Application of Thermoelectric Generator TEG Type Parallel Series Electric Circuit Produces Electricity from Heat Rocket Stove

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Abstract. In rocket stove, wood is burned in a simple combustion chamber. This combustion chamber is connected by chimneys and air holes. Several studies have been carried out to utilize the heat generated by combustion of rocket stove, namely thermoelectric generators. Thermoelectric generators are electrical generator devices that convert heat energy or temperature differences into electrical energy using a phenomenon called the seebeck effect. The thermoelectric generator used in this study is TEG SP1848. How this tool works is a compilation of combustion occurs on a rocket stove then the copper pipe which is wrapped around a rocket stove flowed by water also rises in temperature, and the circulation of water from the chamber passes through a copper pipe, within 30 minutes the water in the chamber reaches 90ºC ± then it is done from the power generated by the TEG connection then the test is done by loading a resistor of 1kΩ-10kΩ. the highest generator efficiency values obtained at the 5k ohm resistor reached 5.38% of the left TEG. For TEG the right side of generator efficiency tends to be stable. The highest value of the right-side TEG generator efficiency is obtained at 0.48% at 2k ohm resistance.

Keywords: Rocket stove, thermoelectric generator, efficiency values, seebeck effect, power

1. Introduction

Rocket stove is a stove that uses small size/diameter wood as fuel. On a rocket stove, wood is burned in a simple combustion chamber. This combustion chamber is connected with a chimney and air holes[1]. Thermoelectric generator (TEG) is a type of energy generator that is based on the Seebeck effect, which in essence in the existing system in a thermoelectric generator is, if there are two metal materials (generally semi-conductors) which then continue to exist in an environment with different temperatures then in this material an electric current or electric motion will flow[2].

In previous research on using a thermoelectric generator by considering the difference in temperature and the resistance variable. The heat used in this study, from the heat source of rocket stove combustion and heatsink cooler, the results obtained in this study are the highest voltage value = 12.62 V and the highest current value = 0.087 A so that the power value is 0.00209 Watt with 10 TEG in series, the obstacles faced by this research are the electric current produced is too small and the chamber water overflows when using the test.
From previous research, we did assembly for chamber design and by adding TEG and parallel circuits to deliver the current generated from the TEG test. The heat source used is from the heat of the combustion chamber in the rocket stove. In this study, the heatsink size was enlarged so that the cooling on the cold side of the TEG was maximized so that a high temperature difference was obtained.

2. Method
This research method describes the design process and the variables to be studied.

2.1. Previous Research

Alfi Tranggono, (2019) conducted research with the rocket stove used was a tube-type rocket stove with pipe iron with a size ratio of 3: 1. The size of the rocket stove is 30 cm high with an upper hole diameter of 6 cm and a bottom 10 cm with a length of 13 cm long tube inserting wood. This rocket stove has a volume of 1497 cm³. The fuel used is stretch wood, result :

![Rocket Stove](image)

**Fig. 1. Rocket Stove**

| Table 1. Test Results for the thermoelectric generator type SP1848 |
|---------------------------------------------------------------|
| **Date:** | **Location:** | **Lab. Automotive Electricity** |
| **Type :** | **Element :** | **TEG** |
| **No.** | **Resistor (Ω)** | **Voltage (V)** | **Electric Current (A)** | **Power (W)** | **Temperature (°C)** |
| | | | | | (T1) | (T2) | (T3) | (T4) | ΔT |
| 1 | 1 kΩ | 6.28 | 0.074 | 0.46472 | 90.6 | 67.6 | 80.1 | 65.4 | 12.5 |
| 2 | 2 kΩ | 6.78 | 0.080 | 0.5424 | 95.6 | 72.1 | 80.6 | 68 | 8.5 |
| 3 | 3 kΩ | 6.59 | 0.082 | 0.54038 | 95.3 | 71.3 | 80.3 | 69.6 | 9 |
| 4 | 4 kΩ | 10.94 | 0.082 | 0.8708 | 95.6 | 50.9 | 87.5 | 47.6 | 36.6 |
| 5 | 5 kΩ | 11.01 | 0.083 | 0.9138 | 96.2 | 55.3 | 88 | 50.4 | 32.7 |
| 6 | 6 kΩ | 11.16 | 0.084 | 0.93744 | 96.6 | 53.7 | 87.7 | 44.3 | 34 |
| 7 | 7 kΩ | 12.53 | 0.085 | 1.06505 | 96.9 | 43 | 64.7 | 46.8 | 21.7 |
| 8 | 8 kΩ | 12.56 | 0.086 | 1.08016 | 96.8 | 53.6 | 87.7 | 49.2 | 34.1 |
| 9 | 9 kΩ | 12.62 | 0.087 | 1.09794 | 96.8 | 50.6 | 80.6 | 46.2 | 30 |
| 10 | 10 kΩ | 11.87 | 0.086 | 1.02082 | 96.6 | 50.6 | 79.9 | 49 | 29.3 |

ΔT is the temperature difference between the cold end of the generator thermoelectric generator and the hot end of the thermoelectric generator.

\[ \Delta T = T3 - T2 \]

T3 = Hot side temperature TEG

2
T2 = Cold side temperature TEG

a) Thermoelectricity on Rocket Stoves in Series

Jojo Sumarjo et al, (2017) conducted a study on the use of heat sources on stoves using 10 thermoelectric generators arranged in series for lighting applications. In this study, the results of measurements, calculations and power analysis that utilize the heat of a fuel stove (firewood, LPG gas and methylated spirits) are obtained.

Thermoelectric Generator System is able to generate electrical energy by utilizing temperature differences, the average results obtained from the overall test $\Delta T$. Thermoelectric $T_{av} = 26 \degree C$ with $V_{av} = 1.08$ volts. The impact of using different fuels (firewood, LPG gas and methylated spirits) affects the temperature difference in the thermoelectric so that it also affects the source of the output voltage provided by the thermoelectric. (firewood $\Delta T$. thermoelectric $T_{av} = 25\degree C$ produces $V_{av} = 1.16$ volts, LPG gas $\Delta T$. thermoelectric $T_{av} = 33\degree C$ produces $V_{av} = 1.43$ volts and spiritus $\Delta T$. thermoelectric $T_{av} = 18\degree C$ produces $V_{av} = 0.66$ volts).

This system has not been able to charge the battery (battery), this is because the voltage source obtained is not sufficient to charge the battery. The temperature difference required by the thermoelectric greatly affects the output voltage. The placement of the thermoelectric installation in the system under study was not taken into account so that the absorption of heat energy was not optimal[3].

b) Thermoelectric Thermal Energy Conversion System

The Peltier element is an important part of the thermoelectric generator. Both sides of the Peltier element are made of ceramics. The ceramics have the functions of hot and cold sides, and then generate positive and negative currents. If the values of Voltage (V) and Current (A) have been obtained, the Peltier power can be calculated based on the equation[4]:

$$ P = V \cdot I $$

Where:
- $P$ = electric power (Watt)
- $V$ = voltage (Volt)
- $I$ = current (ampere)

By adding equation 1 to equation 2, we get[2]:

$$ P = I^2 \cdot R $$

Where:
- $R$ = Resistance (Ohm)

The energy received by the thermoelectric generator module uses the equation with the formula[5]:

$$ Q = M \cdot C \cdot \Delta T $$

Where:
- $Q$ = heat absorbed (joules)
- $M$ = mass of object (kg)
- $C$ = specification heat ($J / kg \degree C$)
- $\Delta T$= difference in temperature ($\degree C$)

Generator efficiency ($\eta_G$) can be calculated by the equation[6]:

\[ \eta_e = \frac{P_a}{Q_H} \times 100\% \] (4)

2.2. Literature Review

a) Rocket Stove

Rocket stove is a stove that uses wood fuel with a small size / diameter as its fuel. On a rocket stove, wood is burned in a simple combustion chamber. This combustion chamber is connected with a chimney and air holes[1].

b) Thermoelectric Generator (TEG)

Thermoelectric technology functions to convert thermal energy into electrical energy directly (TEG), or with the principle of the Peltier effect, from electricity to produce a temperature difference (TEC). To generate electricity, the TEG device is in direct contact with a series of hot and cold sources. Depending on the type of material used, direct current will be generated from the circuit[2]. The thermoelectric plant (TEG) is a power plant based on the Seebeck effect, which was first discovered in 1821 by Thomas Johann Seebeck. The Seebeck concept illustrates that when two connected semiconductor metal materials are in an environment with two different temperatures, the material will flow electric current or electromotive force[7].

3. Results

3.1. Data

In the process of testing the SP1848 thermoelectric generator, it is divided into two stages, namely: preparing the test equipment and testing the SP1848 thermoelectric generator. Prepare the test equipment in advance, namely the DC voltage clampmeter, DC clampmeter, thermocouple thermometer, and multimeter.

a) DC Clamp Meter

The function of the clamp meter is to measure the electric current and the voltage generated by the thermoelectric. In this study, the UNI-T model UT210 digital clamp meter is used to measure electric current, while measuring the voltage uses the digital clamp multimeter UNI-T model UT200.

b) Thermocouple

Thermocouple serves to measure temperature. In this study using the XINTEST thermocouple model HT-9815.

c) Multimeter

The multimeter in this study will be used to measure the resistance to the potentiometer resistor is the Heles brand UX369 TR multimeter, the following are the specifications:
1. Prepare rocket stove fuel, namely dry wood to heat the water in the chamber.
2. Then enter the water into the chamber.
3. Then position the thermocouple temperature measuring instrument in the chamber with the following arrangement:
4. Install the thermocouple like figure above.
5. Then install all measuring instruments according to the test scheme plan. The figure below is a test scheme:
Fig. 5. Implementation of the SP1848 TEG test

After testing and collecting thermoelectric data from the TEG SP1848 generator, the data will be calculated according to the steps in the research method. The calculated data is the power data generated from the thermoelectric generator. The following table shows the test results of 20 SP1848 thermoelectric generators assembled in series and parallel.

The ΔT in the table above is the temperature difference between the TEG on the hot side of T4 and the TEG on the cold side of T2. Through the above test, it is found that the maximum voltage is 3.20 volts and the maximum current is 0.151 amperes. According to formula 2.2, you will get 0.4832Watt power. Then, the data results and the thermoelectric calculation results of the SP1848 generator are generated in graphical form. The figure shows the performance characteristics. The test result data or thermoelectric performance characteristics of SP1848 generator are as follows:

Fig. 6. Graph of electric voltage to temperature differences

Fig. 7. Graph of electric current to temperature differences
a. Current (Ampere) to temperature difference ($\Delta T$).
b. Electric power (Watt) against temperature difference ($\Delta T$).

![Graph](image)

**Fig. 8.** Graph of electric power against temperature differences

### 3.2. Discussion

After obtaining the test data and calculating the data according to the steps in the research method, the last step is to calculate the efficiency value of the generator. The calculation results of the generator efficiency value can be found in Table 4.2 and 4.3: Table 3.5 The generator efficiency value on the right side of the chamber.

#### Table 2. Generator efficiency values of the right side of the chamber

| No | Resistor ($\Omega$) | Temperature $T_h$ (°C) | Temperature $T_c$ (°C) | Object Mass (Kg) | C (specific heat) | $\Delta T$ (°C) | Q (Joule) | $\eta_G$ (%) |
|----|-------------------|------------------------|------------------------|------------------|------------------|----------------|-----------|-------------|
| 1  | 1 KΩ              | 58,6                   | 57,8                   | 0,05             | 450              | 0,7            | 15,75     | 2,73        |
| 2  | 2 KΩ              | 58,1                   | 57,3                   | 0,05             | 450              | 0,8            | 18        | 2,65        |
| 3  | 3 KΩ              | 58,4                   | 57,7                   | 0,05             | 450              | 0,7            | 15,75     | 3,04        |
| 4  | 4 KΩ              | 58,3                   | 57,8                   | 0,05             | 450              | 0,5            | 11,25     | 4,25        |
| 5  | 5 KΩ              | 58,6                   | 58,2                   | 0,05             | 450              | 0,4            | 9         | 5,38        |
| 6  | 6 KΩ              | 59,7                   | 59,3                   | 0,05             | 450              | 0,4            | 9         | 5,36        |
| 7  | 7 KΩ              | 60,7                   | 60,3                   | 0,05             | 450              | 0,5            | 11,25     | 4,25        |
| 8  | 8 KΩ              | 61,4                   | 60,8                   | 0,05             | 450              | 0,6            | 13,5      | 3,5         |
| 9  | 9 KΩ              | 61,2                   | 60,7                   | 0,05             | 450              | 0,5            | 11,25     | 4,25        |
| 10 | 10 KΩ             | 62,3                   | 61,5                   | 0,05             | 450              | 0,8            | 18        | 2,69        |

#### Table 3. The efficiency value of the generator from Teg to the left of the chamber

| No | Resistor ($\Omega$) | Temperature $T_h$ (°C) | Temperature $T_c$ (°C) | Object Mass (Kg) | C (specific heat) | $\Delta T$ (°C) | Q (Joule) | $\eta_G$ (%) |
|----|-------------------|------------------------|------------------------|------------------|------------------|----------------|-----------|-------------|
| 1  | 1 KΩ              | 58                     | 53,7                   | 0,05             | 450              | 4,3            | 96,75     | 0,45        |
| 2  | 2 KΩ              | 59,1                   | 54,7                   | 0,05             | 450              | 4,4            | 99        | 0,48        |
| 3  | 3 KΩ              | 59,4                   | 54,8                   | 0,05             | 450              | 4,6            | 103,5     | 0,46        |
| 4  | 4 KΩ              | 59,9                   | 55                     | 0,05             | 450              | 4,9            | 110,25    | 0,43        |
| 5  | 5 KΩ              | 60,1                   | 55,5                   | 0,05             | 450              | 4,6            | 103,5     | 0,46        |
| 6  | 6 KΩ              | 60,5                   | 55,2                   | 0,05             | 450              | 5,3            | 119,25    | 0,40        |
| 7  | 7 KΩ              | 60,9                   | 54,8                   | 0,05             | 450              | 6,1            | 137,25    | 0,35        |
| 8  | 8 KΩ              | 60,1                   | 54,8                   | 0,05             | 450              | 5,7            | 128,25    | 0,36        |
| 9  | 9 KΩ              | 61,2                   | 55,5                   | 0,05             | 450              | 5,6            | 126       | 0,38        |
| 10 | 10 KΩ             | 61,7                   | 56,1                   | 0,05             | 450              | 5,6            | 126       | 0,38        |
Fig. 9. Generator efficiency graph

It can be seen from the above figure that the efficiency of the generator has been reduced with a resistance of 1k ohm, and then as the resistance increases, the efficiency of the generator also increases. The generator efficiency fluctuates in a resistance of 8k ohm to 10k ohm. In the above figure, the highest generator efficiency value is obtained on the 5k ohm resistor, reaching 5.38% TEG on the right. For the right TEG, the efficiency of the generator tends to stabilize. When the resistance is 2k ohms, the highest value of the TEG generator efficiency on the left is 0.48%.

4. Conclusion
After conducting research on the thermoelectric generator type SP1848 with series and parallel circuits, the following conclusions can be drawn:
From the results of the efficiency values that are generated after the data is obtained, the highest generator efficiency value is obtained when the 5k ohm resistance reaches 5.38% on the right TEG and when the 2k ohm resistance reaches 0.48% on the left TEG, while the lowest generator efficiency value is obtained when the 2k ohm resistance reaches 2.65% on the left TEG and when the 7k ohm resistance reaches 0.35% on the right TEG.

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