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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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ELECTRIC DISCHARGE AS A CONVERTER OF ELECTRICAL ENERGY INTO MECHANICAL ENERGY

In an electric discharge in a medium (gas, liquid, or solid), electrical energy is converted into Joule heat, which is concentrated in the small volume of the discharge channel. As a result of the expansion of the heated volume of plasma and gas, the latter performs mechanical work in displacing the surrounding medium.

Starting from the first law of thermodynamics and the Clapeyron–Mendeleev equation, the following expression was obtained for the mechanical energy produced by a discharge:

$$A = \frac{\alpha_0 PQ}{cm} - \frac{V_0 P^2 c\mu V}{2RQ}, \tag{1}$$

where A is the mechanical energy; α_0 is the coefficient of volumetric thermal expansion of the gas (plasma); P is the specific load per volume V_0 of the heated gas (plasma); c is the heat capacity of the gas (plasma); μ is the molecular weight of the gas; V is the volume of a mole of gas; R is the gas constant; Q is the electrical energy released in the volume V_0 of the discharge channel.

Fig. 1. Dependence of the mechanical energy A, obtained from an electric discharge, as a function of the load P on it

Experimental investigations were carried out on a test bench where, under the action of the expanding discharge plasma, a piston moved. By measuring the

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

displacement of the piston and its weight, it is possible to calculate the mechanical energy obtained from the discharge. On the bench it is possible to vary the quantities P, V_0, and Q; as a result, it was possible to obtain the dependence of the mechanical energy released by the discharge on changes in the indicated parameters. The experimental data are presented in Figs. 1, 2, and 3.

Fig. 2. Dependence of the magnitude of the mechanical energy A on the magnitude of the electrical energy Q supplied to the discharge

Fig. 3. Dependence of the magnitude of the mechanical energy A on the volume of the discharge channel V_0

Qualitatively, the experimental results agree with expression (1). Calculations performed according to (1) for air differ from the experimental results by 15-25% (for P up to 1 kg/cm^2 and Q up to 300 J).

As is evident from expression (1) and the experimental results (Fig. 1), there is a definite load on the discharge channel

$$P_m = R\alpha_0 Q^2 / c^2 m V_0 \mu V, \tag{2}$$

at which the mechanical energy obtained during the expansion of the volume of gas V_0 and plasma in the discharge channel will be maximal:

$$A_m = a_0^2 Q^3 R / 2c^3 m^2 V_\mu V_0. \tag{3}$$

In our experiments, the maximum efficiency of conversion of electrical energy into mechanical energy obtained was 0.43% (at $P = 0.25$ kg/cm^2 and $Q =$ 345 J).

Let us note that, according to expressions (1) and (3), the energy-conversion efficiency can be quite high if R and c are assumed constant; however, it is evident that they vary with changes in the temperature of the gas and plasma in the discharge channel.

Expressions (3) and (2) show that, by varying the quantities V_0 and P, it is possible to attain quite high values of the efficiency of energy conversion in an electrical discharge.

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Note: Figure translations are in progress. See original paper for figures.