A study on the potential of Peltier in generating electricity using heat loss at engine system

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ABSTRACT – In the era of globalisation, the electrical energy usage is the main priority in order to do our job and daily activity. Unfortunately, limited power supply for the electrical energy usage makes it hard to continuously provide electrical energy for 24 hours. By using Peltier device, it is possible to develop a portable generating system using heat loss in machines and vehicles. The generating system theoretically can recycle the heat loss to produce additional electricity for other usage. Generally, the objective of the generating system is to study on the potential of Peltier device to generate useful electricity for additional power supply using heat loss. This generating system can be applied on many types of machines and other type of mechanism such as vehicle that release heat loss. Therefore, the result obtain in term of voltage can be generated by the generating system. As a result, this system has higher efficiency which 12.59% compared to 6% using proper heat sink using the same module.

1. INTRODUCTION

Generally, a Peltier device is an intelligence device that can operate for cooling system by supplying voltage to the device to eject hot and cold air. The cold air will be used for cooling system. Reversely, the device can generate electricity by absorbing heat without supplying any voltage to power up the Peltier device based on W. Thomson in 1851 rewrite Thomas Johann Seebeck foundation on "Seebeck effect" in 1821. In Seebeck effect theory, the electrons in the semiconductor act as transferring agent to transfer the heat from one medium to another medium according to the law of thermodynamics. In this case, the application where the energy conversion system applied is on vehicle engines and exhaust system. Based on Electrical Energy Conversion (E2C) past research at the KTH School of Electrical Engineering 2011, all machines are not working 100% effectively, most appears to work only 70% to 80% effectively as shown in Figure 1 [1].

Meanwhile, the other 30% to 20% are released into energy loss in term of heat. In order to recover the heat loss, this project will design a portable generating system using Peltier device to produce electricity by absorbing heat loss.

2. METHODOLOGY

The basic operations for the device have been discovered for many years by Thomas Seebeck in 1821 where the temperature difference is established between hot and cold npn junction type semiconductors. Heat loss will be absorb on the hot side and leaving to the cold side of the Peltier device as shown in Figure 2. During the process, the electrons in the npn semiconductor will active and vibrate due to heat then collides with each other in order to release the heat to the cold side. The result is voltage will be produced due to Seebeck effect.

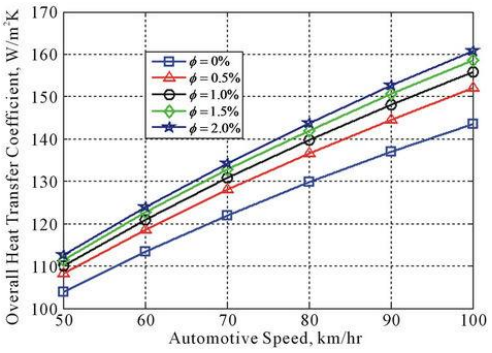

Figure 1 Heat loss in car engine.

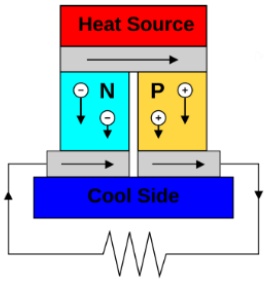

Figure 2 Heat transfer from hot to cold side.

The hot side absorbs heat loss at rate of T_H high temperature ejected by the system and transfer the heat to the cold side to be released at a rate of T_L low temperature. By referring to Seebeck effect, the heat loss absorbed at the hot junction causes electrons to be active and electric current then flow in the npn semiconductor and electrical energy is generated. Using the thermodynamics first law energy conservation principle, the difference between T_H and T_L will generate the electrical energy output power, W_e. The heat released then enter cooling agent which is to maximize the efficiency or the output voltage generated by the device in order to achieve higher temperature gradient between both hot and cold side. The increasing

temperature difference between two junctions will increase voltage generation. The generated voltage will flow to the control circuit to provide 12V output voltage to charge battery for other usage [2].

The experimental data are tested at the engine system in order to determine the maximum efficiency for Seebeck Effect. Figure 3 shows the experimental conducted at the engine system.

Figure 3 Generating system on car engine system.

The maximum efficiency, η of a Peltier device can be defined using the figure of merit, temperatures of the hot side and cold side [3]. For this system the heat loss assume zero.

$$N = n_{carnot}\left[\frac{\sqrt{1+Z\bar{T}}-1}{\sqrt{1+Z\bar{T}}+\frac{T_L}{T_H}}\right] \quad (1)$$

Where:
T_L = Temperature Low
T_H = Temperature High

3. RESULTS AND DISCUSSION

The tests have been carried on the exhaust system and engine system to study the potential of a Peltier device to generate electricity using heat loss. Therefore, experiments have been conducted using:

- Four TEC1-12706 module connected in series
- Short fin heat sink
- Fin heat sink
- High efficient series PWM controller charging
- 12V 1.2Ah battery

The reading was taken at every 5 minutes with total of 30 minutes by considering temperature difference between hot side and cold side is being considered as shown in Table 1. The data was taken when the car stop for every 5 minutes. The car speed was limited to approximately 50 kmh. Temperature of the surrounding are 32-34 ºC which is unstable. Table 1 shows the data collected at the engine system.

Based on the data collected, the generating system with four number of TEC1-12706 modules able to generate voltage up to 12.76 V maximum. As the car engine system become hotter, the temperature difference between hot and cold side of the generating system increases. From the Figure 3, the value of voltage generated and temperature difference are increasing over time then voltage generated reach its maximum value 12.76V due to the maximum operating for four Peltier device.

Table 1 Voltage generated by four Peltier modules at engine system with temperature difference.

Time (min)	Voltage (V)	$T_{Difference}$ (ºC)
0	0	0
5	2.16	16
10	5.34	33
15	7.82	49
20	9.63	67
25	12.58	86
30	12.76	98

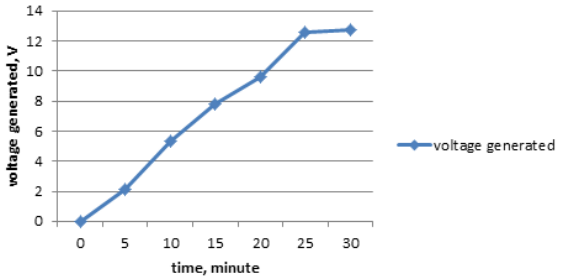

Figure 3 Voltage generated at engine system.

From the efficiency of Carnot, the maximum efficiency of the Peltier TEC1-12706 using equation (1) calculated as shown below.

$$N = n_{carnot}\left[\frac{\sqrt{1+Z\bar{T}}-1}{\sqrt{1+Z\bar{T}}+\frac{T_L}{T_H}}\right]$$

$$N = 0.7481\left[\frac{\sqrt{1+0.5711}-1}{\sqrt{1+0.5711}+\frac{33}{131}}\right]$$

=12.59%

By comparing the maximum efficiency of this generating system to past research by researcher [3], this generating system has higher efficiency which 12.59% compared to 6% using proper heat sink with the same module TEC1-12706.

4. CONCLUSIONS

In conclusion, Peltier modules TEC1-12706 are able to generate voltage from the heat loss at engine system and exhaust system of the car. Therefore, the potential of Peltier in generating electricity is accepted and the generating systems are effectively generates electricity from the heat loss of the vehicle system.

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