Physical entity of the electro-deformation energy generator as a theoretical basis of living organisms movement. Carnot's theorem as a special case.

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Abstract. *The paper focuses on the fact that in order to produce mechanical energy from thermal energy, in addition to gas, liquid and solid bodies may also be used as the working body. In addition to the fact that living organisms might be expanding and contracting in volume, scientists have already created polymer materials that undergo significant deformations under the influence of small electric signals. Therefore, just as nature could, man can create such a composite engine that, even in the conditions of small temperature gradients, under the action of small disturbances (electric signals), will generate useful energy. The paper displays that the efficiency of such converters is much higher than the efficiency of the Carnot heat engine and, contrary to Carnot theorem, depends on the physical properties of the material. The expression of the efficiency is proposed for such a type of low-temperature composite generator, which is a physical model of mechanical energy generation in living organisms. Consequently, it is shown that Carnot's theorem does not have a universal character. By creating and testing new synthetic materials, it is possible to create a completely new type of heat engines with much higher efficiency. Regardless of how effective they prove to be in practical applications, research in this direction is highly relevant, as this direction destroys the theoretical bases of thermodynamics and existing energy industry, as well as proves that humankind is capable of creating machines that efficiently generate energy from the surrounding equilibrium space, with zero or negligible temperature differences.*

1. Introduction

In 1824, when the nature of thermal energy was not yet fully understood and, to denote this energy, the concept of a hypothetical weightless liquid (the calorific fluid) introduced by Lavoisier was used, the French physicist Sadi Carnot proposed a cycle for the ideal heat engine, which most perfectly converts heat into mechanical energy (that is, a driving force, in the terminology of that time). In words, Carnot articulated the efficiency of such a machine as follows:

”... The driving force of the heat can be quite closely compared to the force of falling water: both have maxima that could not be surpassed…

The driving force of falling water depends on the height of the fall (ΔH) and the amount of water; the driving force of the heat also depends on the amount of calorific fluid and depends on what can actually be called the height of its fall, that is, the temperature difference (ΔT) of the bodies between which the calorific fluid exchange occurs. When water falls, the driving force is strictly proportional to the difference in the levels in the upper and lower tanks. In the fall of calorific fluid, the driving force undoubtedly increases along with the temperature difference between the hot and cold bodies....“

Using the ideal gas cycle, Carnot showed that the maximum efficiency of such a machine is determined by the formula:

$$\eta = \frac{\Delta T}{T_{\max}} = 1 - \frac{T_0}{T_{\max}} , \tag{1}$$

Along with this, Carnot formulated the conclusion that is known as Carnot's theorem: “The driving force of heat does not depend on the agents taken for its development; its amount is determined solely by the temperatures of the bodies, between which the calorific fluid is ultimately transferred”

Thus, Carnot offered a simple truth - just as a water mill cannot work without a difference in the levels of the tanks, no heat engine can work without a temperature difference.

Carnot's theorem and the maximum efficiency of thermal machines that is justified by this theorem are so convincing that they became the basis of classical thermodynamics and were reflected in formulations of the second law of thermodynamics articulated by Clausius and Kelvin (as well as in the hypothesis of the heat death of the universe). This theory became the ideological basis of a new energy industry and the fastest technological progress that has led us to the relentless exploitation of natural resources.

Recognizing the far-reaching consequences of such a technology, almost at the same time, genius scientists (including Maxwell and Tsiolkovsky) have questioned these laws, and the discussion emerged in which, at various times, the greatest scientists were involved. Unfortunately, this discussion could not stop either the rapidly developing, environmentally hazardous energy industry, or the research centers serving this sector.

Due to this situation, in all types of power plants that generate useful (mechanical or electrical) energy from heat, high-temperature bodies participate in some forms. For example, inside the most popular internal combustion engines, temperature rises much higher than 1000 degrees. This means that mankind has not been able to create an efficient, low-temperature converter of thermal energy. On the other hand, scientific observations confirm that nature, under conditions of small temperature differences, can generate vast, sometimes devastating amounts of mechanical energy, and we systematically observe this, although we have not fully understood their nature. Since the main source of energy for most natural phenomena, directly or indirectly, is the outer world (the sun), we can relax and assume that everything fits into the framework of classical thermodynamics. However, this is not always the case. Over the past 15 years, dozens of articles and 4 monographs [1-4] that I published, have discussed many amazing processes and natural phenomena, which cannot be explained by the laws of classical thermodynamics, but can be explained by the more general laws of physics. As a rule, such processes occur in the complex thermodynamic systems, in which transformations take place at the micro particles level (chemical reactions, phase transformations, photosynthesis, etc.)

It is well known that Carnot's theory is not universal and is valid for a certain class of thermal processes, since it discusses the issue of obtaining mechanical energy from heat through the periodic alternation of compression and expansion of the ideal gas. But it is overlooked that more perfect processes exist.

In this paper is shown, that in nature, completely different processes of obtaining mechanical energy from heat can be observed, which leads to such conclusion.

The most interesting example of this is provided by the processes in living organisms, in which mechanical energy is generated by polymerization and deformation (shortening) of muscles or protein fibers under the influence of poor signals of ions. The same processes prove that their effectiveness, contrary to Carnot's theorem, depends on the physical properties of the bodies involved in the process.

The existence of such heat energy converters allows saying that there is a certain class of heat engines in nature, and they can also be created artificially, which can be called a type of the electric deformation generators.

2. Theoretical bases of operation of electric deformation generator of energy

Suppose that we have a cylindrical rod of a porous structure with a length L and radius R, which, under the influence of a small signal s, is undergoing structural change (polymerization), which is followed by its shortening. Therefore, if the signal is periodic, the end of the rod will make reciprocating movements. If we apply a force or hang a weight M on the end of the bar, then it will start doing work. It is natural that, without external energy supply to the body, the performance of work will cause its temperature drop and the process cannot continue for a long time.

Accordingly, if the shortening of the rod is accompanied by the release of energy, then its opposite expansion (relaxation) process must take place at a low temperature, during which the rod will receive thermal energy.

Now assume that through the pores of the stem, a certain type of liquid (or a mixture of liquids) flows in it every second, which, due to the same small signals, is undergoing chemical transformation, as a result of which heat is released. In this case, the generator will continue to work for a long time.

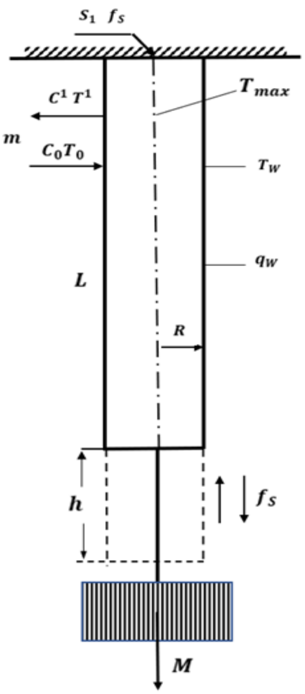

Fig.1. Scheme for physical modeling of energy generation in a living organism

If the frequency of the signal is f_s hertz, then the generator will produce power

$$N = Mghf_s, \tag{2}$$

Suppose that the liquid in an amount of $2\pi RLm$ flows into the porous material from the cylindrical surface, then the heat released as a result of the chemical reaction will be equal to the amount

$$Q = 2\pi RLmr_x, \tag{3}$$

where m is the mass of the liquid passing through a unit area per unit time ($kg/m^2 \sec$)

r_x - the thermal effect of chemical reaction per kilogram of body weight (j/kg).

If only η part of this heat is converted into useful energy, then capacity of the device is defined by the formula:

$$N = 2\pi RLmr_x\eta, \tag{4}$$

and this means that the rest of the energy $2\pi RLmr_x(1-\eta)$ is released as heat from the cylindrical surface of rod. Accordingly, inside the bar, there must be a heat flow $q=-\lambda dT/dr$ with a radial direction, for the determination of which it is necessary to solve the problem of thermal conductivity in conditions when heating is provided in the body.

If we assume that chemical reaction occurs at every point in space with the same intensity, we will have $q_v = 2mr_x / R$ intensity of energy release per unit of volume, and the thermal energy balance equation will then have form:

$$-\lambda \frac{d}{dr}\left[r\frac{dT}{dr}\right] = \frac{2mr_x}{R}(1-\eta)r \ , \tag{5}$$

which leads us to the differential equation of stationary thermal conductivity:

$$-r\frac{d^2T}{dr^2} - \frac{dT}{dr} = \frac{2mr_x}{\lambda R}(1-\eta)r \ , \tag{6}$$

while the solution of the latter equation will be as follows:

$$T = T_{\max} - \frac{mr_x}{2\lambda R}(1-\eta)r^2 \ . \tag{8}$$

Accordingly if the temperature on the surface of a cylindrical rod T_W is known, we obtain:

$$\eta = 1 - 2\frac{T_{\max} - T_w}{R}\frac{\lambda}{mr_x} \ . \tag{9}$$

The heat removed from the cylindrical surface can also be determined by the energy difference between the entering and outgoing liquids with temperature T_0 and T'

$$Q(1-\eta) = 2\pi RLm(c'T' - c_0T_0) \ , \tag{10}$$

therefore, taking in account (3), we have

$$\eta = 1 - \frac{c'T' - c_0T_0}{r_x} \ , \tag{11}$$

or, If the heat capacity of the liquid obtained after the chemical reaction slightly differs from the initial value ($c' = c_0$)

$$\eta = 1 - \Delta T\frac{c_0}{r_x} \ , \tag{12}$$

As we can see, the efficiency of the considered heat device, unlike the Carnot heat engine, depends on the properties of the material, which means that Carnot theorem is not valid.

The movement of the liquid in a cylindrical surface means that, just as in the movement of blood, the flow velocity near the surface of the rod experiences pulsations with some frequency f and average amplitude υ. This means that during one fluctuation of speed, the liquid reaches the distance $\delta \sim \upsilon / f$ inside the bar. Also, because the temperature rises towards the center of the rod, the temperature of the outgoing flow will be the higher, the deeper the liquid reaches inside the cylinder ($\Delta T \sim \delta(T_{\max} - T_0)/R$). In addition, the amount of entering/outgoing flow in the cylindrical surface will be equal to

$$m = 0{,}5 k_f \rho \upsilon , \tag{13}$$

where $k_f \prec 1$ is the porosity of the cylindrical surface.

Accordingly, if we take into account that $\delta \prec\prec R$, the expressions 9 and 12 give us:

$$\eta = 1 - \frac{12\lambda f}{k_f k_T \rho r_x} \Delta T , \tag{14}$$

where $k_T = 0{,}5\upsilon^2$ is the energy of turbulent oscillations or normal turbulent pressure near the cylindrical surface.

Let us consider what result this expression gives us, on the example of a human muscle. 1 kilogram of blood contains 1 gram of glucose on average. As a result of the decomposition of one gram of glucose, 15580 joules of energy is released ($r_x = 15580 j/kg$). Blood is characterized by the following physical parameters $c_0 \approx 4000 j/(kg * K)$, $\rho = 1030 kg/m^3$, Thermal conductivity for organic proteins $\lambda = 0{,}4 w/(m * \sec)$. Let us assume that the porosity created by capillaries gives us $k_f = 0{,}0025$ and the pulsation speed is $0{,}25 m/\sec$ (or $k_T = 0{,}031 m^2/\sec^2$). In addition, we should take into account that $f \approx 70 Hr$, Accordingly, from (12) and (14) we will have:

$$\eta = 1 - 0{,}257 \Delta T , \tag{15}$$

If we take into account that the increase in the temperature of the blood coming out of the muscles is not significant $(\Delta T \prec 2^0)$, we can conclude that the efficiency of the muscle is within 50%. On the other hand, according to Carnot's theory (formula 1), under the conditions of such a small temperature difference, the efficiency cannot be even 1 percent.

It should be noted here that Swedish scientists have developed the material that changes size under the influence of a mild electrical pulse (https://hightech.plus/2019/10/30/novii-material).

Scientists at the University of Linköping have discovered a new conductive polymer, the volume of which experiences many changes when exposed to an electric current. Therefore, it is quite realistic to use similar materials in order to conduct research in this direction.

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