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DETERMINATION OF PARAMETERS OF THE PELTIER MODULE WITHOUT INTERFERENCE IN ITS STRUCTURE

ABSTRACT *This work describes new method to determine parameters of Peltier module. Classical method requires module to be disassembled, rendering it useless after the experiment. Described new method does not require interference in structure of the module allowing it to be used after experiment. This is helpful in designing of new modules, where there is few samples to test.*

Keywords: *parameters, experiment, non-invasive, TEC, TEG.*

1. INTRODUCTION

Peltier modules are an interesting alternative to conventional heat exchange systems. The principle is very simple: they use a Peltier effect - flow of current through the p-n junction heats one side of the module and heats the other.

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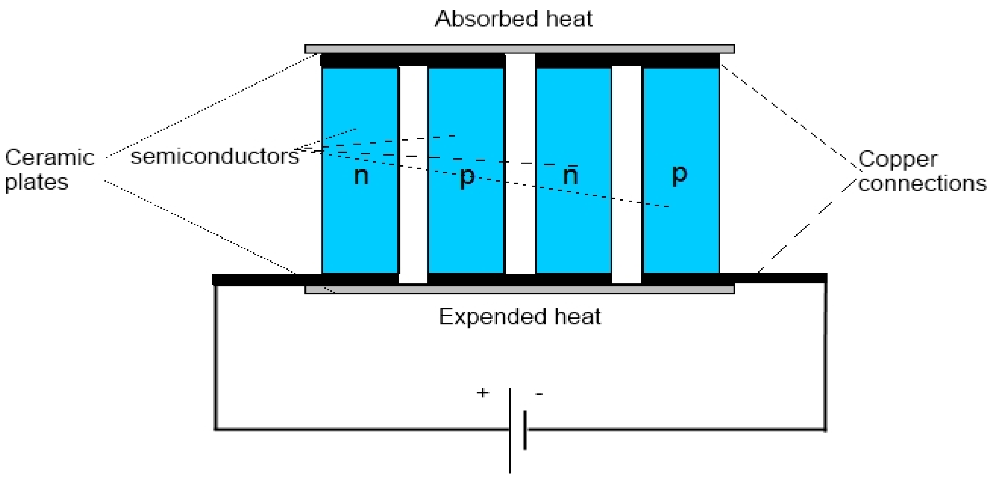

Fig. 1. Construction of the Peltier module. Metal connector does not affect the behaviour of the p-n junction

In addition, there are no moving parts, they are lightweight and maintenance free. Thanks to this property they are used where it is not possible or is impractical to use heavy and noisy cooling units. So why not apply it universally? There are several reasons for this. The efficiency of the module is small compared to conventional units and require hefty power supply with high current efficiency (small modules 40x40x2 mm in dimensions require up to 30 A supply current to work), it also requires efficient cooling of the hot side – you have to take the heat "pumped" from the cold as well as the Joule heat generated in the module under through current flow.

Fig. 2. Sample Peltier module

Peltier module, thanks to the reversibility of the Peltier effect (Seebeck effect), can serve as a power generator operating using the temperature difference on both sides of the module. Thanks to this phenomenon, we can recover some energy from other exothermic processes – in internal combustion engines, power stations, unmanned measuring stations on gas pipelines, etc.

To know what are the parameters of Peltier module, it must be examined in terms of its thermal and electrical properties. The processes mentioned above occur simultaneously during normal operation of the module. Desired from our point of view, the Peltier effect is partially negated by the Seebeck effect, the flow of current through a conductor generates heat which must also be transferred to the "hot" side, heat permeability also results in reducing the thermal efficiency of the cell. It is also essential to compromise between dimensions and materials used to manufacture – the thickness of the cell reduces the influence of heat penetration, but increases Joule heat; increase of the contact surface of p-n junction reduces heat generated due to current flow but also increases the permeability of the heat.

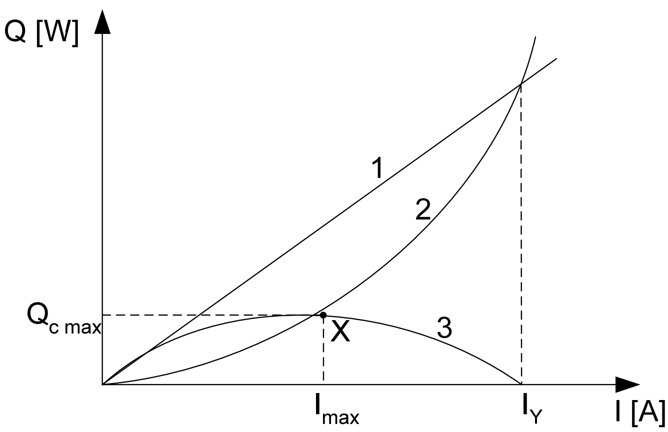

Fig. 3. Peltier module performance in relation to the supply current: 1 – power transmitted by the Peltier effect, 2 – thermal power resulting from Joule's law, 3 – net cooling power of the cold side, I_{max} – current at which the performance of the module is the largest, I_Y – current at which the entire performance of Peltier cells is used to remove the Joule heat

For this reason, Peltier module is designed for specific task: as cooling element TEC or a termogenerator TEG. The complexity of the phenomena occurring in a newly designed module can only roughly be approximated, so to determine its electrical and thermal characteristics, it is necessary to carry out a series of experiments to determine its working parameters. To this end it is necessary, among other, the know the temperature of p-n junctions on both sides of the module when works as TEG. Until now it was the biggest problem - to accurately measure the temperature it was necessary to remove the module housing, which ultimately led to its destruction.

2. METHODOLOGY

The new method to determine the parameters of the Peltier elements [1, 2], consists in measuring the heat flux and currents and voltage in the states of closed and open electrical circuit. It is also essential to measure currents at the very moment of closing and voltage on opening of the circuit. Thanks to that parameters of Peltier module can be calculated. This method does not require interference with the structure of the module, which is its main advantage in comparison with the classical method.

To avoid having to intervene in the structure of the cell, we propose the following methodology of the experiment.

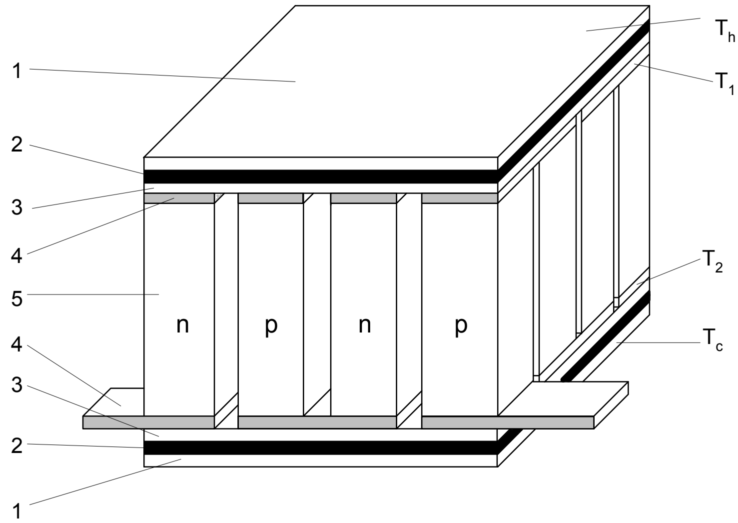

Fig. 4. Schematic diagram of the Peltier element, with surface of the heat source and heat drain

Figure 4 highlights the following elements:
1) fragments of the surface, heat source and the drain;
2) contact between the heat source and the Peltier element;
3) electrical insulation;
4) wiring network;
5) semiconductor elements.

Heat balance equations take the form (1-4):

$$Q_h = \frac{(T_h - T_1)}{\Psi_t}; \tag{1}$$

$$Q_h = \frac{(T_1 - T_2)}{\Psi_p} + I \cdot A \cdot T_1 - \frac{I^2 R}{2}; \tag{2}$$

$$Q_c = \frac{(T_1 - T_2)}{\Psi_p} + I \cdot A \cdot T_2 - \frac{I^2 R}{2}; \tag{3}$$

$$Q_c = \frac{(T_2 - T_c)}{\Psi_t}; \tag{4}$$

electrical equations (5) and (6):

$$I = \frac{E}{(R_N + R)}; \tag{5}$$

$$E = A \cdot (T_1 - T_2); \tag{6}$$

where:

T_h is temperature of the heat source (hot side); T_c is temperature of the heat drain (cold side); T_1 and T_2 are temperatures of metallic connectors; $A = n \cdot (|\overline{\alpha_n}| + |\overline{\alpha_p}|)$ is Seebeck coefficient for the Peltier module; α is Seebeck coefficient for semiconductors, "n" or "p", Ψ_p is thermal resistance of semiconductors (item 5 in Figure 4); Ψ_t is thermal resistance of the electrical contact between the casing of the Peltier element and the heat source (items 2, 3, 4 in Figure 4); Q_h is heat flux between the source and the Peltier element; Q_c is heat flux between the heat drain and the Peltier element; R is electrical resistance of Peltier module; R_N is resistance of the receiver; E is SEM of Peltier module; I is current.

When temperatures are known T_h and T_c, and additionally is known electrical resistance of the receiver is in the system of equations remain unknown following parameters:

- Heat flux between the source and the Peltier element Q_h;
- Heat flux between the heat drain and the Peltier element Q_c;
- Temperature of metallic connectors, T_1 and T_2;
- Thermal resistance and Ψ_t and Ψ_p;
- Seebeck coefficient A;
- Peltier module's electrical resistance R;
- SEM of Peltier module E.

To avoid measurement errors of Q_h, we will conduct measurements for temperature of hot side equal to the ambient ($T_h = T_{ot}$) thus heat loss associated with the exchange of heat to the environment will be zero and the measurement of Q_h will be correct.

Under this conditions, we obtain the following equations:

for $I = 0$
$$E_0 = A \cdot \Delta T \frac{\Psi_p}{2\Psi_t + \Psi_p}; \tag{7}$$

$$Q_0 = \frac{\Delta T}{2\Psi_t + \Psi_p} \tag{8}$$

$$I = I_z \qquad I_z = A \cdot \frac{\Delta T - 2\delta t}{R} \tag{9}$$

$$Q_z = \frac{\Delta T - 2\delta t}{\Psi_p} + I_z^2 R \frac{\bar{t}}{\Delta T - 2\delta t} \tag{10}$$

where:

$$\Delta T = T_h - T_c \tag{11}$$

$$\bar{t} = \frac{T_h + T_c}{2} \tag{12}$$

$$\delta t = \frac{\Delta T - (T_h - T_1)}{2} = \frac{\Delta T - (T_2 - T_c)}{2} \tag{13}$$

After transforming the above equations we get:

$$A = \left(\frac{Q_z}{I_z} - \frac{Q_0}{E_0 / R} \right) \frac{1}{\bar{t}} \tag{14}$$

$$\Psi_p = \frac{E_0}{A \cdot Q_0} \tag{15}$$

$$\Psi_t = k \cdot \Psi_p \tag{16}$$

where:

$$k = \frac{\Psi_t}{\Psi_p} = \frac{1}{2}\left(\frac{A \cdot \Delta T}{E_0} - 1 \right) \tag{17}$$

3. EXPERIMENTAL SET-UP AND DISCUSSION

In order to verify the above method, the test site was constructed (Fig. 5) consisting of a heat source (Fig. 6), with regulated power so that the temperature of the hot side was equal to ambient temperature and a heat drain (Fig. 7) allowing greatest possible heat flux.

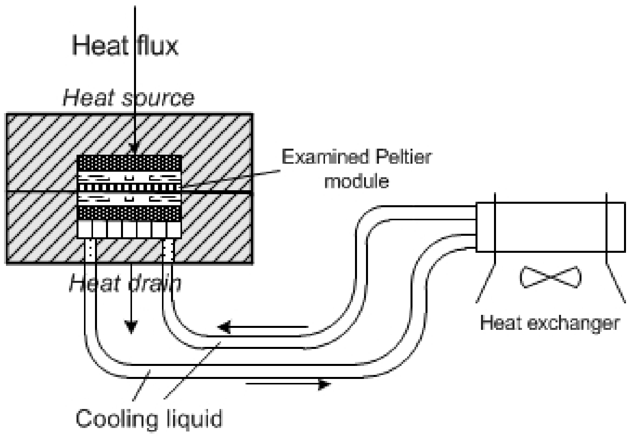

Fig. 5. Schematic drawing of the measuring system

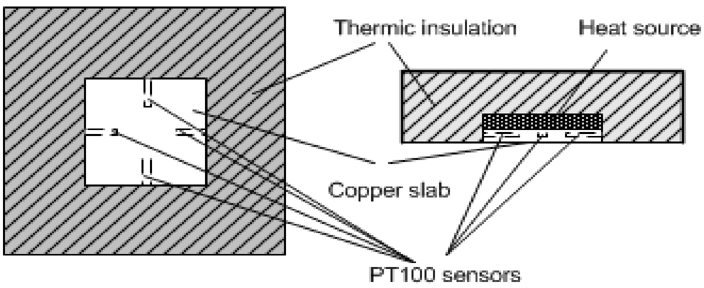

Fig. 6. Schematic diagram of the test systems heat source

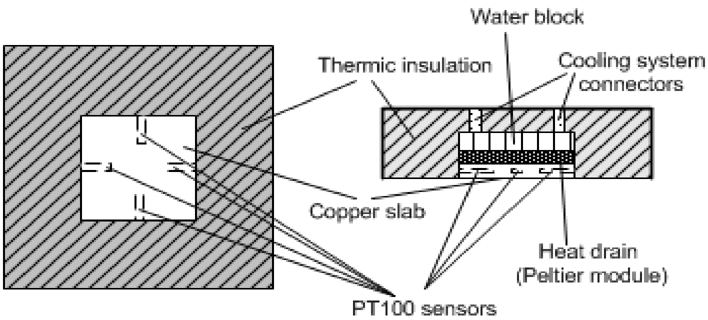

Fig. 7. Schematic diagram of the heat drain of the test system

Heat is collected at the bottom by the radiator, which has also adjustable power. Due to the large amount of heat generated by the measuring system, the cooling system should have the greatest possible efficiency. The temperature of the heater and temperature of the radiator is measured at four points by platinum temperature sensors PT100 (Figure 6 and 7) connected in series. This results in average temperature. PT100 sensors convert temperature to resistance (to the nearest 0.5°C) according to the formula:

$$R_{PT100} = 100(1 + 0{,}00389 \cdot t) \tag{18}$$

where t is the temperature in degree Celsius.

Peltier module electrical circuit is closed by the ammeter for measuring the short circuit and a voltmeter for measuring the state opening. Thanks to this arrangement of measurement we are able to examine the Peltier elements without interfering with their structure and identify the parameters of unidentified elements – the only thing we need to know is the number of p-n junctions in the module.

LITERATURE

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WYZNACZANIE PARAMETRÓW MODUŁU PELTIERA BEZ KONIECZNOŚCI INGERENCJI W JEGO STRUKTURĘ

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STRESZCZENIE *Praca opisuje nową metodę wyznaczania parametrów modułów Peltiera. Metody klasyczne wymagają rozmontowania modułu, co powoduje jego zniszczenie. Prezentowana metoda zapewnia precyzyjny pomiar parametrów modułu Peltiera bez konieczności ingerencji w jego fizyczną strukturę. Jest ona szczególnie pomocna przy wytwarzaniu i testowaniu modułów prototypowych.*

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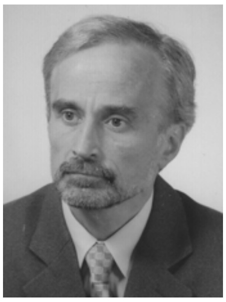

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