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Using the Initiation System of Electrical Discharge in the Case of Electrohydraulic Forming

The paper presents the results of the author experimental research in order to find the influence of exploding wire geometry on the pressure obtained in the discharge chamber, in the case of electrohydroimpulses drawing in the high voltage domain, between 20...50 kV. The fusible was made by Cu, being studied as follows: the influence of the diameter, of the discharge space length, of the developed length of the exploding wire, of the distance between base electrodes and also of the different types and dimensions of the plane or spatial geometrical configuration of the exploding wire.

Keywords: *pressure, electrohydraulic forming, wire initiation*

1. Introduction

Electrohydroimpulses drawing represents a technological alternative completing the range of cold plastic strain procedures and it is based upon the so-called technique of high energies-bearing impulses. Are known studies regarding the parameters which influences the size and the distribution of pressure in discharge chamber, for discharge voltages under 15 kV. In the case of discharge initiation by using exploding wire it is to be noticed the absence of a uniform theory which could entirely describes the phenomenon from electrical and hydrodynamics point of view. This lack of data leads to contradictories using recommendations.

This is the reason why, for discharge voltages between 20…50 kV, has been examined for an influence study, those parameters which are considered to be of great importance from technological point of view and which, due to the construction of the deformation equipment, can be set in certain limits. Nevertheless, working in mono and multiimpulse regime, these parameters are:

1. the charge voltage of condensers battery;
2. the condensers battery capacity;
3. discharge axis - plate distance and electrode gap;

4. the material, the diameter, the length and configuration – planar or spatial – of the exploding wire;

5. the material, the geometry and the diameter of the used electrodes (in the case of discharge with direct impulse breakdown of discharge space).

Present paper wishes to study, on a side, the dependence of shock wave front maximal pressure on the parameters listed at the fourth point mentioned above and, on the other side, to verify the usability in the high voltages domain of the rules determined at relative low voltages.

So, regarding the discharge initiated by exploding wire, it is admited the existence of an optimal diameter of the exploding wire, the value of this optimal diameter being dependent on the electrical parameters of the discharge circuit and on the wire material [1,3,6]. A dependence between the shock wave pressure and voltage, for different materials and diameters of the exploding wire, is presented in [5]. In this case, the condensers battery capacity was of 24 μF.

For any combination of the parameters of the discharge electrical circuit there are optimal values of wire diameter and length, these values giving the best efficiency in transforming a type of energy into another.

Some experimental results are presented in [2] concerning the amplitude of shock wave pressure relative to the material and dimensions of the wire, for different experimental conditions.

The researches regarding the influence of the material on the efficiency in transforming electrical energy in mechanical energy by electrohydraulic explosion, leads to an order list as follows, in descendent order: wolfram, aluminum, copper, magnezium [2].

As a general rule, the papers devoted to this theme contains experimental researches, some of them indicating calculus relations (empirical or analitical) for the optimal dimensions, these relations being valid only for certain work conditions. Also, it seems that close upon to the influnces of dimensional parameters of the exploding wire, another influence can be recover, namely the shape of the exploding wire.

Taking into account all we said above, results that the electrohydroimpulses drawing requires to know and to control a large number of independent processes, on these processes acting the influences of a lots of factors. Even if the papers which treats this proceeding are not quite a few, its doesn't succeed to offer valid and truth-like indications on the concrete model of the process development, indications which could allows to prescribe technological recommendations with universal validity.

2. Experimental hardware and results

In some of the author's previous papers [4] had been presented the construction parameters of the own designed universal discharge chamber used in the experiments and also, of the electric system whereon the chamber was coupled (russian origin, model GIT 50 – 5x1/4C). A general view of the discharge chamber is presented in fig 1. The sensing device system for the shock wave front pressure measurement was also designed and manufactured by the author (fig. 2).

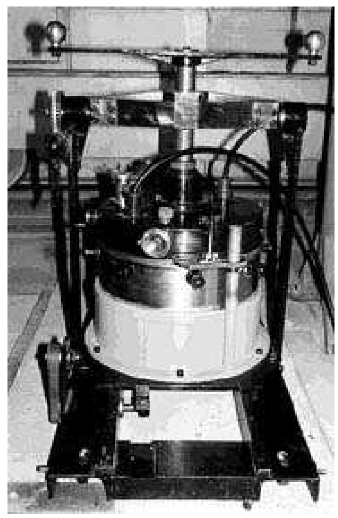

Figure 1. General view of discharge chamber

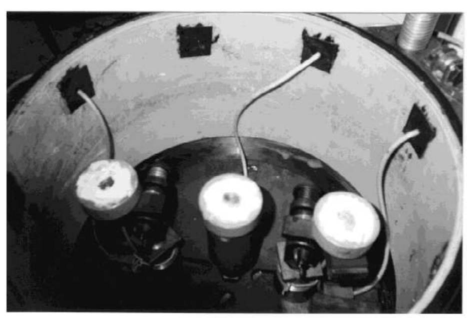

Figure 2. General view of the sensing device

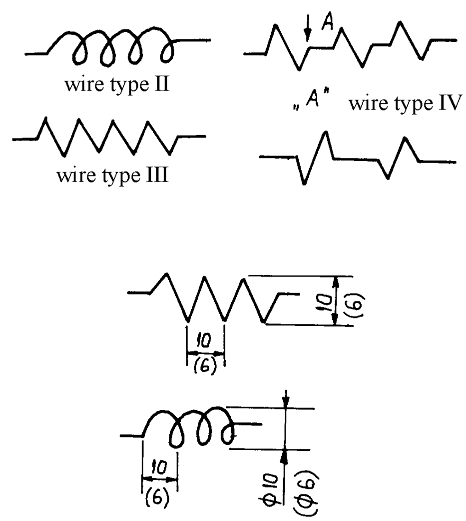

Figure 3. Shapes of exploding wires.

In all cases, the exploding wires was made by copper. Even if from industrial use point of view doesn't present too much interest, (because the construction of such automatic feed systems adapted to these wire shapes is too complicated), has been subjected to experiments, in comparison, 3 shape types (planar or spatial) of copper exploding wire. These shapes are presented in figure 3 (the wire type I is considered to be the linear one). Each of them are defined by certain geometrical parameters (developed length of the wire, interval between staggers or spiral walk, the spire diameter or the staggers high, number of spires or staggers, etc.).

For same values domains of the discharge circuit parameters, the comparison of the effects was made observing the following condition: equal developed length of the wires, which leads (if the geometrical characteristics of the shape are maintained the same) to a decrease of the distance between support electrodes in the case of the wire with an arbitrary shape, in comparison with the linear wire. The study was made for two groups of dimensions (fig. 3). The wire type IV had the same dimensions as the wire type III.

3. Results and conclusions

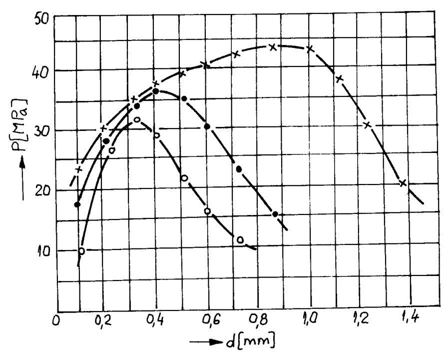

Figure 4. The variation of pressure relative to the diameter of copper linear conductors

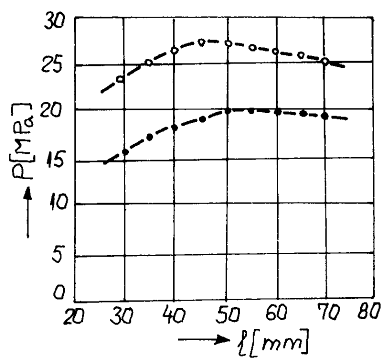

Figure 5. The variation of pressure relative to the discharge space length

Regarding the discharge when initiing by exploding wire, it is to be noticed from the beginning that, in comparison with the discharge with direct impulse breakdown, it doesn't automaticaly lead to an increasing of the shock wave pressure, but to a stabilization of the discharge. This fact increases both the reproductibility capacity and the prediction degree of the process. Near all these, the existence of the conductor bridge between electrodes eliminates the danger of arc-over, and this is the reason why the report value h / l can be decreased under the unity value (h / l < 1, where h - discharge axis - plate distance; l - electrode gap). This aspect is of a great importance, because is the only way to obtain pressures with the same values as in the case of the discharges with direct impulse breakdown of discharge space. As a general rule, for same experimental conditions, the pressure obtained by initiation is about 70 % from that obtained by direct stroke. The explanation stands in a higher power loss in the time before formation of the discharge channel, both for fusing and vaporization of the wire (sublimation). In fig. 4 is presented the variation of pressure relative to the diameter of some linear copper conductors, for different charge voltages of condensers battery (l = 80 mm; h = 50 mm; • U_0 = 26,8 kV; ° U_0 = 23.3 kV; x U_0 = 35,6 kV).

From presented diagram results that the principle of optimal wire diameter is also true in the high voltages domain, the optimal value of the diameter increasing when voltage or discharge energy increase. The evaluation of pressure maximal value can be made similar to direct impulse breakdown, taking into account [6] changing of spark characteristic value *($A \approx 0{,}25 \cdot 10^5\ V^2 \cdot sec / m^2$)*.

Regarding the optimal length of the wire, the experiments made with values of the discharge parameters in the same domains as in the case of direct impulse breakdown shown that it increases with about 10 … 20 % (in comparison with optimum electrode gap in the case of free discharge). To show that, the diagram in figure 5 is presented (U_0 = 23,3 kV; h = 140 mm; • wire Cu, Φ 0,32 mm; ° direct impulse breakdown). The increasing ratio is higher at higher voltages.

The experiments made with spatial exploding wire, when the condition mentioned in chapter 2 is valid, in the domain *l_d = 55...165 mm* (l_d - developed length), shown that the eventual rising of pressure is small and doesn't justify the necessary costs to introduce this type in industrial use.

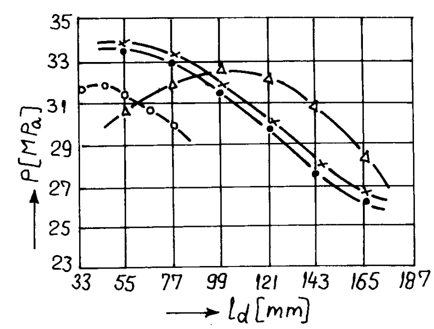

Figure 6. Variation of pressure relative to developed length of the exploding wire

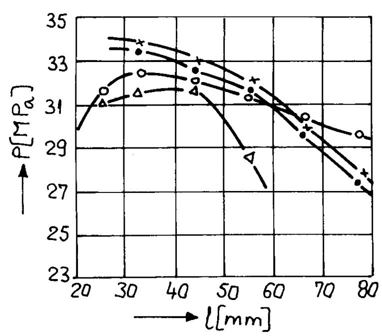

Figure 7. Variation of pressure relative to the distance between support electrodes

In fig. 6 are presented the variations of the pressure relative to the developed length of the wire, fo those 7 used types, and in fig. 7 is presented the dependence of pressure relative to the electrode gap (in both cases: U_0 = 26,8 kV; h = 80 mm; Φ 0,32 mm; ° wire type I; • type III and IV, dimension 10 mm; Δ type II, dimension 10 and 6 mm; x type III and IV, dimension 6 mm). How the pressure varies can be explained if is accepted the supposition of cumulative influence of both wire length and distance between support electrodes. So, a certain wire length releases, by it's explosion, a certain quantity of energy. For the same values of electric parameters of the discharge circuit (voltage, capacity, inductance) and same diameter, at equal wire lengths (no matter what kind of configurations), the quantity of energy released is the same, because the vaporization current is identical. As a general rule it can be established that in the same space (distance between support electrodes), a longer wire leads to a higher quantity of energy radiated in that space.

With all these, the rule is not universal valid, due to the existence of optimal value of wire length. So, in the studied values range for l_d , for the curves in fig. 9 noted with (•) and (x), the developed lengths are over optimal values, which leads to a decreasing of pressure. The values are bigger in comparison with those of wire type I because, at the same developed length, the space between support electrodes is smaller. For the curve noted with (Δ), the increasing portion is the cumulative result of very short distances between electrodes (which leads to a regime similar with that of short-circuit) and of wire length increasing (even over optimal value), simultaneous with increasing of adequate distance between support electrodes. An optimum is then reached, given by the realization of a favourable ratio between these two lengths, and after that starts the decreasing portion of the curve. This portion is above of those two curves previously mentioned, because the distance between support electrodes is shorter than those two (at the same l_d).

In conclusion, for such configurations of the initiation wires is necessary a permanent control, both of electrode gap and wire length, these two being each other dependent on. This difficulty is another reason why such initiation methods doesn't spread in industrial use.

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