Surface Temperature Distribution of Aluminum Fins Heated using Thermoelectric

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Abstract. The thermoelectric device has advantages for heating and cooling element. The thermoelectric can be used easily as a heater. In applications for small volumes, the temperature distribution of the heating element is necessary to ensure that different samples at different locations receive the same heat treatment. This experiment shows an aluminum fin's temperature distribution heated using different heat amount. TEC-12706 was used to heat an aluminum fin with a dimension of 40x40x20 mm. The aluminum was placed in a chamber made using a 3D printer with a material of ABS. The surface temperature distribution of the aluminum fin was measured using a thermal camera Fluke-Ti20S. The measurement data showed that the fin's surface temperature is not the same at all points at the surface, especially the center and the edge. During the heating process, the temperature at the aluminum fin's center has a higher temperature than the fin's edge. The lower the duty cycle used, the better the temperature distribution on the heat sink. For 50% duty cycle or more, the temperature variation in the middle with a square dimension of 20x20 mm has a temperature variation of less than 1°C. Therefore, if the temperature distribution between points is important, it is recommended to use an aluminum fin around the center.

1. Introduction

Many material testing samples, sensors work, chemical reactions, material characteristics relate to temperature. In most cases, the temperature needs to be controlled, including the distribution. Temperature control can be performed by using many devices. Controlling object temperature requires a heater and cooler [1].

A Thermoelectric Cooler (TEC) can be used easily as a heater dan cooler [2]. TEC is known as green energy and has no moving parts [3]. The heating or cooling speed to achieve a temperature target can be controlled by the current flow to the thermoelectric [4]. TEC itself needs a heatsink or cooling system to release the dissipated heat during the cooling process [5]. To obtain fast heat dissipation from TEC, an active cooling is used instead of passive cooling [6].

Aluminum is commonly used as a heatsink, but it can be used as a heat spreader in a chamber. The physical form of the heatsink is usually in the form of a fin type. Using the fin shape, the surface area in contact with the gas or liquid object becomes larger, thereby increasing the heat transfer process. In an application where a homogeneous temperature distribution is a critical aspect, the aluminum fin's temperature distribution is crucial. The temperature distribution in a fin depends on the height of the fin to the bottom plate [7]. Different fin shapes contributed to heat distribution [8]. However, there is no adequate information on how good the temperature distribution is at the aluminum fin when heated from the bottom. The effect of the heat flows to the fin's surface temperature was also not reported. This experiment shows an aluminum fin's temperature distribution heated using different heat amount. The variation of the heat was given using a thermoelectric, TEC-12706. The heat was controlled by using the given current to the TEC by pulse width modulation control.
2. Material and Method

The experiment's material consists of a chamber, thermoelectric, aluminum heatsink, copper cooler, and a microcontroller control system. The chamber was made by a 3D printer using ABS material, a chamber with an open section on the upper side. The chamber wall has a thickness of 1cm. The part of the chamber that opens at the top has an area of 40×40 mm.

The thermoelectric used is TEC-12706 with a dimension of 40×40×3.9mm. The TEC-12706 has a maximum current of 6A at a voltage of 12V. The aluminum heatsink fin with a dimension of 40×40×20 mm is affixed to the top of the TEC surface with the fins facing up. The TEC's bottom is attached to the copper block of a cooling water system. Figure 1 shows the construction of the measurement system. The contacts between TEC and heatsink and TEC and cooper block were done directly without thermal paste. The temperature sensor was placed in the middle of the heatsink. Figure 1 shows the chamber construction.

![Figure 1. Chamber construction.](image1)

Many control system methods are used to control the thermoelectric, including PID and Fuzzy [9]. However, this study only applies an on/off control system with a temperature sensor functioning as a feedback signal for the control system. Heating and cooling were done by providing current to the TEC using the PWM method [10].

The temperature distribution on the aluminum surface was measured using a thermal camera, Fluke Ti20s. The camera is positioned perpendicular to the aluminum surface with a distance of 12cm. Data recording is done automatically by recording the temperature of the aluminum and capturing the temperature image. Measurement data is transferred and stored on a computer. Figure 2 shows the measurement system configuration. The measured chamber with aluminum heatsink was placed under the Fluke Ti20s.

![Figure 2. Measurement configuration.](image2)

The heating process is carried out using a 490 Hz PWM value at a duty cycle of 50%, 70%, 90%. Data collection starts at 45°C. Thermal Image data were taken every 10 seconds with the help of the
auxiliary servo. It was carried out until the temperature reached 95°C. These steps are repeated with the
next duty cycle.

3. Result and Discussion
The data obtained consists of the NTC sensor's temperature, the average current flowed to the TEC, and
the temperature distribution as image data. Figure 3 is the data retrieved by the software. The figures
show the heatsink temperature, current to the TEC, and a time and temperature where the temperature
images were taken. The heating process with PWM 50% obtained 12 temperature image data, 70%
PWM obtained nine temperature image data, and 90% duty cycle obtained seven temperature image
data. Only data in the temperature range 80-90°C was chosen to be compared among duty cycles.

![Graphs of Temperature, Current, and Thermal Imaging Capture Data](image1)

**Figure 3. Temperature, current, and Thermal imaging capture data.**
(a) 50% duty cycle. (b) 70% duty cycle. (c) 90% duty cycle.

The temperature image data from Fluke-Ti20S is a temperature matrix of 240x320 points. With the
given distance at 12cm, the image covered the chamber and its surrounding. As the concern is the
chamber temperature, the data were cropped accordingly. The interest area is located between the x and
y coordinates (55, 20) and (255, 220). An area of 200 x 200 points represents 4x4cm, which is the TEC
area used. Figure 4 shows an example of cropped temperature data in the area of interest.

The TEC consists of two or more n-type and p-type elements of a doped semiconductor material.
They are connected electrically in series and thermally in parallel. In the middle of the TEC, this element
is surrounded by other elements. The heat generated by the PN semiconductor cells flows to the ceramic
plates of the TEC. The heat was dissipated to the heatsink attached to the TEC's hot side and the edge
side. It was expected that the temperature in the middle of the heatsink should be higher than the edge.

Figure 5 (a) depicts the heatsink's surface temperature using the 50% duty cycle. The temperature
data was taken when the temperature sensor in the heatsink indicated 83.4°C. It can be seen that the
green color dominates almost all parts of the chamber. This green color represents a temperature of
around 83°C. The deviation from the bounded part of the profile line is 0.67°C. The color distribution,
which represents the temperature distribution, shows the temperature distribution at those temperatures almost cover all parts of the TEC except for the black part. The black color was set for the temperature below 80.40°C.

![Temperature data on the area of interest](image)

Figure 4. Temperature data on the area of interest.

![Contour plot of the aluminum heatsink](image)

(a) 50% duty cycle. (b) 70% duty cycle. (c) 90% duty cycle.

Figure 5. Contour plot of the aluminum heatsink. (a) 50% duty cycle. (b) 70% duty cycle. (c) 90% duty cycle.

Figure 5 (b) represents the surface temperature obtained using the 70% duty cycle. The temperature read by the sensor was 85.3°C. The deviation from the bounded part of the profile line is 0.74°C. The plot has a slightly larger temperature difference than the 50% duty cycle ones, indicated by more blue distribution, especially in the corner area. These two contour data illustrate that the heat distribution in the middle of the surface is higher than the other. The black color was set for the temperature below 81.40°C.
Bigger temperature different and much smaller area with similar temperature was observed when the heatsink was heated using TEC driven using 90% duty cycle. Figure 5 (c) shows the aluminum heatsink's temperature distribution when heated using TEC with a 90% duty cycle. The temperature value read by the sensor was 88.04°C. The deviation from the bounded part of the profile line is 0.97°C. Just like before, these values are around yellow and green. The average temperature represented in green appears to be narrower. The blue color and even the black color become more dominant, indicating that this section has a large enough difference. The black color was set for the temperature below 84.40°C.

It is not yet clear the origin of the narrower area, which has a homogeneous temperature when the TEC was driven with a high duty cycle. By comparing those three figures, we can say that to achieve a wider homogeneous temperature distribution on the heatsink should be done using the 50% duty cycles. However, the time to reach the desired temperature is longer.

4. Conclusion
This experiment shows that the higher the value of the duty cycle used, the narrower the area, which has a homogeneous temperature. The lower the duty cycle used, the better the temperature distribution on the heatsink. For a duty cycle of 50% or more, temperature variation in the center with a square dimension of 20×20 mm at 40×40mm TEC has a temperature variation less than 1°C.

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