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Experimental Study of Thermoelectric Module Utilization as Water Heater

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Abstract:

In this study, the utilization of thermoelectric module (TEM) for water heater is evaluated. 200 ml of water inside stainless steel container is heated up by using TEM SP-1848 27145 SA. The bottom of container is contacted to the hot side of thermoelectric module. The increase of water temperature is measured by using DS18B20 sensor. The electrical power consumption is also calculated by measuring voltage and current on the TEM. Heating efficiency of the system is then evaluated at several set point temperature from 25 ºC to 60 ºC and various volume of water from 50 mL to 200 mL. The highest heating efficiency is achieved 93% at 45 ºC of set point temperature with 150 mL of water volume.

INTRODUCTION

Thermoelectric module (TEM) is a device made of number of thermoelectric material pellets which are connected electrically serial and thermally parallel. Thermoelectric module can act as electrical generator by creating temperature difference between the two side of TEM and heat pump by supplying DC current to the module [1].

The TEM has many advantages in which no moving part, compact, and no need working fluid. However its efficiency is much lower than other conventional technology [2]. Therefore many studies are conducted to achieve higher efficiency by investigate the thermoelectric material and geometry for TEM [3].

The development of thermoelectric module allows wide of applications. The harnessing of heat dissipation from CPU processor to produce electrical energy has been studied by N. H. Pranita *et al* [4]. Heat waste from automobile for electrical generator have also been studied [5-6]. The cooling system based on thermoelectric module is also conducted in many studies [7-9]. Moreover, since the TEM has advantages easy to control, this technology is also used for thermal conductivity measurement [10-11].

In this study, the utilization of thermoelectric module for water heater is experimentally conducted. The change of water temperature and electrical current are observed during heating process. The highest heating efficiency is also investigated by varying the set point temperature and volume of water.

EXPERIMENTAL SETUP

Figure 1 shows the experimental set up of the experiment. Water container is made of stainless steel with diameter of 5.5 cm and height of 11 cm. The insulation layers were attached on the wall and the top of container to reduce heat losses to the surrounding. Thermoelectric module SP 1848 27145 SA is used as heater and is attached under the container. The hot side of the module was contacted to the container. The cold side of the module is contacted with heat sink and fan.

During the experiment, 12 V DC voltage is supplied to the TEM by DC power supply. The relay is automatically opened if the set point temperature achieved so the system is not connected to the power supply. While, it is closed again if the temperature lower than set point. Arduino system was used as controller. For the measurement, DS18B20 was used as temperature sensor then temperature of water is read using LCD display. The scheme of electrical system in this experiment is shown in figure 2.

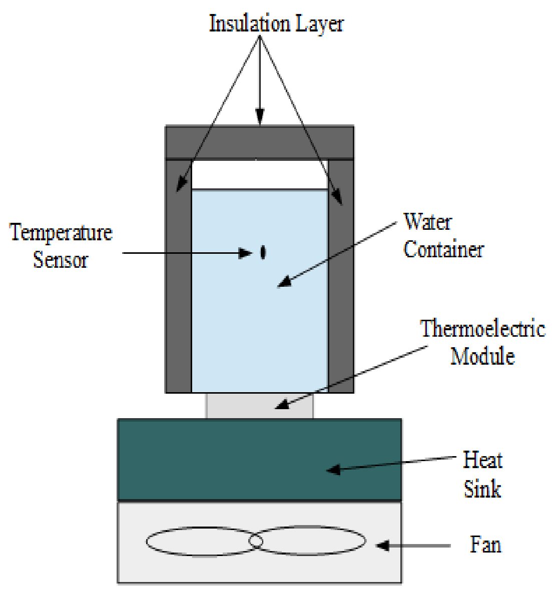


Figure 1. Experimental setup

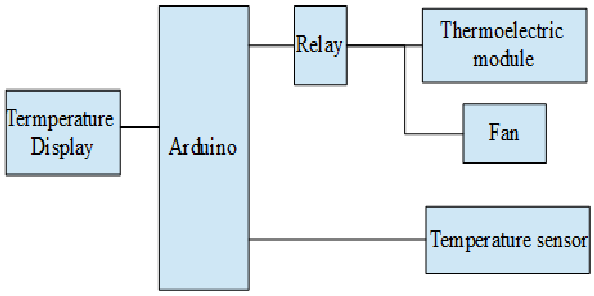


Figure 2. Electrical scheme of experiment

First experiment was to observe the thermoelectric module to heat 200 ml of water without controller where the system keep turning on until steady state condition achieved. Second experiment was to investigate the heating efficiency of system at various condition, i.e several set point temperature and volume of water.

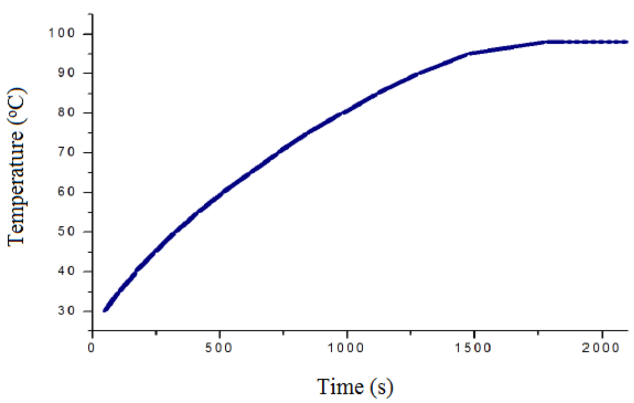
The heating efficiency of the system is the ratio between heat absorption in the water to the electrical energy input to the system. It was calculated by:

$$\eta = \frac{m_w c(T_f - T_i)}{P_{el} t}$$

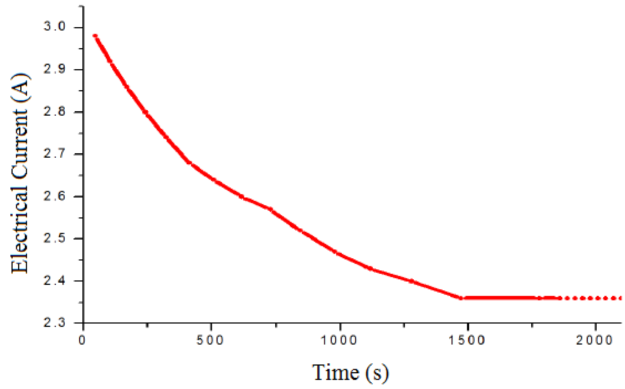
Where m_w is the mass of water (kg), c is the specific heat of water (J/kg.K), T_f is final temperature of water (°C), T_i is initial temperature of water (°C), P_{el} is electrical power consumed by the module (W), t is time duration of heating (s).

RESULT AND DISCUSSION

In the first experiment, the increases of temperature during heating process is shown in figure 3 (a). The water initially was at ambient temperature. Then, the temperature increases until maximum at 98 °C in 1781 second. After that, the water remains at the same temperature. At this steady condition the water is near the saturation temperature of water, thus the water latent heat is dominant and causes no temperature increases.



(a)



(b)

Figure 3. (a) The increase of temperature without controller, (b) Electrical current on Thermoelectric module

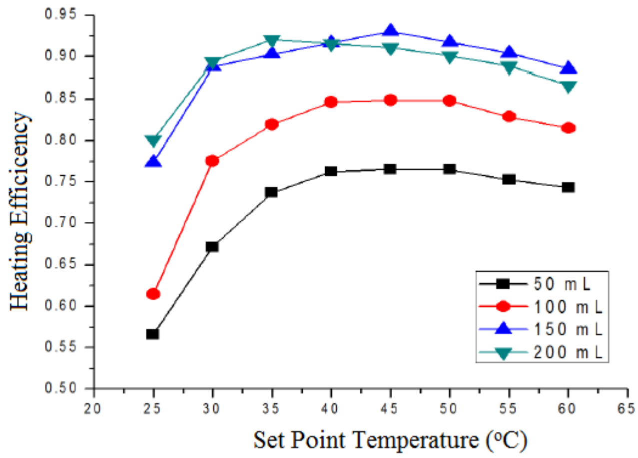


Figure 4. Heating efficiency of the system

The electrical current during heating process is shown in figure 3 (b). It tends to decreases until one point temperature. The electrical current initially at around 3 A, then finally stays at 2.36 A. The TEM properties i.e Seebeck coefficient, thermal resistance, and electrical resistance are changed by temperature. Electrical resistance increases at higher temperature [12]. This phenomena causes the decrease of electrical current since the input voltage was constant. It also means that the power consumption high at the beginning of heating process when the TEM temperature is still low.

The investigation of heating efficiency of system to increase the water temperature at specific set points are shown in figure 4. The volume of water varies from 50 mL to 200 mL with the increment of 50 mL. In this experiment the heating process is controlled by arduino at various set point temperature of 25 °C to 60 °C. The heating efficiency of all volume have the same trend which is increase significantly at the beginning and then slightly decrease. The heating efficiency is higher at more volume. However the difference between 150 mL and 200 mL is not significant.

At low volume of water, the heat absorbed by water is less since the container is much empty. It causes the heat loss increases. The electrical current is not significantly changed. This causes low heating efficiency. Based on the result the highest efficiency of the system is achieved at 45 ºC set point with 150 mL of water.

CONCLUSSION

In this study, the experiment to investigate the utilization of thermoelectric module for water heater is performed. 200 mL of water is heated from ambient temperature to 98 ºC is 1781 second. The electrical current decreases from around 3 A to 2.36 A during the experiment. The highest heating efficiency of system is obtained at 150 mL of water with 45 ºC of set point temperature.

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