

Disruption of Shaped-Charge Jets by a Current

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In our previous experiments on disruption of metal shaped-charge jets by a capacitor-bank current, we attained almost complete disruption of the entire jet. In those experiments, the distance between the shaped charge and the current electrodes was approximately equal to the diameter of the shaped-charge cavity. Physically, jet disruption by a high current consisted of initial development of MHD instability of the jet in the form of growth of necks and subsequent electric explosion of the necks. The present paper describes similar experiments in which the distance between the shaped charge and electrodes was increased. It is shown that this can worsen results of jet disruption because the change in the initial state of the jet changes the physical picture of the process of jet disruption by a current.

Key words: shaped-charge effect, shaped-charge jet, capacitor bank, MHD instability, electric explosion of a conductor, electric-current pulse.

Physical aspects of the action of a pulsed electric current on metal shaped-charge jets have been the subject of extensive studies. However, the mechanism of disruption of shaped-charge jets by a current has been studied inadequately, which is due to the complex nature of the process and the higher cost of experiments compared, for example, to similar experiments with exploding conductors.

In such experiments, the source of current is usually a capacitor bank connected to two plate metal electrodes. The shaped-charge jet, shorting these electrodes, closes the discharge circuit, and a current begins to flow in the jet. Figure 1 shows diagrams of the experiments performed in [1–9].

In the experimental setup shown in Fig. 1a, the current flows only in the segment of the shaped-charge jet between the electrodes. Therefore, this version yields the worst results on reduction of jet penetration into a target. However, this setup makes it possible to perform radiography of a jet when it leaves the interelectrode

gap and to observe results of action of the current on the jet. Almost all the photographs in [1–9] were taken using a charge with a cavity diameter of 40–45 mm (only this charge will be considered below); charges with a cavity diameter of ≈ 100 mm were also used [2].

The setup shown in Fig. 1b is more effective. Here the shaped-charge jet, leaving the interelectrode gap, immediately penetrates the target, producing a cavity, which acts as an inverse current lead with respect to the jet. As a result, the length of the segment of the shaped-charge jet acted upon by the current increases, and so does the time of action of the current on the jet elements. On such experimental setup, maximum reduction in jet penetration into a target h was reached: from ≈ 200 mm with no current to ≈ 50 mm with a current [1, 2]. However, further reduction in h in this case is difficult because with closure of the interelectrode gap by the shaped-charge jet, the current begins to increase under a sine law, and the jet head penetrates into a target, without being subjected to critical action.

Pavlovskii [9] proposed an experimental setup (Fig. 1c) in which a pile of thin metal plates separated by air gaps is placed between the electrodes and the

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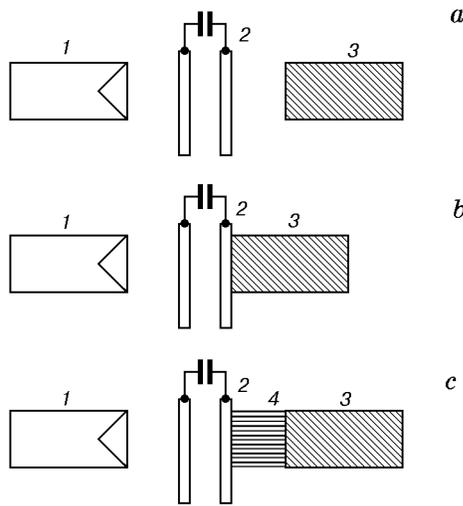


Fig. 1. Diagram of experimental setups: 1) shaped charge; 2) metal plate electrodes connected to the capacitor bank; 3) metal target (Steel 3); 4) pile of thin metal plates separated by air gaps (4).

target. As a result, the head of the shaped-charge jet, having passed through the electrodes, remains under the action of the current when moving through these plates. At a current amplitude of 500–550 kA, the jet was almost completely disrupted: $h \approx 10\text{--}15$ mm or a cavity was absent altogether [9].

In all the above-mentioned experiments, the shaped charge was placed rather close to the electrodes (at a distance of 1–2 cavity diameters) and the shaped-charge jet was not strongly stretched and had no necks. The action of the current on such a jet leads first to necking and then to the formation of disk-shaped strata, which increase the jet diameter by a factor of 3 or 4. The axial symmetry of the jet is approximately retained. After that, an electrical explosion of the necks occurs, which is strong enough to disrupt the next segments of the jet.

However as the distance between the charge and the electrodes increases, the shaped-charge jet approaching the electrodes becomes more stretched and deformed. Necking is pronounced. Figure 2 shows a photograph of the jets taken at the moment when its “tip” traveled a distance of ≈ 300 mm (approximately 30 mm of the jet is beyond the photograph) from the charge. The shape of the jet is already strongly distorted, rather thin necks have formed, and the axial symmetry of the jet is markedly disturbed. However, the jet is still continuous and retains notable penetration capability.

It would seem that the presence of such thin necks should facilitate the rupture of the shaped-charge jet by a current. However, in our experiments with such stretched jets, the results were worse than in experi-

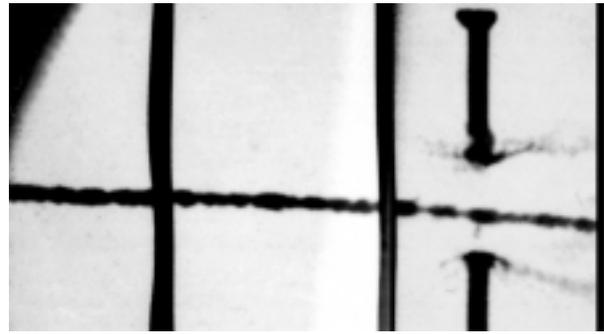


Fig. 2. Shaped-charge jet from a charge with a cavity diameter of 45 mm placed at ≈ 300 mm from the charge (the head of length ≈ 30 mm is beyond the photograph); nail diameter 3.3 mm; vertical strips are the protection of the cassette.

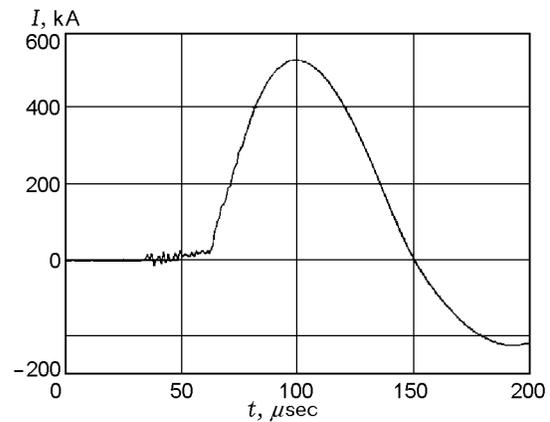


Fig. 3. Variation of current in one experiment.

ments with smaller distances between the charge and the electrodes. Complete disruption of the jet did not occur, and results of experiments with such jets using the setup of Fig. 1c were comparable to the results of experiments on the setup shown schematically in Fig. 1a.

In the present paper, we describe some experiments performed to compare the nature of current disruption of shaped-charge jets with different degree of their deformation, i.e., at different distances between the charge and the electrodes.

In the experiments, we used charges with a cavity diameter of 45 mm, similar to those used in [8, 9] but differing from them in that the explosive was more powerful. As a result, the penetrating capability of the shaped-charge jet was reduced: $h = 170, 145,$ and 130 mm at standoff distances of 55, 160, and 220 mm, respectively. The deformation of the stretched jet was noticeable.

A 1200 μF capacitor bank charged to 20 kV was used. The variation of the current in one of the experi-

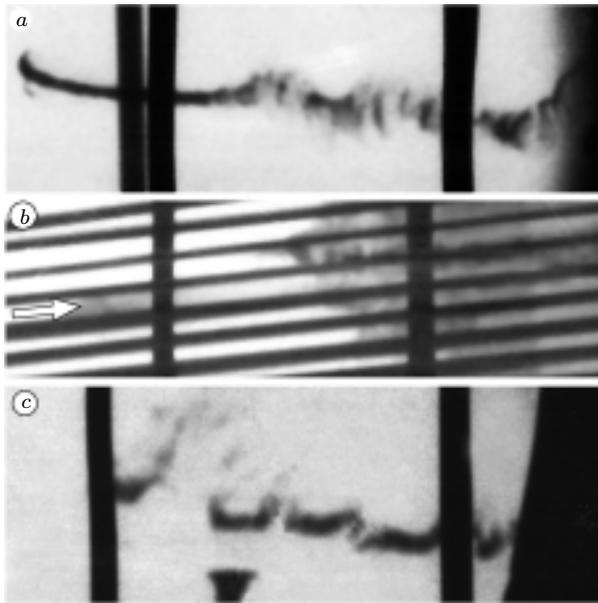


Fig. 4. X-ray photographs taken in the experiment (the jet moves from right to left): (a) setup of Fig. 1a with a distance between the charge and electrodes of 160 mm; (b) setup of Fig. 1c with a distance of 160 mm (the arrow shows the position of the intact element of the jet head); (c) setup of Fig. 1a with a distance of 220 mm.

iments is shown in Fig. 3. The current amplitude was 520–560 kA.

We compared data of experiments performed on the setups shown schematically in Fig. 1a and Fig. 1c. In the experiments, we used aluminum electrodes 4 mm thick and 80 mm wide spaced 20 mm apart. The photographs taken in the experiments are presented in Fig. 4. In Fig. 4a (setup of Fig. 1a), necks formed by jet stretching rather than by the current are evident on the head segments of the shaped-charge jet issuing from the interelectrode gap. One can clearly see elements with necks formed by the current, followed by the region of formation of disk strata on the jet. It is evident that the asymmetry of the jet due to the asymmetry of the necks formed upon jet stretching is considerably enhanced by the action of the current, but this increase is not strong enough to complicate the experiment. In this experiment, $h = 48$ mm.

In photograph 4b (setup of Fig. 1c with a pile of aluminum plates 1 mm thick and 120 mm long spaced 4 mm apart) one can see only a small intact element of the jet head, whose penetration into the target was the greatest — 6–7 mm. In fact, there is no cavity in the target.

The photograph presented in Fig. 4c (setup of Fig. 1a) is very interesting. When the distance be-

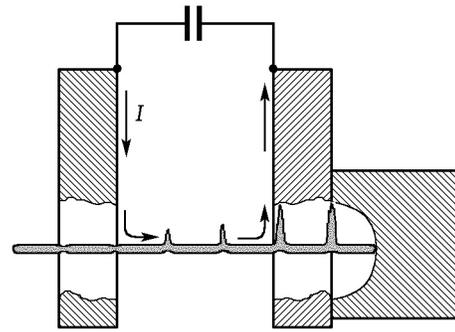


Fig. 5. Diagram illustrating the effect of radial metal ejections from the jet on the operation of the experimental setup.

tween the charge and the electrodes is 220 mm, the necks between the jet elements become thin enough, so that their electrical explosions are possible even in the head elements of the jet. Because the necks are thin, the explosions do not damage the neighboring segments of the jet. Because of the initial asymmetry of the necks, these explosions produce rather long radial ejections of the metal and do not produce disks. In the experiment, $h \approx 40$ –45 mm. In a similar experiment using the setup of Fig. 1c, several elements of the jet remain intact and the depth of the cavity is about the same: $h \approx 40$ mm.

In experiments using the setup shown in Fig. 1a with a distance of 280 mm between the charge and the electrodes, the jet was severely disrupted but the cavity was nevertheless noticeable: $h = 35$ mm. In similar experiments on the setup shown in Fig. 1c, this jet is effectively disrupted. A cavity is not produced in the target, and only very small holes are present on the surface of the target.

The experiments show that the initial shape of a shaped-charge jet subjected to a current has a significant influence on the physical pattern of the jet disruption process. When the radial metal ejections from a neck, developed under the action of the current, reach the next current-carrying plate, they shunt the jet element ahead of this neck, and the current in this element decays rapidly. Such ejections can also develop on the jet segments that are still between the electrodes. They can shunt the output electrode (Fig. 5). In this case, the experimental setup of Fig. 1b and c become identical to that in Fig. 1a and the efficiency of jet disruption degrades.

It is necessary to study in greater detail the processes of current disruption of shaped-charge jets with various degrees of jet tension and strain and to develop methods for protecting from the action of radial ejections.

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