SEMICONDUCTOR THERMAL-MECHANICAL ENERGY CONVERTER

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ABSTRACT

Among unusual autonomous systems for conversion of energy, the most interesting is the conversion of low potential thermal energy into mechanical energy. That is why such sources of energy are practically inexhaustible and ecologically clean.

DISCUSSION

References [1,2] describe thermoelectric motors (TEM) where an interactional principle of thermoelectric currents appearing in a conductor is used. The conductor can revolve on its axis in a magnetic field. However, because of low efficiency and some imperfection in construction, this kind of motors is not used. As comparative analysis has shown, the best prospect from the energetic point of view could be converters which make use of the advantages of short-circuited [3,4] thermoelectric generators (under small differences of temperatures 0T).

We propose that a short-circuited thermoelectric converter of thermal energy into mechanical one can be produced [5]. See Fig. 1. In cylindrical frame (stator) on the conducting axis in a magnetic field (not in the figure) there is a ferromagnetic disk (rotor). Electric current is generated by thermoelectric battery. The electric current goes to the axis (see the arrow and *i* on the drawing) from the current conducting busbar and through the liquid metal contact to rotor and spreads around the rotor radially. Owing to Ampère's forces, the rotor will pivot around its axis.

The motor work in stationary regime as can be described with the help of Maxwell's equation [6] and the generalized law of electrical conductivity [3] See equations (1), (2) where $\vec{E}$, $\vec{B}$, and $\vec{j}$ are the electric field, magnetic and current density respectively, σ, α are coefficient of electrical conductivity and the Seebeck coefficient.

$$rot\ \vec{E} = -\frac{d\vec{B}}{dt}, \tag{1}$$

$$\vec{j} = \sigma \vec{E} - \sigma\alpha\ \nabla T, \tag{2}$$

Using the expressions (1) and (2) and integrating around the circuit a-b-c-d (Fig. 1) to compute the mechanical power of the converter we obtain equation (3)

$$P = \frac{(\alpha_{pn} \Delta T)}{r_{pn}(1+\rho)} S(1-S), \tag{3}$$

where $\rho = r_0/r_{pn}$, α_{pn} and r_{pn} are Seebeck coefficient and the electrical resistance p-n thermocouple, r_0 is a summary result of rotor resistance, liquid metal contact, and current conducting busbar; S = (n_{max} -

n) /n_{max} is sliding, n is rotor rotation frequency, n_{max} is rotor rotation frequency under idling.

Maximum power of converter is obtained when S = 1/2 and it is given by equation

$$P_{\max} = \frac{(\alpha_{pn} \Delta T)}{4 r_{pn} (1 + \rho)} \ . \tag{4}$$

Using (4) for the electromagnetic moment one can obtain

$$M = \frac{1}{2\pi} \ \frac{\alpha_{pn} \Delta T \Phi}{r_{pn} (1 + \rho)} \ S \, , \tag{5}$$

where Φ is the magnetic flow going through rotor of the motor.

Obviously, the maximum moment (5) is reached under regime of short circuit, where S = I. For rotation frequency of rotor we have the fundamental expression

$$n = \frac{\alpha_{pn} \Delta T}{\Phi} \ (1 - S) \, , \tag{6.}$$

This expression reaches maximum value under idling (where S = 0).

Using a calculation method for the efficiency of thermoelectric generators [4] for efficiency of converter we get

$$\eta = \frac{\Delta T}{T_1} \ \frac{S (1 - S)}{(z_c T_1)^{-1} + S + S^2 (\Delta T / 2T_1)} \, , \tag{7}$$

where $z_d = z_n (1 + \rho)^{-1}$: is a thermoelectric figure of merit of the p-n couple [3] $z_m = \alpha_{pn}^2 / [(æ_p / \sigma_p)^{1/2} + (æ_n / \sigma_n)^{1/2}]^2$. T_1 - is hot junction temperature.

The maximum efficiency of the motor is reached when $S = S_0$ and is given by

$$\eta_{\max} = \frac{\Delta T}{T_1} \ \frac{1 - 2S_0}{1 - S_0 + S_0 T_2 / T_1} \, , \tag{8}$$

where T_2 is the cold junction temperature,

$$S_0 = \frac{1}{(z_d T_a + 1)^{1/2} + 1} \ . \qquad T_a = \frac{T_1 + T_2}{2} \ . \tag{9}$$

We have come to the conclusion that using typical thermoelectric materials based upon Bi-Sb-Te-Se working under a mid-range temperature of about T =300°K and under temperature difference of about 0T = 20°K, the efficiency of converter is only several percent. It is approximately five times less than the thermodynamic efficiency of an ideal reversible engine under the same temperatures. The efficiency of converter will increase with and increase in the temperature difference and, of course, if the thermoelectric characteristics of materials can be improved.

In addition to power application in autonomous systems, this suggested converter can be used for making autonomous counter measurements of thermal energy.

REFERENCES

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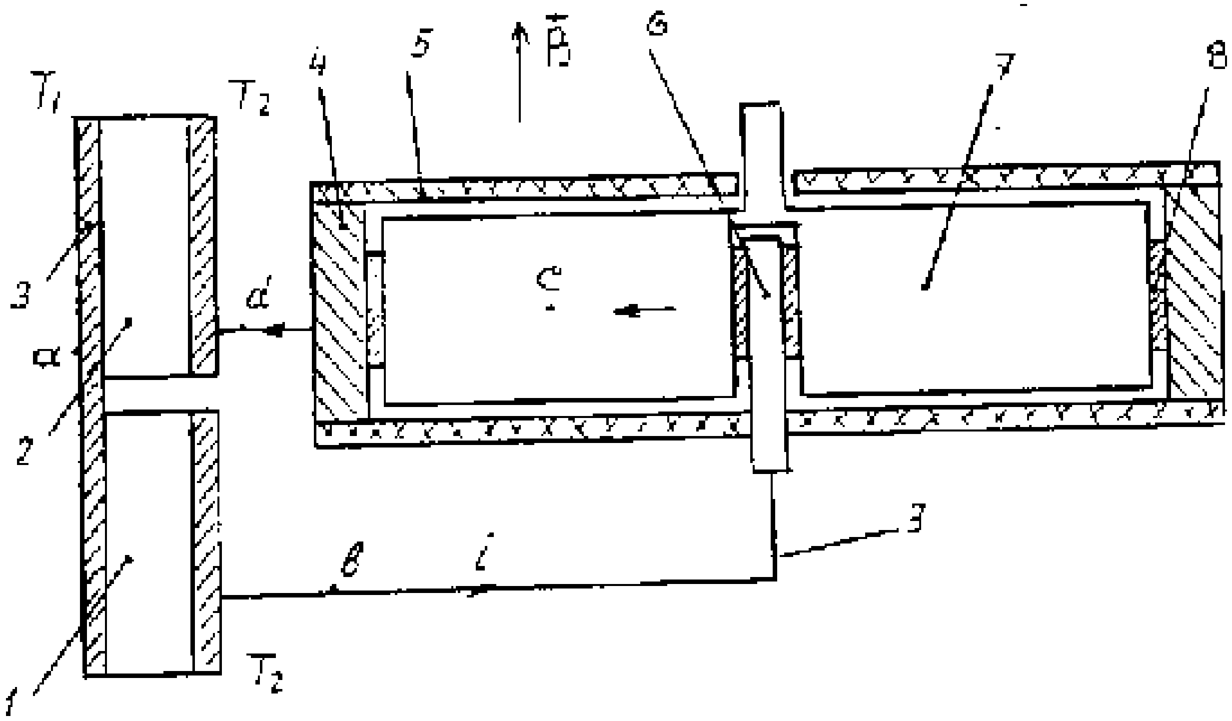

Fig. 1. Scheme of thermal-machanical energy converter.
1 - Thermoelement branch p-type; 2 - thermoelement branch n-type; 3 - Current conducting busbar; 4 - stator; 5 - insulator; 6 - axis; 7 - rotor; 8 - liquid metal contact.