heat exchanger (CLOHP and CLOHP/CV) were made of copper tubes in combination of following dimension: 2.03 mm inside diameter: 40 turns, with 20, 10 and 20 cm for evaporator, adiabatic and condenser sections lengths. The working fluid was filled in the tube at the filling ratio of 50%. The evaporator section was given heat by heater while the condenser section was cooled by air. The adiabatic section was properly insulated. In the test operation, it could be concluded as follows. It indicated that the heat transfer performance of closed-looped oscillating heat pipe with check valves heat exchanger better than closed-looped oscillating heat exchanger**.**

Key words: Closed-looped oscillating heat-pipe, performance, heat exchanger, heat transfer

INTRODUCTION

The heat pipe is the high efficient heat transfer devices. Akachi *et al*.,[1]. There are three types as shown in Fig. 1, 2, 3. The first is a closed-end oscillating heat pipe (CEOHP) which has no check valve and is closed both ends. The second is a Closed-Loop Oscillating Heat Pipe (CLOHP). Which is connected at both ends of tube to form closed loop but check valves are not installed in the loop. The third is a Closed-Loop Oscillating Heat Pipe with Check Valve (CLOHP/CV). In this case, capillary tube is bent into many meandering turns and connected the both ends of tube to form closed loop and has one or more check valves in the loop. Miyazaki *et al*.,[2]. The check valve is a floating type valve that consists of a stainless ball and copper tube, in which ball stopper and conical valves seat are provided at the ends, respectively. The ball can move freely between the ball stopper and the valves seat in shown Fig. 4. It incorporates one or more direction-control one-way check valves in the loop so that the working fluid can circulate in specified direction only. They can be heat transfer by itself with latent heat of working fluid in the tubes and heat transfer with heat sink such as Water or Air. Pipatpaiboon *et al*.,[3]: studies the effect of inclination angle working fluid and number of check vales on the characteristics of heat transfer in a Closed-Looped Oscillating Heat-Pipe with Check Valves (CLOHP/CV). It was found that the CHOHP/CV is equipped with 2 check valves, as highest heat transfer. The CHOHP/CV is equipped with 2 check valves, as highest heat transfer. Rittidech *et al*.,[4]. Studies the correlation to predict heat transfer of a Closed-Looped Oscillating Heat-Pipe with Check Valves (CLOHP/CV). Meena *et al*.,[5]: studies the application of Closed-Loop Oscillating Heat-Pipe with Check Valves (CLOHP/CV) air-preheater for reduced relative-humidity in drying systems. It was found that the (CLOHP/CV) air-preheater can be reduced relative humidity in a drying system. Meena *et al*., [6] studies the effect of evaporator section lengths and working fluids on operational limit of Closed Loop Oscillating Heat Pipes with Check Valves (CLOHP/CV). It was found that the evaporator lengths increased the critical heat flux decreased. There was working fluids change from R123 to Ethanol and water the critical heat flux decreased. Rittidech *et al*.,[7]: investigated the effect of inclination angles, evaporator lengths and working-fluid properties on the heat-transfer characteristics of the CEOHP under normal operating condition. Rittidech *et al*.,[8] devised a correlation to predict the heat-transfer characteristics of a CEOHP.

Rittidech *et al*.,[9] studies the effect of evaporator lengths and ratio of check valves to number of turns on internal flow patterns of a closed-loop oscillating heat

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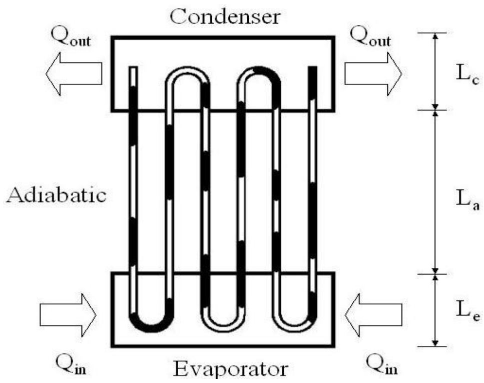

Fig. 1: Closed-End Oscillating Heat Pipe

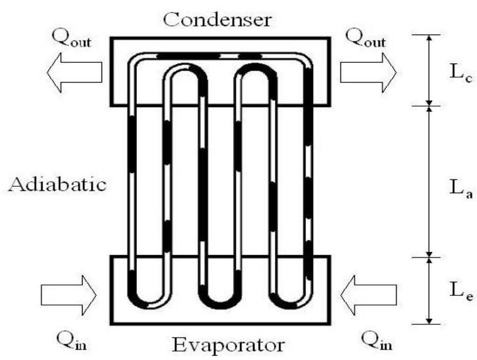

Fig. 2: Closed-Loop Oscillating Heat Pipe

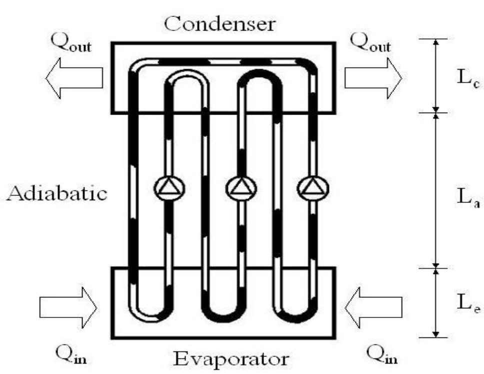

Fig. 3: Closed-Loop Oscillating Heat Pipe with Check Valve

pipe with check valves. It was found that when the evaporator section length decreased the heat flux rapidly increased. During the past several years, many study have been presented on the experimental and theoretical studies, but heat transfer performance of closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers

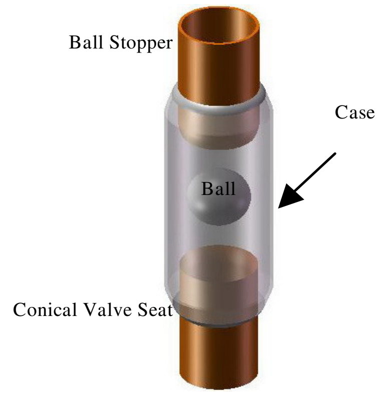

Fig. 4: The check valve

are not explained clearly due to the comparisons of heat transfer performance of closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers.

In the present research, experimental study to the comparisons of heat transfer performance of closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers:

- To study the effect of temperature of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers on the heat transfer rate
- To study the effect of working fluids of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers on the heat transfer rate
- To study the effect of temperature of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers on the effectiveness
- To study the effect of working fluids of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers on the effectiveness

The check valves: The check valve is a floating type valve that consists of a stainless ball and copper tube, in which ball stopper and conical valves seat are provided at the ends, respectively. The ball can move freely between the ball stopper and the valves seat in shown Fig. 4.

MATERIALS AND METHODS

Test rig: The CLOHP/CV was made of copper tube. With R123 was used as the working fluid. A set of

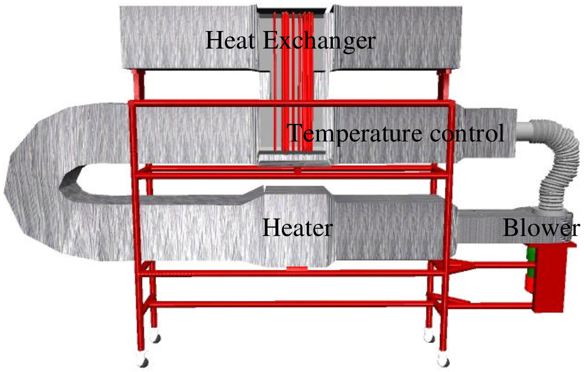

Fig. 5: Test rig

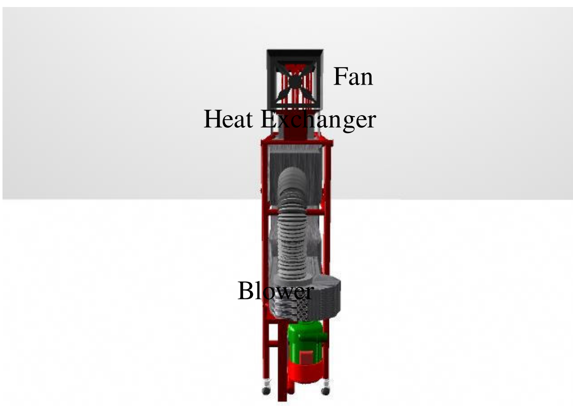

Fig. 6: The experimental setup

CLOHP/CV were made of copper tubes in combination of following dimensions: 1.77 and 2.03 mm inside diameter: 10 turns: 5, cm equal lengths for evaporator, adiabatic and condenser sections. The working fluid was filled in the tube at the filling ratio of 50% in shown Fig. 5.

Figure 5, 6 shows an experimental setup which consists of a CLOHP and CLOHP/CV with the evaporator section was given heat by heater while the condenser section was cooled by air. The adiabatic section was properly insulated.

In the test operation increase the temperature of the evaporator section from 60-80^{o}C, with the working fluids changed from R134a to water. The data logger Yokogawa-MX100 was used with type K thermocouples (Omega with ±1°C accuracy) attached to the inlet and outlet of the condenser section on heat exchanger, the thermocouples were attached to the outside surface wall of the CLOHP and CLOHP/CV and data were recorded. These were 3 points on the evaporator, 2 points on the condenser and 2 points on the adiabatic section. The evaporator section was given heat by heater, while the condenser section was cooled by air. They were used to calculate the heat transfer of the test CLOHP/CV by using the calorific method, as the following Eq:

$$Q = m^{\bullet} c_p \left(T_{out} - T_{in} \right)$$

$$\text{Effectiveness } (\varepsilon) = \frac{Q_{exp}}{Q_{max}}$$

And

$m^{\bullet}$	=	Mass per unit time
C_p	=	Specific heat capacity, constant pressure
T_{out}	=	Outlet temperature at condenser section
T_{in}	=	Inlet temperature at condenser section
$T_{evap.}$	=	Temperature at evaporator section
$T_{cond.}$	=	Temperature at condenser section
ε	=	Effectiveness
Q_{act}	=	Actual heat transfer rate
Q_{max}	=	The maximum heat transfer rate

Variable parameters were:

- Temperatures were 60, 70 and 80 ^{o}C.
- Working fluids were R134a, Ethanol and Water.
- An inner diameter of the tubes was 2.03 mm.

RESULT AND DISCUSSION

The effect of temperature on the heat transfer rate: Figure 7 shows comparisons the effect of temperature on the heat transfer rate of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers. It indicated that the value of the heat transfer rate of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the temperature increased, the value of heat transfer rate increased.

The effect of working fluids on the heat transfer rate: Figure 8 shows comparisons the working fluids on the heat transfer rate of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers. It indicated that the value of the heat transfer rate of a closed-looped oscillating heat pipe with check valves is higher than a closed-

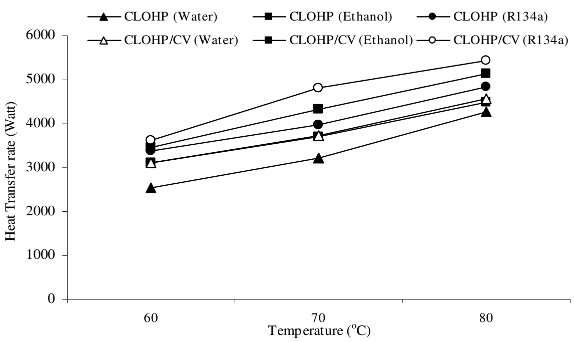

Fig. 7: Temperature and heat transfer rate

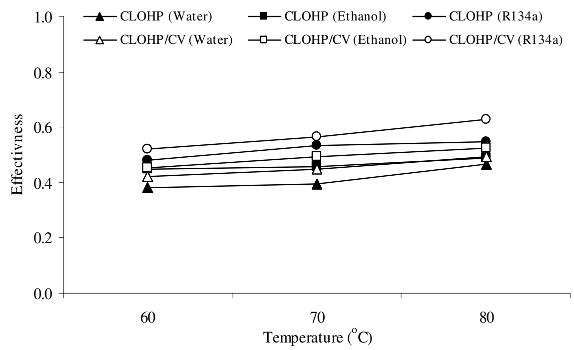

Fig. 9: Temperature and effectiveness

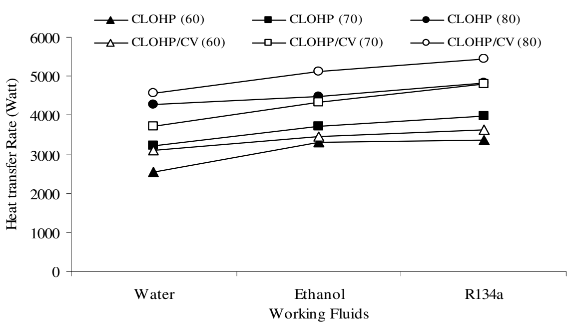

Fig. 8: Working fluids and heat transfer rate

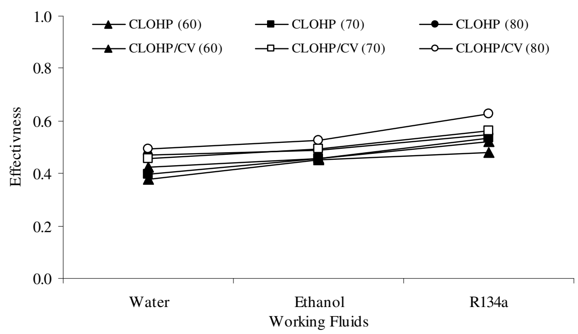

Fig. 10: Working fluids and effectiveness

looped oscillating heat pipe. Also when the working fluids changed from R134a to water, the value of heat transfer rate decreased.

The effect of temperature on the effectiveness: Figure 9 shows comparisons the effect of temperature on the effectiveness of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers. It indicated that the value of the effectiveness of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the temperature increased, the value of effectiveness increased.

The effect of working fluids on the effectiveness: Figure 10 shows comparisons the effect of working fluids on the effectiveness of a closed-looped oscillating heat pipe and closed-looped oscillating heat pipe with check valves heat exchangers. It indicated that the value of effectiveness of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the working fluids changed from R134a to water, the value of effectiveness decreased.

CONCLUSIONS

- The value of heat transfer rate of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the temperature increased, the value heat transfer rate increased
- The value of heat transfer rate of a closed-looped oscillating heat pipe with check valves higher a closed-looped oscillating heat pipe. Also when the working fluids changed from R134a to water the heat transfer rate valued decreased
- The value of the effectiveness of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the temperature increased, the value of effectiveness increased
- The value of effectiveness of a closed-looped oscillating heat pipe with check valves is higher than a closed-looped oscillating heat pipe. Also when the working fluids changed from R134a to water, the value of effectiveness decreased

It indicated that the heat transfer performance of closed-looped oscillating heat pipe with check valves heat exchanger better than closed-looped oscillating heat exchanger**.**

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