Research Article

Effect of inclined heat transfer rate on thermosyphon heat pipe under sound wave

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Abstract

This research studied the heat transfer rate enhancement of a thermosyphon heat pipe using sound wave to ease evaporation process. The experiment was done on a single thermosyphon with sound wave.

The experimental set up was composed of a bare copper tube having 0.0223 m od and 0.45 m evaporator and condenser sections length. Inlet hot air temperature ranged between 50, 60, 70, 80 and 90°C and R-123 was the thermosyphon working fluid. Filling fraction of the thermosyphon was 60, 70 and 80%. The sound wave generator was installed at the evaporator section of each tube creating 70, 80, 90 and 100 Hz wave frequency and input power of 110 W.

The results of this experiment showed that a thermosyphon under sound wave could increase the heat transfer rate by about 67.65%, depending on the best case of a heat pipe at 15 degree incline, 70°C of hot water at evaporating section, with 100 Hz and a filling ratio of 70% working fluid.

Keywords: energy, heat transfer coefficient, evaporator, condenser, working fluid, Thailand

Introduction

Thermosyphon heat pipe is a heat exchanger that is increasingly finding use in many industrial processes. This is because it provides a higher heat transfer rate and is relatively simple to produce. Thermosyphon heat pipes are comprised of three major parts, evaporating section, adiabatic section and condensing section, as shown in Figure 1. The evaporating section receives heat from a high temperature source and will transform the working fluid by boiling to vapour. The vapour will then move to the condensing section at
the top, and then condense to liquid to flow down to the evaporating section again in a cyclical process.

Normally the heat transfer efficiency of a thermosyphon depends on the temperature of the heating source. In cases where the source has low temperature, it is found that the heat transfer process is insufficient. This is because it is difficult to boil the working fluid at low temperature. The problem can be solved by selecting the technique of vibrating the working fluid by using a sound wave in order to actuate the working fluid inside the heat pipe to be turbulent, with subsequent on heat transfer.

![Figure 1. Schematic of simple thermosyphon heat transfer.](image)

Oh *et al* [1], studied the effect of ultrasonic waves on heat transfer in changing phase process of working fluid. It was found that the ultrasonic wave can increase the melting process by as much as 2.5 times compared to no ultrasonic process.

Siriwichai [2], studied the incremental performance of a thermosyphon heat pipe, including ultrasonics. Dimensions of the heat pipe were a diameter of 0.029 m, 0.16 m in length of evaporating and condensing section, the hot water temperature of 35-65°C with 5°C of cool water, including an ultrasonic source at the end of evaporating section. This research sets the frequency at 8-14 kHz. It was found that the heat pipe performance increases 20-60%, depending upon working fluid and hot water temperature. The optimum frequency was found to be 8 kHz.

Techana [3], studied the performance of boiling inside a thermosyphon heat pipe that included an ultrasonic system. The research studied the position of the heat pipe in the vertical and incline by focusing on the relationship of convective heat transfer and inlet temperature of water at the evaporating section and the angle to level of heat pipe. The study used hot water and hot water as the heat exchange. The heat exchanger was made from copper without any fins. Dimensions were 27.75 mm inside diameter, 1.3 mm thickness, 1.2 m length, 0.5 m evaporating length and 0.2 m adiabatic length, with 50-80°C hot water temperature. The working fluid was water with 50% filling of the evaporating section. The
ultrasonic system was set at the bottom of the heat pipe at the evaporating section with 8, 10 and 14 kHz. It was found that the ultrasonic wave could increase the convective heat transfer coefficient at the evaporating section to 370% at hot water inlet temperature 50-60°C. However, at increasing water temperature it was found that the heat pipe performance with no ultrasonic was the same as using ultrasonic. In the case of a heat pipe set to an incline, it was found that performance was the highest when set at a 30° incline.

From the previous research [4, 5, 6], there has to date been no known study of thermosyphon heat pipe performance with sound waves and the heat pipe set to incline at varying degrees, and is thus the purpose of this research. Our study can also be applied to the case of solar water heating which uses a heat pipe.

Figure 2. Heat transfer experimental set-up of thermosyphon heat pipe including sound wave system.

Methodology

Installation

Figure 2 shows the experiment set-up for the study of heat transfer characteristics of a thermosyphon heat pipe that includes an ultrasonic system. The thermosyphon is made from copper tubes with a diameter of 0.0223 m, 1.3 mm thickness, 1 m length, evaporating section 04.5 m in length, 0.1 m adiabatic section with working fluid filling 80% of the evaporating section. Thermocouples, type K, are used to measure the temperature with 18 points [7]. They are the inlet and outlet water of both evaporating and condensing sections, outer wall temperature of heat pipe at both evaporating and condensing sections, and inside heat pipe temperature of both evaporating and condensing sections with 3 points for each spot. ROTameter is used to measure the inlet flow rate of the water in the range 1-10 l/min.
with 0.01 l/min in error. The heat source consists of a stainless vessel with dimensions 50 x 50 x 45 cm, including 6 sets of 1 kW heaters and sound wave source with a high power of 110 watts that generates a wave of 40 kHz.

**Heat Transfer Analysis**

Heat transfer rate of the thermosyphon can be determined from heat transfer at the condensing section:

\[
Q_c = \dot{m}C_p(T_{\text{sc,out}} - T_{\text{sc,in}})
\]  

(1)

In the case of adiabatic process, the heat transfer rate at the condensing section will be equal to the heat transfer rate at evaporating section as per the equation:

\[
Q_e = Q_c
\]

(2)

**Figure 3. Heat Circuit Resistance.**

From the heat circuit resistance as shown in Figure 3, the heat transfer rate at the evaporating section will be:

\[
Q_e = \frac{T_{\text{eo}} - T_{\text{ei}}}{Z_1 + Z_2}
\]

(3)

Where,

\[
Z_1 = \frac{\ln \left( \frac{D_o}{D_i} \right)}{2\pi K_{\text{copper}} L_e}
\]

(4)

So that the heat transfer coefficient at the evaporating section can be calculated from:
Results and Discussion

Figure 4 shows the case of thermosyphon heat transfer at 15° incline and 80°C hot water at the evaporating section and 80 Hz sound wave. The results show that the heat transfer resistance value inside the pipe is the lowest.

![Figure 4](attachment:image.png)

**Figure 4.** Relationship between heat transfer resistance inside the pipe and water temperature inlet to evaporation with sound wave at 0, 70, 80, 90, and 100 Hz, respectively. At 15° incline of heat pipe the filling rate of working fluid is 70%.

Figure 5 shows the case of thermosyphon heat transfer with 15° incline, 80°C hot water inlet and 80 Hz of sound wave. The results show that the convective heat transfer coefficient inside the pipe is the highest.
Figure 5. Relationship between heat transfer rate inside the pipe and water temperature inlet to evaporation with sound wave at 0, 70, 80, 90 and 100 Hz, respectively. At 15° incline of heat pipe the filling rate of working fluid is 70%.

Figure 6 shows the case of thermosyphon heat transfer with 15° incline, 90°C hot water inlet and 100 Hz sound wave. The results show that the heat transfer rate inside the pipe is the highest.

Figure 6. Relationship between heat transfer rate inside the pipe and water temperature inlet to evaporation with sound wave at 0, 70, 80, 90 and 100 Hz, respectively. At 15° incline of heat pipe the filling rate of working fluid is 70%.

Conclusion

The experimental results show that in the case of thermosyphon heat pipe at 15° incline, 80°C hot water inlet at evaporating section and 80 Hz sound wave, the heat transfer
resistance is 0.013 K/W. In the case of thermosyphon heat pipe at 15° incline, 70°C hot water inlet at evaporating section and 80 Hz sound wave it is shown that the convective heat transfer coefficient can be increased to 48.51%. Finally, in the case of thermosyphon heat pipe at 15° incline, 80°C hot water inlet at evaporating section and 100 Hz sound wave it is shown that the heat transfer rate is 67.65%.

This experiment and the calculations are part of ongoing research. The results show that heat transfer in a thermosyphon can be enhanced using sound waves. This research can be applied to the heat transfer enhancement of a thermosyphon flat-plat solar collector by applying the sound waves.

**References**


