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Liviu Coman, Codruta Hamat

The Influence of Distance between Electrodes at Electrohydraulic Forming

The paper presents the results of the author`s experimental research for the influence of electrode gap on the maximum drawing depth and shock wave pressure in the case of the electrohydraulic drawing, in the high voltage domain, between 20...50 kV, in which the studies are in small number and, in a large measure, incomplete or contradictories.

***Keywords**: drawing depth, electrohydraulic forming, electrode gap*

1. Introduction

Electrohydraulic forming represents a technological alternative completing the range of cold plastic strain procedures. It is based upon the so-called technique of high energies-bearing impulses. In any of the cases when working in mono or multiimpulse regime, if the discharge initiation is realised through direct stroke, the electrode gap is an essential geometric parameter for the obtained pressure to the shock wave front and, obvious, for the maximum drawing depth which can be realized to the plate.

2. Experimental hardware and results

In some of the author's previous papers [1,2] 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. A general view of the discharge chamber and electrode system are presented in figures 1 and 2. The sensing device system for the shock wave front pressure measurement and form detecting was also designed and manufactured by the author.

Here we remind only that had been subjected to the experiments disk-shaped plates, made form different steel qualities and having different thickness. The diameter of the plates used was of 293 mm and the deformation was done in the mobile flange regime, discharge axis being parallel with the surface of the semi-manufactured plate. The condensers battery capacitance was of 4...8μF and the discharge circuit inductance of 3,2 μH. The semi-manufactured plates was greased both on the die-block side and on the retaining ring one, only on the contact area, with 5-degree consistence grease (hard), of the type **U 75 Ca 2**, STAS 562-86. It was proved that, due to the high consistence, one can thus also ensure the sealing of the system retaining ring - plate - die-block. The tightening force on the screw at the retaining ring, measured with a dynamometric wrench was of 20 daN. The die-block used, made of OLC 60 (LC steel), had the semispheric cavity diameter of 200 mm, the entrance connection radius being of 3 mm. The electrodes was made by Cu, having a conical shape, 8 mm diameter and a non-isolated surface of 2,56 cm^2.

In the speciality papers [3,4] are presented relative enough experimental data, for the 5...15 kV voltage domain, on which basis has been established the related relations between maximum drawing depth and shock wave pressure on a side and geometrical parameters on the other side.

In the experiments made by the author [1] it was followed if optimal values existence rules also keeps theirs validity into the voltage domain of 20 ÷ 50 kV (a domain in which both national and international work's number is limited) and what kind of relations exists between them. Some of the diagrams of $\mathbf{s_{max}}$ and P (maximum drawing depth in the center of the part and pressure on shock wave front respective) depending on electrode gap, are presented in figures 3, 4, 5, 6 and 7 (where **h** - discharge axis - plate distance; **l** - electrode gap; **g** - plate thickness; $\mathbf{U_0}$ - discharge voltage of condensers battery through spark discharger; P - shock wave front pressure; T.N. - black sheet metal; T.Z. - galvanized sheet).

Figure 1. General view of the discharge chamber.

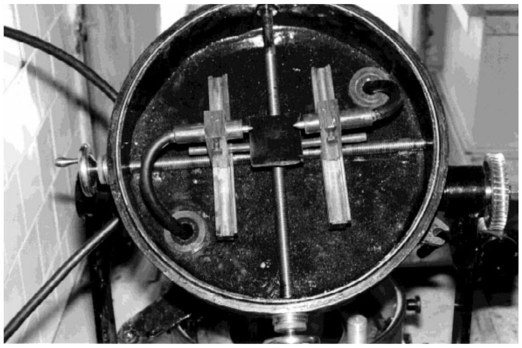

Figure 2. General view of the electrode system.

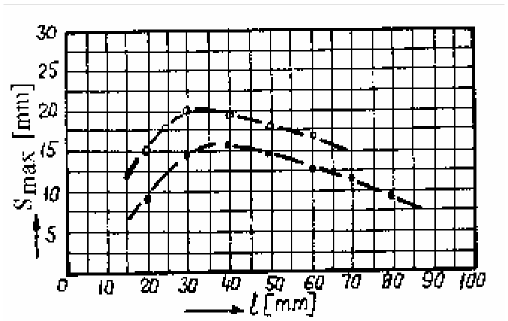

Figure 3. Diagram $\mathbf{s_{max} = f (l)}$.
° T.Z. , g = 0,7 mm; h = 60 mm; U_0 = 23,3 kV;
•T.Z. , g = 0,7 mm; h = 80 mm; U_0 = 23,3 kV.

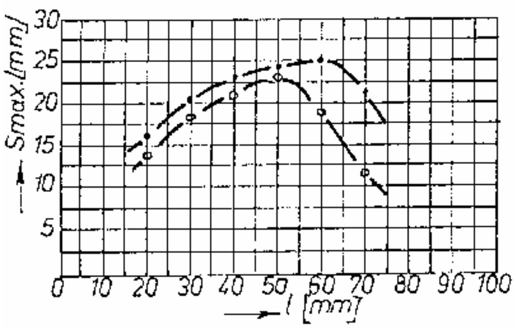

Figure 4. Diagram $\mathbf{s_{max} = f (l)}$.
° T.N. , g = 1 mm; h = 50 mm; U_0 = 26,8 kV;
•T.N. , g = 1 mm; h = 50 mm; U_0 = 30 kV.

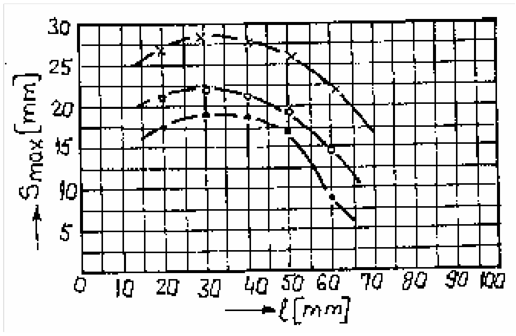

Figure 5. Diagram $\mathbf{s_{max} = f (l)}$.
° T.N. , g = 1 mm; l = 50 mm; U_0 = 26,8 kV; •OL 37 , g = 1,2 mm; l = 50 mm; U_0 = 26,8 kV; x T.Z. , g = 0,5 mm; l = 50 mm; U_0 = 26,8 kV.

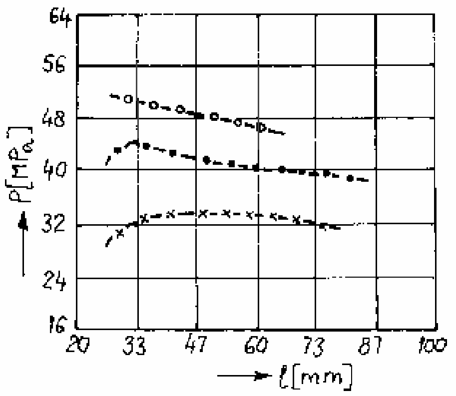

Figure 7. Diagram **P = f (l)**.
U_0 = 26,4 kV; • h = 80 mm; ° h = 60 mm; x h = 120 mm.

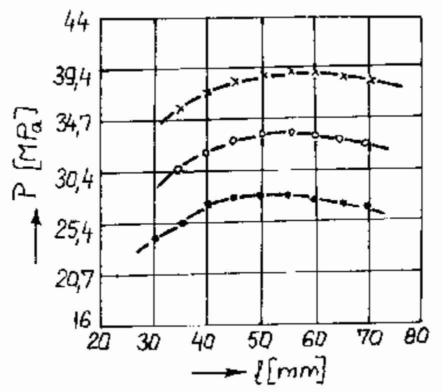

Figure 6. Diagram **P = f (l)**.
h = 140 mm; • U_0 = 23,6 kV; ° U_0 = 30 kV; x U_0 = 36,4 kV.

3. Conclusions

Regarding to the variation of pressure relative to electrode gap **l** it is to be noticed that also in this domain of high voltage exists optimal values of **l**, for which both drawing depth and pressure has maximal values. But, due to slow dependence of the pressure on distance **l**, the conclusion is that, from technology point of view, is more adequate to speak about a domain of optimal values instead of a determinate, unique value.

The experiments performed in parallel to determinate the influence of the same parameters on pressure obtained on shock wave front [1] proved that influence of ***l*** distance is more important at high *h* distance, due to the modification of shock wave front shape and quickly decreasing of pressure at lower ***l*** distances.

In order with this last aspect, it is to be noticed the modification of the influence character of electrode gap at high voltage, by comparison with that presented to the lower voltage, where pressure follows more rapidly the variation of this parameter.

To estimate the optimal value of electrode gap, it can be studied to extremely the calculus relation of pressure in according with cylindrical-spherical transition zone of shock wave front [1], obtaining:

$$l_{opt} = 0{,}28 \cdot \sqrt{\frac{U_0 \cdot h}{A^{1/2}}} \cdot (L \cdot C)^{1/8} \qquad (1)$$

where **L** - discharge circuit inductance; **C** - condensers battery capacity and **A** - spark parameter.

Experiments shown that, in according with this calculated value, the variations of pressure which occurs in the domain:

$$l_{opt} = (\ 0{,}26 \div 0{,}31\ ) \cdot \sqrt{\frac{U_0 \cdot h}{A^{1/2}}} \cdot (L \cdot C)^{1/8} \qquad (2)$$

are little, under 6%. So, the relation (1) can be used with enough precision to estimate the optimal electrode gap, for which is obtained the highest pressure amplitude on shock wave front. For industrial installations working in automatic multiimpulse regime, the existence of the values range given by relation (2) has a benefactor effect, because it offers a longer life to the electrode system, until due to the reaching of electrode gap upper limit, will be necessary electrode's changing or a new adjustement of this distance.

In conditions of constancy of the others parameters values, both increasing voltage and increasing discharge axis-plate distance has like effcet increasing of optimal electrod gap. It is to be mentioned that this optimal value can be hardly reach, due to the correlations of this three parameters: voltage - electrode gap - discharge axis-plate distance and to a double restriction for the electrode gap. So, working with high voltage impose to choose long electrode gap (to avoid discharges in short-circuit regime) but, in the same time, low distances between discharge axis and plate leads to even lower electrode gap (to avoid contour discharges).

On the other side, because of the existence of a second pressure impulse, due to gas bubble, occurs the necessity to adopt some corrections in according with the fact that the value of the second pressure impulse has maximum values at lowest distances from discharge axis (this distance can not be lower than electrode gap, because of contour discharge danger) and that the gas bubble pressure increase with voltage increasing. So, for the experiments performed in the range $U_0 = 20 \ldots 45$ *kV*, $l = 30 \ldots 80$ *mm*, $h = 30 \ldots 160$ *mm*, with $h/l = 1 \ldots 2$, is recommended to multiply the value of shock wave front pressure with a correction factor of $k_1 = (1{,}4 \ldots 1{,}7\ )$. The lower limits can be adopted for low voltage and for values of *h/l* ≅ *2*; the upper limits can be adopted for high voltage and for values of *h/l* ≅ *1*. Also, if the specific resistance of the used water is under 15 Ω· m, then is recommended that electrode gap to be chosen at lower limit of the range which, from the technology point of view, leads to the same results. The appropriate value is determined by experiments, in according with construction of the discharge chamber and electrode system.

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Addresses:

- Dep. Prof. Dr. Eng. Liviu Coman, "Eftimie Murgu" University of Reşiţa,
  Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, l.coman@uem.ro
- Prof. Dr. Eng. Codruta Hamat, "Eftimie Murgu" University of Reşiţa,
  Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, c.hamat@uem.ro