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B. S r e b r o v

Applications of the Theory of Explosion with Release of Mass and Energy

This work shows the applications of the theory of point exsplosion with release of mass and energy for investigations of short gap electrical discharge (gap length 0.1–10μm). This discharge in gas or liquid medium is used in Electric Discharge Machining (EDM) technologies. The investigation of movement of the ambient medium in the time is described in the present work.

The disturbances caused by the discharge in the ambient medium are "strong discontinuities" of this medium. They are optical nonuniformitis in a transparent refracted medium. For the registration of these nonuniformitis the method of shadowgrams was used [1] with application of pulse laser system [2]. The pictures of the disturbances in the time interval of 800ns to 1800ns are found [3]. In Fig.1 the picture of ambient area of the short gap discharge in the time t=800ns is shown. In the photograph we see well two lines, the fronts of a shock waves. In Fig.2 measured average values of the radius R_1 of the first shock wave are shown. These data by least squares method are fitted with the curve of the following kind:

(1) $$R_1 = \text{const}.t^{0.8}$$

The results from this exsperiment prove the existence of two shock waves in the ambient space of the short gap discharge which are caused by it. The movement law of the first shock wave is the power relation of the time as this was found at the self-similary observation of the problem of strong exsplosion in the gas, taking into account the release of mass and energy.

In the works [4] and [5] a model investigation is made of the movement of the gas during short gap discharge. These investigations are based on the mechanics of continuous media and on the similarity methods [6]. In the model it is supposed that before the breakdown (time $t<0$) the gas is at rest and has initial density ρ_1 and initial pressure p_1. After the breakdown ($t>0$) mass and energy release begins at a point. This point is in the origin of coordinates.

The flows of release of mass M and energy N are approximated with following functions:

$$M = mt^{\alpha}, \quad N = nt^{\beta} \qquad t>0, \tag{2}$$

where α, β, m and n are constants which describe the realese of mass and energy at the time of the discharge and t is the time. The fundamental quantities of the problem which must be found are velocity v, density ρ and pressure p.

If we consider the medium in which the disturbances are in movement as an ideal gas with neglecting viscosity, heat conductivity and chemical change, the equations which describe the movement of the metal vapoures from the electrodes and of the ambient gas are the gas dynamic equations.

The disturbance which move in the gas may be strong discontinuities (jumps of the parametres v, ρ and p or shock waves). This shock wave at a non-dimensional flow has coordinate r_0 as at the wave front the boundary conditions of the problem are realized.

At self-similar movement of the gas medium the solutions of the system of the gas dynamics equations depend only on the dimensionless quantity λ, which can be expressed by nondependant variables, the coordinate r and the time t. As regards to the problem of strong point exsplosion with release of mass and energy and in case of a spherical symmetry of the medium movement characterized by initial density $\rho_1 \doteq$const., the functions can be expressed by λ in the following way [7], [8]:

$$v = \frac{r}{t} V(\lambda), \qquad p = \rho_1 \frac{r^2}{t^2} P(\lambda), \qquad \rho = \rho_1 R(\lambda) \tag{3}$$

After substituting into the hydrodynamic equations the presentations of v, p and ρ from (3) and introducting $Z = \gamma_i P/R$, one finds the system of ordinary differential equations for functions V, Z and R:

$$\frac{dZ}{dV} = \frac{Z}{(V-\delta)W(V,Z)} \Big\{ \Big[Z(V-1) + 3(\gamma_i-1)V \Big] (V-\delta)^2 -$$

$$-(\gamma_i-1)V(V-1)(V-\delta) - \Big[2(V-1) + \kappa_i(\gamma_i-1) \Big] Z \Big\},$$

$$\frac{d\ln\lambda}{dV} = \frac{Z-(V-\delta)^2}{W(V,Z)}, \quad (V-\delta)\frac{d\ln R}{d\ln\lambda} = -3V - \frac{W(V,Z)}{Z-(V-\delta)^2}, \tag{4}$$

$$W(V,Z) = V(V-1)(V-\delta) + (\kappa_i - 3V)Z, \quad \delta = \frac{\beta+3}{5},$$

$$\kappa_i = 2\frac{1-\delta}{\gamma_i}, \qquad Z = \gamma_i \frac{P}{R},$$

where γ_i is the adiabatic coefficient of the ambient gas (i=1) or of the metal vapoures (i=2).

The quantitive analysis of the integral curves of the first equation (4) in the work [5], [8], [7] and [9] shows, that in order to satisfy the boundary conditions the solution must have the jumps of the medium parameters (strong discontinuities). They are situated at the contact surface (vapoures-gas), at the front of the first shock wave and at the front of the second shock wave.

In this problem with spherical symmetry the radius of the front of the first shock wave r_0 as a function of time is found in the form:

(5) $$r_0 = \text{const.}t^{0.8}.$$

The results established by the model investigations of the movement of the gas and the vapours in the ambient space of the electrical discharge in short gap are in accordance with the following exsperimental facts:

i. There are two shock waves.

ii. The law of the movement of the first shock wave has the form $R_1 \sim t^{0.8}$.

iii. The second shock wave is situated at $\lambda = 0.74$.

The integral curves of the form Z=f(V) which are found for conditions which are characteristic of the electrical discharge in short gap are shown in Fig.3. For the first shock wave the value of λ is $\lambda = 1$, at the contact surface $\lambda = \lambda_1 < 1$ and at the front of second shock wave $\lambda = \lambda_2 < \lambda_1$. The integral curve is vertical at the boundary of the discharge channel $\lambda = \lambda'$. In $\lambda = \lambda'$ the temperature T increases up to 8.10^3K when an ionization of the medium appears.

The radius of the discharge channel obtained in such a way as a function of the time gives a possibility the current density of the discharge to be established. The variation of this density in the time determines the variations of the energy fluxes at the electrodes [4]. This is important for the optimisation of the EDM technologies.

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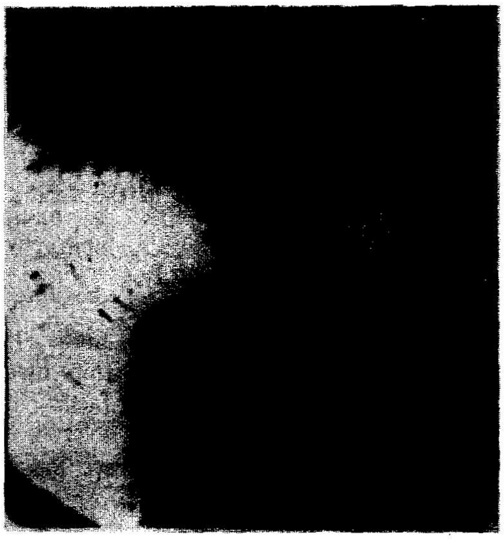

Fig.1

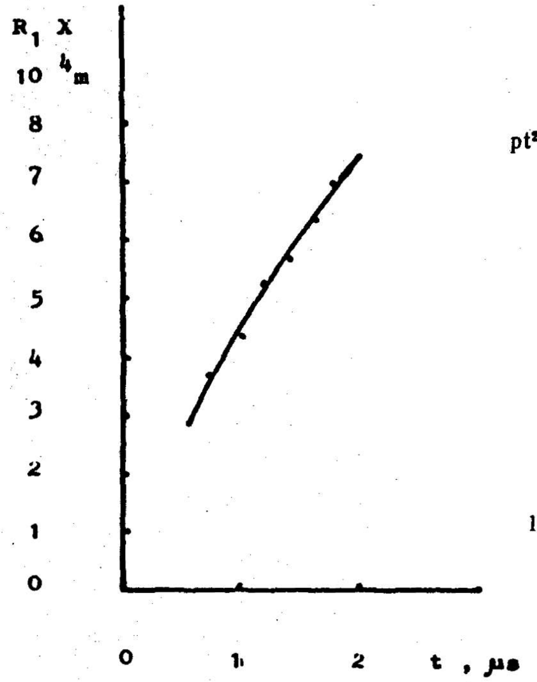

Fig.2

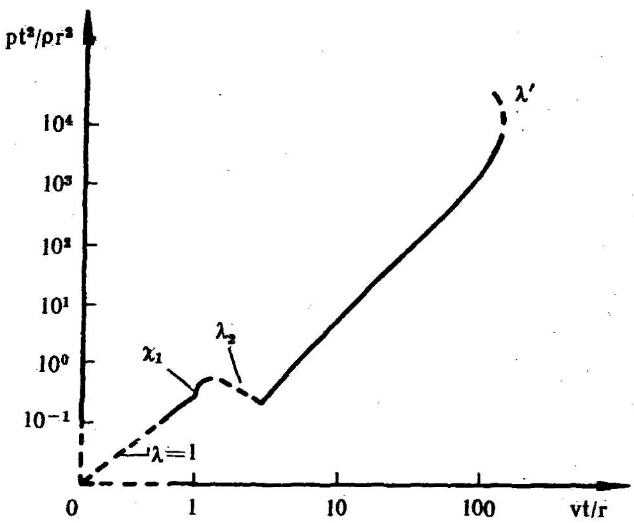

Fig.3