Liquid cooling in the mini-rectangular fin heat sink with and without thermoelectric for CPU

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A B S T R A C T

In the present study, the liquid cooling in the mini-rectangular fin heat sink with and without thermoelectric for CPU is studied. Six mini-rectangular fin heat sinks with two different material types and three different channel widths are fabricated from the copper or aluminum with the length, the width and the base thickness of 37, 37, 5 mm, respectively. The de-ionized water is used as coolant. Effects of channel width, coolant flow rate, material type of heat sink and run condition of PC on the CPU temperature are considered. The liquid cooling in mini-rectangular fin heat sink with thermoelectric is compared with the other cooling techniques. The thermoelectric has a significant effect on the CPU cooling of PC. However, energy consumption is also increased. The results of this study are expected to lead to guidelines that will allow the design of the cooling system with improved heat transfer performance of the electronic equipments.

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1. Introduction


To the best of author’s knowledge, the papers presented the study on the heat transfer and pressure drop in the minichannel and micro-channel have been reported. However, only few works reported on the heat transfer characteristics of the mini-rectangular fin heat sink with and without thermoelectric. The objective of this paper is to study on the heat transfer characteristics of the mini-rectangular fin heat sink with and without thermoelectric of CPU of PC. Effects of relevant parameter on the cooling CPU are considered.

2. Experimental apparatus and method

A schematic diagram of the experimental apparatus is shown in Fig. 1. The test loop consists of a set of PC, cooling de-ionized water loop and data acquisition system. The test section and the connections of the piping system are designed such that parts can be changed or repaired easily. The close-loop of de-ionized water consists of a $10^{-3}$ m$^3$ storage tank, water pump, flow meter, and radiator. The cooling de-ionized water is chilled by the atmospheric air. After the temperatures of the water are cooled to achieve the desired level, the cooling water is pumped out of the storage tank, and is passed through a flow meter, CPU and returned to the storage tank. The flow rates of the cooling water are controlled by adjusting the valve and measured by the flow meter with the accuracy of ±0.2% of full scale. The test sections fabricated from the blocks of copper or aluminum with the details are listed in Table 1. The measured temperatures of cooling water at various positions are shown in Fig. 1.

De-ionized water was used as coolant. The de-ionized water was pumped into the mini-rectangular fin heat sink which installed on the hot side of thermoelectric and the CPU of PC, respectively. The inlet temperature of coolant water before entering the cooling section was kept nearly constant of 28–30 °C. The mini-rectangular fin heat sink unit was shown in Fig. 2. Experiments were conducted with various cooling water flow rates, channel width of heat sink, material type of heat sink and run condition of PC. The supplied load into the CPU was adjusted to achieve the desired level by setting run condition of PC.

### Table 1

Dimensions of the mini-rectangular fin heat sinks

<table>
<thead>
<tr>
<th>Channel</th>
<th>Fin height (mm)</th>
<th>Fin size (mm)</th>
<th>Channel width (mm)</th>
<th>Size of heat sink (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>4</td>
<td>1.00*1.00</td>
<td>0.50</td>
<td>37<em>37</em>5</td>
</tr>
<tr>
<td>Aluminum</td>
<td>4</td>
<td>1.00*1.00</td>
<td>1.00</td>
<td>37<em>37</em>5</td>
</tr>
<tr>
<td>Aluminum</td>
<td>4</td>
<td>1.00*1.00</td>
<td>1.50</td>
<td>37<em>37</em>5</td>
</tr>
<tr>
<td>Copper</td>
<td>4</td>
<td>1.00*1.00</td>
<td>0.50</td>
<td>37<em>37</em>5</td>
</tr>
<tr>
<td>Copper</td>
<td>4</td>
<td>1.00*1.00</td>
<td>1.00</td>
<td>37<em>37</em>5</td>
</tr>
<tr>
<td>Copper</td>
<td>4</td>
<td>1.00*1.00</td>
<td>1.50</td>
<td>37<em>37</em>5</td>
</tr>
</tbody>
</table>
The consumption electrical power of the PC was measured by the watt-hour meter. The temperatures at each position were recorded in the period time of 200 min. Data collection was carried out using a data acquisition system (DataTaker, DT800). The uncertainty and accuracy of the measurement are given in Table 2.

### 3. Results and discussion

Each condition of the experiment was performed at the room temperature of 26–27 °C in the period time of 200 min for the steady state condition. The cooling water in the radiator was cooled by the atmospheric air at this temperature. Therefore, the inlet temperature of coolant water before entering the cooling section was kept nearly constant of 28–30 °C. In the present study, the cold side of thermoelectric is attached on the CPU of computer while the hot side of thermoelectric is attached with heat sink. The heat is removed from the cold side to the hot side when the electric current passes through the module and then removed to the heat sink. In Fig. 3, the variation of CPU temperature with time for no load and full load conditions are shown. The hot and cold side temperatures of thermoelectric depend on the input electric current. To avoid the condensation of water vapor, the input voltage of the thermoelectric was set constant of 6 volts. It can be seen from both figures that the CPU temperature is nearly constant with time. For the two heat sinks, the temperature obtained from the heat sink fabricated from the copper lower than that from the aluminum. This is because the copper gives the thermal conductivity higher than the aluminum.

Effects of cooling flow rate on the CPU temperatures for different load conditions of the copper heat sink with the channel width of 0.5 mm are shown in Fig. 4. For the four different coolant flow rates, a larger CPU temperature drop is found for a larger coolant flow rate. A larger coolant flow rate results in lower capacity resistance and consequently lower heat sink thermal resistance.

Fig. 5 shows effect of channel width of heat sink on the CPU temperature of PC for no load condition and full load condition. Due to higher heat transfer surface area, the heat transfer rate from CPU to the heat sink increases. Therefore, the CPU temperatures obtained from the heat sink with lower channel width are lower than those from higher especially for full load condition. It can be seen from figure that the CPU temperatures for the full load condition are higher than those from the no load condition for the whole range of the period time as shown in Fig. 6. This is because the full load condition generates the heat higher than the no load condition. The CPU temperatures obtained from the liquid cooling for mini-rectangular fin heat sink with thermoelectric are compared those from the other cooling techniques as shown in Fig. 7. It can be seen from both figures that the liquid cooling with thermoelectric gives the CPU temperature lower than other systems especially for no load condition. The thermoelectric has significant effect on heat transfer from the CPU as shown in Fig. 8. The basic TEC operating principle can be found in the thermoelectric text book [31].

The CPU temperature and the energy consumption obtained from the water cooling without thermoelectric technique, water cooling with thermoelectric technique, air cooling with heat pipe technique, are compared with those from the conventional air cooling technique.

### Table 2

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Accuracy</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage supplied by power source, (volt)</td>
<td>0.2%</td>
<td>±0.5</td>
</tr>
<tr>
<td>Current supplied by power source, (ampere)</td>
<td>0.2%</td>
<td>±0.5</td>
</tr>
<tr>
<td>Flow meter</td>
<td>0.2%</td>
<td>±0.5</td>
</tr>
<tr>
<td>Thermocouple type T, Data logger, (°C)</td>
<td>0.1%</td>
<td>±0.1</td>
</tr>
</tbody>
</table>
Fig. 3. Effects of heat sink material type on CPU temperature for (a) no load conditions and (b) full load conditions.

Fig. 4. Effects of coolant flow rate on CPU temperature for (a) no load conditions and (b) full load conditions.

Fig. 5. Effects of channel width on CPU temperature for (a) no load conditions and (b) full load conditions.
where the plus symbol is represented the higher value while the minus symbol is represented the lower value as compared with the value from the air cooling technique. It can be seen from Table 3 that thermoelectric has significant effect on the cooling of the CPU of PC, however, the energy consumption is also increased especially for full load condition. In addition, the water cooling with thermoelectric give the largest CPU temperature drop and the largest energy consumption. While the water cooling without thermoelectric gives a larger CPU temperature drop while the energy consumption slightly increases.

4. Conclusions

Due to the air cooling limitation of the electronic devices with high level of heat generation, the liquid cooling in the mini-rectangular fin channel heat sink with and without thermoelectric for CPU has been investigated with de-ionized water as working fluid. Effect of thermal conductivity and channel width of heat sink, coolant flow rate and run condition of PC on the CPU temperature are considered. The results obtained from this technique are compared with those from other cooling techniques. The results of this study are expected to lead to guidelines that will allow the design of the cooling system with improved heat transfer performance of the electronic devices.

Table 3

<table>
<thead>
<tr>
<th>Cooling techniques</th>
<th>CPU temperature</th>
<th>Energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No load</td>
<td>Full load</td>
</tr>
<tr>
<td>Water cooling with thermoelectric</td>
<td>−68.4%</td>
<td>−1.8%</td>
</tr>
<tr>
<td>Water cooling</td>
<td>−13%</td>
<td>−10.4%</td>
</tr>
<tr>
<td>Air cooling with heat pipe</td>
<td>−3.2%</td>
<td>−7.8%</td>
</tr>
</tbody>
</table>

Fig. 6. Variations of CPU temperature with time for different load conditions.

Fig. 7. Effects of cooling technique on CPU temperature for (a) no load conditions and (b) full load conditions.

Fig. 8. Effects of cooling technique on cooling rate for full load conditions.
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References


