ONE FORM OF STRATIFICATION IN THE ELECTRIC EXPLOSION OF WIRES

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UDC 534.222.2

In the transient mode of the electrical explosion of a copper wire a redistribution of the explosion products takes place during the escape of the particles. This observation is confirmed by high-speed optical photographs and also by reference to the appearance of the deposited film.

Among the various opinions which exist in regard to the rupture of conducting materials during an electrical explosion, two may particularly be distinguished: prethreshold explosions, which appear as bends and subsequent breaks in the wire material, and postthreshold explosions, which are accompanied by the separation of the wire into individual strata [1].

In the authors' own experiments, bending and stratification were observed simultaneously. The stratification was the result of the accumulation of explosion products during the disintegration process.

The process was recorded optically with a high-speed camera having a frequency of 2 million frames/sec. The method of recording the electrical parameters at the same time as the optical recording was described in [2]. The explosion of the wire was effected by means of a condenser battery of 60 F with a circuit inductance of 1 μH.

Figure 1 illustrates successive stages in the development of an explosion rupturing a copper wire in air. The central region 15-mm long was photographed in this experiment. The photographs show the time in microseconds from the beginning of the current pulse. In order to remove the plasma stage, the current was disconnected after the first half wave by the explosion of a thinner auxiliary wire connected in series. The voltage U_0 was 7.0 kV. The parameters of the principal and auxiliary wires were: diameter d = 0.500 ± 0.005 and 0.475 ± 0.005 mm, length l = 50 and 150 mm. At the instant of disconnecting the current (13 μsec) the wire was slightly bent and surrounded with vapor. Then the development of a vapor sheath began. At these points of the initial bend moving along the normal to the surface of the wire, the vapor created cumulative outsurges, directed perpendicularly to the original axis.

The outsurges are caused by collisions between flows of vapor arising from parts of the wire disposed at an angle to one another. Together with the development of a vapor sheath there is an increase in the diameter of the wire; the wire takes the form of an expanding hollow cylinder [3], the sheath (outer shell) of which consists of liquid drops of various degrees of dispersion. For large increases in the diameter of the

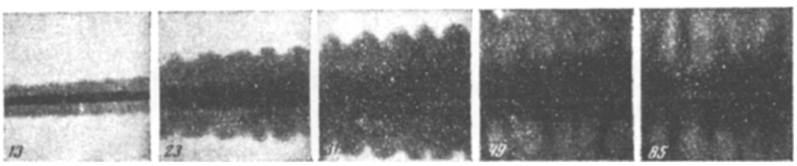

Fig. 1

Moscow. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, No. 1, pp. 161-163, January-February, 1974. Original article submitted August 31, 1973.

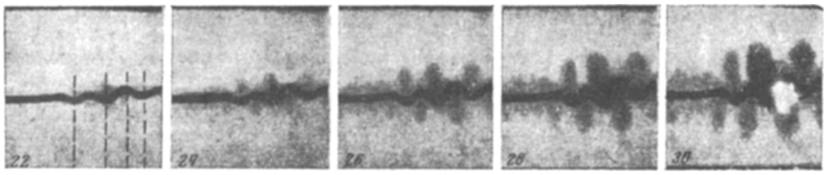

Fig. 2

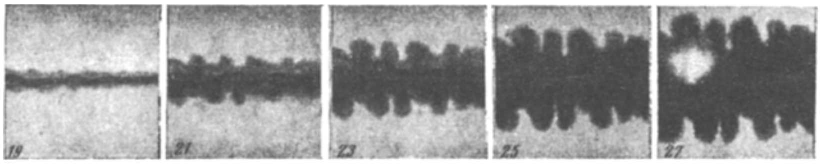

Fig. 3

TABLE 1

Time, μsec	Cross section	Velocity of cumulative vapor jet, m/sec
22	1	—
	2	375
	3	290
	4	360
24	1	250
	2	315
	3	395
	4	320
26	1	430
	2	400
	3	520
	4	410
28	1	210
	2	—
	3	305
	4	320

wire the drops are drawn into motion by the cumulative vapor jets, forming condensed regions clearly visible in the photographs. At the final stage (85 μsec) almost all the material of the coarsely dispersed disintegration fragments is concentrated in the condensed regions. This is further confirmed by the fact that the deposit formed on a glass plate close to the wire takes the form of a set of sharply-delineated bands perpendicular to the axis of the wire.

Figure 2 shows the successive stages in the development of an explosion in which the auxiliary wire was too short to eliminate the plasma stage entirely. Here the voltage U_0 = 5.7 kV, for the main wire d = 0.500 ± 0.005 mm, l = 50 mm, for the auxiliary d = 0.410 ± 0.005 mm, l = 50 mm. Clearly seen on the photographs are the distinctive cumulative formations; first the onset of the vapor (22 μsec) and then that of the drop-like fraction of the explosion products (26 μsec). The velocities of the cumulative vapor flows of (Table 1) projected on the vertical plane were found for the various cross sections indicated in Fig. 2 by graphical differentiation from measurements made on the trajectories of the surges.

The rate of expansion of the vapor on the rectilinear parts of the curve is 145 m/sec, the rate of expansion of the wire 30 m/sec. Measurements made on the velocities of the vapor-drop jets gave a considerable scatter owing to the diffuseness of the leading edge. The mean velocity was 190 m/sec.

The formation of the cumulative outsurges of material was also recorded during the explosion of a wire without any current cut-off (Fig. 3, U_0 = 3.7 kV, d = 0.500 ± 0.005 mm, l = 50 mm). The difference here lies in the fact that the secondary breakdown distorts the final distribution of the material.

Thus for a certain range of initial conditions the observed stratification in the electric explosion of wires is due not to the primary disintegration processes but to the redistribution of the wire material in flight. This effect takes place in a transient mode, in which a vapor cloud is formed at the same time as the bend.

LITERATURE CITED

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