EXPERIMENTAL DETERMINATION
OF CONDENSER LENGTH EFFECT ON THE
THERMOSYPHON PERFORMAN

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ABSTRACT

In the current work, a thermosyphon was used to investigate the effect of condenser length on its performance. Experimentally by using a pipe of copper having same evaporator length of 120 mm and three different condenser lengths which were 400 mm, 500 mm and 600 mm. The internal and external diameters of the thermosyphon were 26 mm and 28 mm respectively. The evaporator part of the thermosyphon was immersed in the electrical transformer oil, which heated by external heater from ambient temperature to approximately 80 oC, while the condenser part was left to cool naturally by air. Five thermocouples were located on the thermosyphon wall to read the temperature distribution at different positions. The working fluid was water with filling ratio of 50%.

The results have obviously shown that temperature gradient was decreased when the condenser length increased and giving a better performance for heat dissipation. The percentage of temperature gradient was positively correlated to the condenser length and it was found that condenser length of (400, 500, 600) mm gave percentage of decreasing temperature gradient are 67.94%, 72.94%, and 77.06% respectively with respect to that without using thermosyphon.

Key Words: Thermosyphon, condenser length, evaporator, temperature gradient, performance. Thermosyphon resistance.

LIST OF SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Units</th>
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<tr>
<td>$C_p$</td>
<td>Specific heat</td>
<td>(J/Kg K)</td>
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<tr>
<td>$c_1, c_2, c_3, c_4$</td>
<td>Condenser wall temperatures</td>
<td>K</td>
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<tr>
<td>$e$</td>
<td>Evaporator temperature</td>
<td>K</td>
</tr>
<tr>
<td>$L_c$</td>
<td>Condenser length</td>
<td>mm</td>
</tr>
<tr>
<td>$m$</td>
<td>Mass of oil</td>
<td>kg</td>
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<tr>
<td>$Q_{oil}$</td>
<td>Heat absorbs by the oil</td>
<td>W</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>Temperature difference</td>
<td>K</td>
</tr>
<tr>
<td>$\nabla T$</td>
<td>Temperature gradient</td>
<td>K/min.</td>
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<tr>
<td>$T$</td>
<td>Temperature in any time</td>
<td>K</td>
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<tr>
<td>$T_{max}$</td>
<td>Maximum temperature</td>
<td>K</td>
</tr>
<tr>
<td>$T_{amb}$</td>
<td>Ambient temperature</td>
<td>K</td>
</tr>
<tr>
<td>$\Delta t$</td>
<td>Time difference</td>
<td>min.</td>
</tr>
<tr>
<td>$R$</td>
<td>Thermal resistance</td>
<td>K/W</td>
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INTRODUCTION

A thermosyphon is a device of heat-transfer instrument (passive devices) which combine the principles of both phase transition and thermal conductivity to efficiently handle the heat of transfer between two mediator. The material of the thermosyphon is made from a material with higher thermal conductivity and compatible with working fluid, for example water for copper thermosyphon and ammonia for aluminum thermosyphon. The thermosyphon always contains two phases liquid and vapor over the operating temperature range, Vanyasree [2017] and Piyush [2007]. The thermosyphon is composed of two parts which are evaporator section and the condenser section as shown in Figure(1), Stéphane [2009]. Figure (1) shows the working mechanism of the thermosyphon. When a heat is applied to evaporator section the working fluid will be evaporated and flow upwards to the condenser section. In the condenser section the vapor will be condensation on the internal wall due low temperature. The condensation liquid flows downwards on the internal wall to the evaporator section as a thin film due to the gravity effect, Kannan [2014]. The effect of condenser lengths of a vertical thermosyphon with different flow rates to condenser and different inputted heat to evaporator had been investigated experimentally, Anjankar [2012]. It has been found that higher performance of thermosyphon would be achieved with condenser of longer length. The effect of inclination and filling ratio on the evaporator section of a thermosyphon have been investigated by previous studies Khazaee [2010] and Ong [2011]. The results presented that the boiling period was decreased as the heat load increased, while increased as the filling ratio increased. An experiment of a numerical model was developed by other works Toshiaki [2014] and Hamidreza [2014] to simulate the operation of thermosyphon by using various working fluids and filling ratios. It was found that the flux of heat at the beginning fluctuation of the temperature was increased as connecting pipe size increased. The objective of the present study is to investigate the effect of the various condenser lengths on the performance of a water filled thermosyphon to determine a better condenser length.

EXPERIMENTAL PROCEDURE

Figure (2) shows the experimental apparatus of the testing used in this work. The thermosyphon was made from copper tube having an internal diameter of 26 mm and external diameter of 28 mm. The experiments were carried out with different lengths of condenser section with a constant evaporator length of 120 mm for different thermosyphon as shown in Figure (3). The working fluid of distilled water with 50% filling ratio The heat was applied to the evaporator section via heating electrical transformer oil while the condenser section was subjected to the ambient temperature that surrounding the thermosyphon. Temperatures were measured with five Type-K thermocouples, as shown in Figure 1b. The thermosyphon was first charged with water and then fully evacuated to -760 mm Hg. Temperatures were logged every minute using temperature recorder. The electrical transformer oil heated by external heater with power of 700 W. The oil was heated from ambient temperature to approximately 80 °C and then the heater power has been switched off once the system cooled naturally while the condenser part was cooled naturally by air.

CALCULATIONS

The thermal performance tests of thermosyphon were performed and the rate of heat transfer \( Q_{oil} \) for the oil was calculated by the following equation, Ahmet [2018].
Where $m$, $c_p$, are the mass and specific heat of oil and $\Delta T$, temperature difference.

Oil specific heat can be calculated by following equation, Alejandro [2018].

$$c_p = 807.163 + 3.58 \times T$$  \hspace{1cm} (2)

$T$: Is the oil temperature (K)

Where the dimensionless temperature was equal to:

$$\text{Dimensionless temperature} = \frac{T - T_{\text{amb}}}{T_{\text{max}} - T_{\text{amb}}}$$  \hspace{1cm} (3)

Temperature gradient ($\nabla T$) = $\frac{\Delta T}{\Delta t}$  \hspace{1cm} (4)

Percentage decrease in the temperature gradient equal to:

$$\nabla T\% = \frac{\nabla T_{\text{without thermosyphon}} - \nabla T_{\text{with thermosyphon}}}{\nabla T_{\text{without thermosyphon}}} \times 100\%$$  \hspace{1cm} (5)

The thermosyphon thermal resistance is given by the following equation, Vanyasree [2017]:

$$R = \frac{T_e - T_c}{Q}$$  \hspace{1cm} (6)

**RESULT AND DISCUSSION**

Figures (4), (5) and (6) show the relation between the temperatures distribution along the thermosyphon wall and the time of different condenser lengths which were 400 mm, 500 mm and 600 mm respectively. These figures show that the curves were wobbling at condenser section, which increasing from the bottom to the top of the condenser section firstly, and secondly increasing when the length of the condenser section increased. This is due to forming a thin film of the condensation liquid on the internal wall of the thermosyphon. Also this thin film of the condensation liquid become thicker toward the bottom of the condenser section as shown in Figure(1). These results are backed by those of previous study, Fadas (2015). Figure(7) shows the dimensionless temperature of the heating transformer oil temperature gradient for the different thermosyphon and that without using thermosyphon. This figure shows that the temperature gradient was decreased towards increasing condenser lengths of the thermosyphon due to increasing the surface area of the thermosyphon which increases the heat transfer to the surrounding. Also, the figure shows that the heat dissipation was more in the case of using thermosyphon rather than being without using thermosyphon. Figure 8 shows the percentage of decreasing in the temperature gradient for the different thermosyphon; it had indicated that the highest percentage decreased in the temperature gradient for different thermosyphon was for the longest condenser length than the others due to highest heat dissipation. Figure (9) shows oil heat rate without and with three different condenser lengths thermosyphon. From this figure, it can be showed that the maximum oil heat was without thermosyphon but when thermosyphon was added, the heat rate was decreased and gave minimum value at condenser length of 600 mm due to higher heat dissipation. Figure (10) shows relationship between thermosyphon resistances with condenser length. From this figure, it has been noticed that, the resistance is decreased with increasing condenser length because the heat dissipation by condenser it maximum at condenser length equal to 600 mm, which lead to a higher heat transfer to the surrounding.

**CONCLUSIONS**

The importance of heat transfer capability was limited by length of thermosyphon, especially condenser section. So in this study, the effects of length of condenser section on performance of thermosyphon have been investigated. It has been found that:
- The heat distribution along the thermosyphon wall was decreased towards the tip of thermosyphon.
- It was observed that the temperature curves were wobbling at low temperature on the thermosyphon.
- The heat dissipation was increased as the condenser length increased.
- The decreasing of temperature gradient was equal to 67.94 %, 72.94 % and 77.06 % of the thermosyphon condenser length were 400 mm, 500 mm and 600 mm respectively.

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**Fig. 1. Thermosyphon schematic**

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**Fig. 2 Experimental test**
Fig. 3 Thermosyphon with three different lengths of condenser section and the same evaporator section.

Fig. 4 Temperatures distributions along the thermosyphon wall with respect to time for the condenser length of 400 mm.

Fig. 5 Temperatures distributions along the thermosyphon wall with respect to time for the condenser length of 500 mm.
Fig. 6 Temperatures distributions along the thermosyphon wall with respect to time for the condenser length of 600 mm.

Fig. 7 Dimensionless temperatures comparison for the three different thermosyphon.

Fig. 8 Percentage decreased in the temperature gradient for different thermosyphon.
Fig. 9 The oil heat with and without for the three different thermosyphon.

Fig. 10 Relationship between thermosyphon resistances with condenser lengths

REFERENCES


