RESEARCHES ON THE INFLUENCE OF ELECTRICAL PARAMETERS OF CIRCUIT ON DEPTH OF DRAWING OF CIRCULAR PARTS THROUGH ELECTRO-HYDRAULIC PROCESS

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Abstract: *This paper deals with the influence of the discharge electrical parameters such as wire length and diameter priming discharge, discharge capacity and battery voltage on the stamped depth to electrohydraulic method*

Keywords: *drawing, electrohidraulic, tension, capacity.*

1. Introduction

Research geometrical parameters influence of the discharge channel, determined by the length l and diameter d of the conductor priming of discharge was performed by many researchers but at much higher energies discharge, 50 -150 *KJ* [1] [2] [3].

In this paper we studied the influence of these factors at energies much smaller download up to 1200 J and rooms small volume to 1 dm3.

It was also studied the influence of the capacity and voltage of the capacitors, the stamping depth.

Studying these influences at energies much smaller download up to 1.5 *KJ* is absolutely necessary because the material behavior is different from the energy behavior of large and very large download that typically uses for industrial plants [2] [3] [4].

The research was conducted on laboratory installation IDEH 1260 electro deformation with maximum energy of 1260 *J* and whose technical characteristics are: the maximum capacity of the capacitors 70 μF and maximum discharge voltage of 6000 *V*.

Necessary conditions for deformation were provided, using FePO3Am sheet for deep drawing, EN 10130, with the following mechanical properties: yield strength R_p = 240 *MPa*, tensile strength m average R_m= 320 *MPa*, relative elongation at break A_{5min} = 34%.

Semi-finished products used had a thickness of 0.5 *mm* and diameter d_s = 80 *mm* and bore diameter active plate mold d_m = 40 *mm*, height *H* = 40 *mm* hole to allow free deformation of the material and the joining radius of stamp r_M=5 *mm*.

Distance *J*, between semi-finished products and retaining plate was 0.5 *mm*, to prevent high levels of ripple and at the same time to allow easy movement of the semi-finished product.

2. Plan development experience

To study these influences, we used the Taguchi method [5].

For the study we used a factorial plan for 4 factors and 2 levels as $2 \cdot 2 \cdot 2 \cdot 2 = 2^4 = 16$ experiences

The factors are:

A - length of initiation wire

B - diameter of the initiation wire

C - tension of loading

D – capacity of the battery

Levels are: low (1) and maximum (2)

Values of the four factors are date in table 1.

Table 1

Factor	Level 1 (minimum)	Level 2 (maximum)
A	20 mm	80 mm
B	0,2 mm	0,8 mm
C	1000 V	6000 V
D	12 μF	70 μF

Factors and levels are shown in table 2

Table 2

Nr. exp.	Factori A	Factori B	Factori C	Factori D	Y_{mi} mm
1	1	1	1	1	0,1
2	1	1	1	2	8,3
3	1	1	2	1	12,4
4	1	1	2	2	18,7
5	1	2	1	1	0,8
6	1	2	1	2	9,5
7	1	2	2	1	16,9
8	1	2	2	2	21,7
9	2	1	1	1	0,3
10	2	1	1	2	10,2
11	2	1	2	1	18,6
12	2	1	2	2	24,9
13	2	2	1	1	1,1
14	2	2	1	2	12,7
15	2	2	2	1	20,6
16	2	2	2	2	28,4

3. Calculation of the average effects

Calculate the overall average responses Y_{mi}

$$M = \frac{1}{n}\sum_{i=1}^{n} Y_{mii} = \frac{205{,}2}{16} = 12{,}825mm \qquad (1)$$

Calculation the effect of the factor A

$$E_{A1} = \frac{1}{8}\sum_{i=1}^{8} Y_{A1i} - M = -1{,}775mm \qquad (2)$$

$$E_{A2} = \frac{1}{8}\sum_{i=1}^{8} Y_{A2i} - M = +1{,}775mm \qquad (3)$$

Figure 1 is present the effect of the factor A

Calculation the effect of the factor B

$$E_{B1} = \frac{1}{8}\sum_{i=1}^{8} Y_{B1i} - M = -1{,}1375mm \qquad (4)$$

$$E_{B2} = \frac{1}{8}\sum_{i=1}^{8} Y_{B2i} - M = +1{,}1375mm \qquad (5)$$

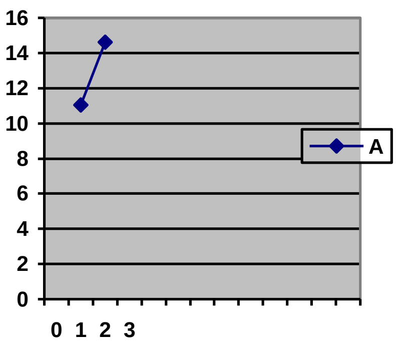

Figure 1

Figure 2 is present the effect of the factor B

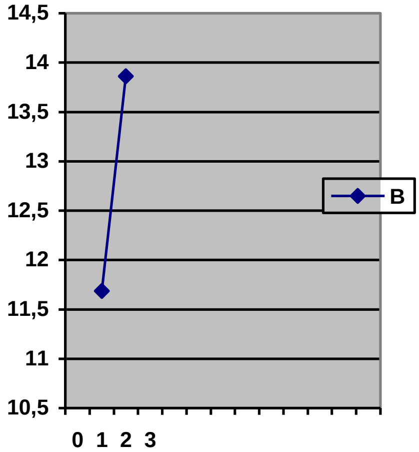

Figure 2

Calculation the effect of the factor C

$$E_{C1} = \frac{1}{8}\sum_{i=1}^{8} Y_{C1i} - M = -7{,}45mm \qquad (6)$$

$$E_{C2} = \frac{1}{8}\sum_{i=1}^{8} Y_{C2i} - M = +7{,}45mm \qquad (7)$$

Figure 3 is present the effect of the factor C

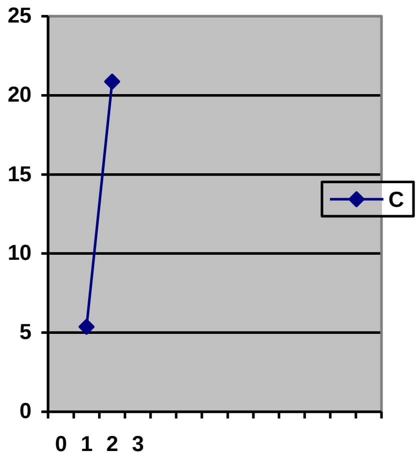

Figure 3

Calculation the effect of the factor D

$$E_{D1} = \frac{1}{8}\sum_{i=1}^{8} Y_{D1i} - M = -3{,}975mm \qquad (8)$$

$$E_{D2} = \frac{1}{8}\sum_{i=1}^{8} Y_{D2i} - M = +3{,}975mm \qquad (9)$$

Figure 4 is present the effect of the factor D

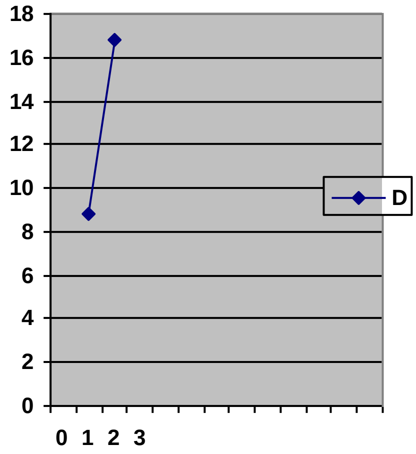

Figure 4

Figure 5 present the effect of factors A, B, C, and D on the drawing depth.

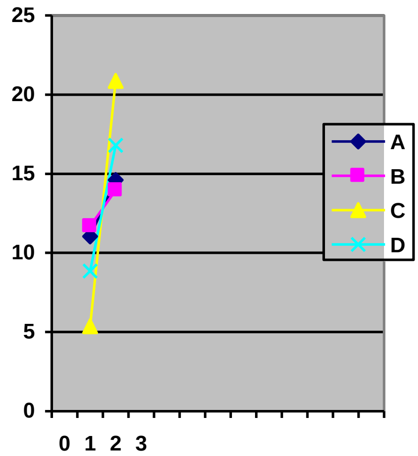

Figure 5

4. Calculation of the interaction

A-B Interaction

$$E_{A1B1} = M_{A1B1} - M - E_{A1} - E_{B1} = = +1{,}455mm \quad (10)$$

$$E_{A1B2} = M_{A1B2} - M - E_{A1} - E_{B2} = = +0{,}31875mm \quad (11)$$

$$E_{A2B1} = M_{A2B1} - M - E_{A2} - E_{B1} = = -0{,}32mm \quad (12)$$

$$E_{A2B2} = M_{A2B2} - M - E_{A2} - E_{B2} = = -1{,}45625mm \quad (13)$$

A-B interaction is present in table 3.

Table 3

Factors		B	
		1	2
A	1	+1,455	+0,31875
	2	-0,32	-1,45625

A-C Interaction

$$E_{A1C1} = M_{A1C1} - M - E_{A1} - E_{C1} = = +4{,}6125mm \quad (14)$$

$$E_{A1C2} = M_{A1C2} - M - E_{A1} - E_{C2} = = -2{,}5375mm \quad (15)$$

$$E_{A2C1} = M_{A2C1} - M - E_{A2} - E_{C1} = = +2{,}8375mm \quad (16)$$

$$E_{A2C2} = M_{A2C2} - M - E_{A2} - E_{C2} = = -4{,}3125mm \quad (17)$$

A-C interaction is present in table 4.

Table 4

Factors		C	
		1	2
A	1	+4,6125	-2,5375
	2	+2,8375	-4,3125

A-D Interaction

$$E_{A1D1} = M_{A1D1} - M - E_{A1} - E_{D1} = = +2{,}875mm \quad (18)$$

$$E_{A1D2} = M_{A1D2} - M - E_{A1} - E_{D2} = = -1{,}1mm \quad (19)$$

$$E_{A2D1} = M_{A2D1} - M - E_{A2} - E_{D1} = = +1{,}1mm \quad (20)$$

$$E_{A2D2} = M_{A2D2} - M - E_{A2} - E_{D2} = = -2{,}295mm \quad (21)$$

A-D interaction is present in table 5.

Table 5

Factors		D	
		1	2
A	1	+2,875	-1,1
	2	+1,1	-2,295

B-C Interaction

$$E_{B1C1} = M_{B1C1} - M - E_{B1} - E_{C1} = = +4{,}2925mm \quad (22)$$

$$E_{B1C2} = M_{B1C2} - M - E_{B1} - E_{C2} = = -2{,}8575mm \quad (23)$$

$$E_{B2C1} = M_{B2C1} - M - E_{B2} - E_{C1} = = +3{,}15625mm \quad (24)$$

$$E_{B2C2} = M_{B2C2} - M - E_{B2} - E_{C2} = = -3{,}99375mm \quad (25)$$

B-C interaction is present in table 6.

Table 6

Factors		C	
		1	2
B	1	+4,2925	-2,8575
	2	+3,15625	-3,99375

B-D Interaction

$$E_{B1D1} = M_{B1D1} - M - E_{B1} - E_{D1} = = +2{,}555mm \quad (26)$$

$$E_{B1D2} = M_{B1D2} - M - E_{B1} - E_{D2} = = -1{,}42mm \quad (27)$$

$$E_{B2D1} = M_{B2D1} - M - E_{B2} - E_{D1} = = +1{,}41875mm \quad (28)$$

$$E_{B2D2} = M_{B2D2} - M - E_{B2} - E_{D2} = = -2{,}55625mm \quad (29)$$

B-D interaction is present in table 7.

Table 7

Factors		D	
		1	2
B	1	+2,555	-1,42
	2	+1,41875	-2,55625

C-D Interaction

$$E_{C1D1} = M_{C1D1} - M - E_{C1} - E_{D1} = = +5{,}7125mm \quad (30)$$

$$E_{C1D2} = M_{C1D2} - M - E_{C1} - E_{D2} = = +1{,}7375mm \quad (31)$$

$$E_{C2D1} = M_{C2D1} - M - E_{C2} - E_{D1} = = -1{,}4375mm \quad (32)$$

$$E_{C2D2} = M_{C2D2} - M - E_{C2} - E_{D2} = = -5{,}4125mm \quad (33)$$

C-D interaction is present in table 8.

Table 8

Factors		D	
		1	2
C	1	+5,7125	+1,7375
	2	-1,4375	-5,4125

5. Calculation of theoretical responses Y_{Ci} and the residues

$$Y_{C1} = M + E_{A1} + E_{B1} + E_{C1} + E_{D1} + + E_{A1B1} + E_{A1C1} + E_{A1D1} + E_{B1C1} + + E_{B1D1} + E_{C1D1} = 19{,}99 \quad (34)$$

$$Y_{C2} = M + E_{A1} + E_{B1} + E_{C1} + E_{D2} + + E_{A1B1} + E_{A1C1} + E_{A1D2} + E_{B1C1} + + E_{B1D2} + E_{C1D2} = 16{,}015 \quad (35)$$

$$Y_{C3} = M + E_{A1} + E_{B1} + E_{C2} + E_{D1} + + E_{A1B1} + E_{A1C2} + E_{A1D1} + E_{B1C2} + + E_{B1D1} + E_{C2D1} = 14{,}8775 \quad (36)$$

$$Y_{C4} = M + E_{A1} + E_{B1} + E_{C2} + E_{D2} + + E_{A1B1} + E_{A1C2} + E_{A1D2} + E_{B1C2} + + E_{B1D2} + E_{C2D2} = 9{,}465 \quad (37)$$

$$Y_{C5} = M + E_{A1} + E_{B2} + E_{C1} + E_{D1} + + E_{A1B2} + E_{A1C1} + E_{A1D1} + E_{B2C1} + + E_{B2D1} + E_{C1D1} = 18{,}85625 \quad (38)$$

$$Y_{C6} = M + E_{A1} + E_{B2} + E_{C1} + E_{D2} + + E_{A1B2} + E_{A1C1} + E_{A1D2} + E_{B2C1} + + E_{B2D2} + E_{C1D2} = 14{,}88125 \quad (39)$$

$$Y_{C7} = M + E_{A1} + E_{B2} + E_{C2} + E_{D1} + + E_{A1B2} + E_{A1C2} + E_{A1D1} + E_{B2C2} + + E_{B2D1} + E_{C2D1} = 12{,}30625 \quad (40)$$

$$Y_{C8} = M + E_{A1} + E_{B2} + E_{C2} + E_{D2} + + E_{A1B2} + E_{A1C2} + E_{A1D2} + E_{B2C2} + + E_{B2D2} + E_{C2D2} = 11{,}32925 \quad (41)$$

$$Y_{C9} = M + E_{A2} + E_{B1} + E_{C1} + E_{D1} + E_{A2B1} + E_{A2C1} + E_{A2D1} + E_{B1C1} + E_{B1D1} + E_{C1D1} = 26{,}165 \quad (42)$$

$$Y_{C10} = M + E_{A2} + E_{B1} + E_{C1} + E_{D2} + E_{A2B1} + E_{A2C1} + E_{A2D2} + E_{B1C1} + E_{B1D2} + E_{C1D2} = 14{,}82 \quad (43)$$

$$Y_{C11} = M + E_{A2} + E_{B1} + E_{C2} + E_{D1} + E_{A2B1} + E_{A2C2} + E_{A2D1} + E_{B1C2} + E_{B1D1} + E_{C2D1} = 11{,}665 \quad (44)$$

$$Y_{12} = M + E_{A2} + E_{B1} + E_{C2} + E_{D2} + E_{A2B1} + E_{A2C2} + E_{A2D2} + E_{B1C2} + E_{B1D2} + E_{C2D2} = 8{,}27 \quad (45)$$

$$Y_{C13} = M + E_{A2} + E_{B2} + E_{C1} + E_{D1} + E_{A2B2} + E_{A2C1} + E_{A2D1} + E_{B2C1} + E_{B2D1} + E_{C1D1} = 17{,}08125 \quad (46)$$

$$Y_{C14} = M + E_{A2} + E_{B2} + E_{C1} + E_{D2} + E_{A2B2} + E_{A2C1} + E_{A2D2} + E_{B2C1} + E_{B2D2} + E_{C1D2} = 13{,}68625 \quad (47)$$

$$Y_{C15} = M + E_{A2} + E_{B2} + E_{C2} + E_{D1} + E_{A2B2} + E_{A2C2} + E_{A2D1} + E_{B2C2} + E_{B2D1} + E -_{C2D1} = 10{,}53125 \quad (48)$$

$$Y_{C16} = M + E_{A2} + E_{B2} + E_{C2} + E_{D2} + E_{A2B2} + E_{A2C2} + E_{A2D2} + E_{B2C2} + E_{B2D2} + E_{C2D2} = 7{,}13625 \quad (49)$$

In figure 6 are measured values Y_{mi} and values calculated Y_{Ci} in points of the experimental plan.

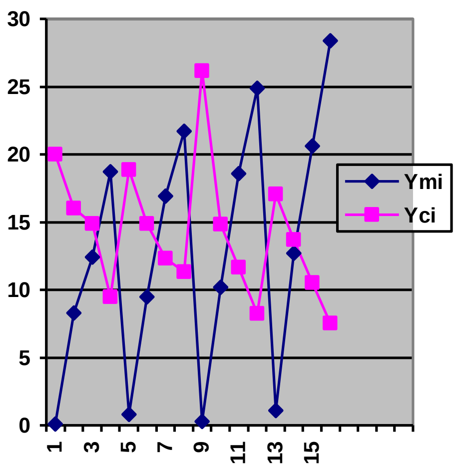

Figure 6

In table 9 are given measured values Y_{mi} theoretical answers Y_{Ci} and residues R_i

Table 9

Nr. exp.	Y_{mi}	Y_{ci}	R_i
1	0,1	19,99	-19,89
2	8,3	16,015	-7,715
3	12,4	14,8775	-2,4775
4	18,7	9,465	9,235
5	0,8	18,85625	-18,05625
6	9,5	14,88126	-5,38126
7	16,9	12,30625	4,59375
8	21,7	11,32925	10,37075
9	0,3	26,165	-25,865
10	10,2	14,82	-4,62
11	18,6	11,665	6,935
12	24,9	8,27	16,63
13	1,1	17,08125	-15,98125
14	12,7	13,68625	-0,98625
15	20,6	10,53125	10,06875
16	28,4	7,53125	20,86875

6. Analysis of the variation of results

The parameters have the following meaning:

$V_A;V_{B;};V_C;V_{AB};V_{BC};V_{CB}$ - Variation between experiences

V_R - is residual dispersion from interior of the experiences.

n - number of the experiences

n_a - number of levels A factor;

n_b - number of levels B factor;

n_c - number of levels C factor;

n_d - number of levels D factor;

$n_R = 16$, number of residues

v_1 - first degree freedom Fisher-Snedecor test;

v_2 - second degree freedom Fisher-Snedecor test

$\nu_R = n - 1 = 15$, number degree freedom of the residues

$$\nu_R = n - 1 = 16 - 1 = 15 \quad (50)$$

$$\nu_{1A} = n_a - 1 = 2 - 1 = 1 \quad (51)$$

$$\nu_{1B} = n_b - 1 = 2 - 1 = 1 \quad (52)$$

$$\nu_{1C} = n_c - 1 = 2 - 1 = 1 \quad (53)$$

$$\nu_{1AB} = (n_a - 1)(n_b - 1) = 1 \quad (54)$$

$$\nu_{1AC} = (n_a - 1)(n_c - 1) = 1 \quad (55)$$

$$\nu_{1CB} = (n_c - 1)(n_b - 1) = 1 \quad (56)$$

$$\nu_2 = n-1 = 16-1 = 15 \quad (57)$$

7. Calculating sums, dispersions and coefficients for Fhiser-Snedecor test

$$S_A = \frac{n \cdot \sum_{i=1}^{n_a} E_{Ai}^2}{n_a} = 50,4 mm^2 \quad (58)$$

$$V_A = \frac{S_A}{n_a - 1} = \frac{50,4}{2-1} = 50,4 mm^2 \quad (59)$$

$$F_A = \frac{V_A}{V_R} = \frac{50,4}{189,22} = 0,26 \quad (60)$$

$$S_B = \frac{n \cdot \sum_{i=1}^{n_b} E_{Bi}^2}{n_b} = 20,70 mm^2 \quad (61)$$

$$V_B = \frac{S_B}{n_b - 1} = \frac{20,70}{2-1} = 20,70 mm^2 \quad (62)$$

$$F_B = \frac{V_B}{V_R} = \frac{20,70}{189,22} = 0,109 \quad (63)$$

$$S_C = \frac{n \cdot \sum_{i=1}^{n_c} E_{Ci}^2}{n_c} = 888,04 mm^2 \quad (64)$$

$$V_C = \frac{S_C}{n_C - 1} = \frac{888,04}{2-1} = 888,04 mm^2 \quad (65)$$

$$F_C = \frac{V_C}{V_R} = \frac{888,04}{189,22} = 4,69 \quad (66)$$

$$S_D = \frac{n \cdot \sum_{i=1}^{n_c} E_{Di}^2}{n_c} = 252,81 mm^2 \quad (67)$$

$$V_D = \frac{S_D}{n_C - 1} = \frac{252,81}{2-1} = 252,81 mm^2 \quad (68)$$

$$F_D = \frac{V_D}{V_R} = \frac{252,81}{189,22} = 1,33 \quad (69)$$

$$S_{AB} = \frac{n \cdot \sum_{i=1}^{n_a} \sum_{j=1}^{n_b} E_{AiBj}^2}{n_a \cdot n_b} = 17,76 mm^2 \quad (70)$$

$$V_{AB} = \frac{S_{AB}}{(n_a - 1)(n_b - 1)} = 17,76 mm^2 \quad (71)$$

$$F_{AB} = \frac{V_{AB}}{V_R} = \frac{17,76}{189,22} = 0,093 \quad (72)$$

$$S_{AC} = \frac{n \cdot \sum_{i=1}^{n_a} \sum_{j=1}^{n_c} E_{AiCj}^2}{n_a \cdot n_c} = 217,45 mm^2 \quad (73)$$

$$V_{AC} = \frac{S_{AC}}{(n_a - 1)(n_d - 1)} = 217,45 mm^2 \quad (77)$$

$$F_{AC} = \frac{V_{AC}}{V_R} = \frac{217,45}{189,22} = 1,149 \quad (75)$$

$$S_{AD} = \frac{n \cdot \sum_{i=1}^{n_a} \sum_{j=1}^{n_d} E_{AiDj}^2}{n_a \cdot n_d} = 63,81 mm^2 \quad (76)$$

$$V_{AD} = \frac{S_{AD}}{(n_a - 1)(n_d - 1)} = 63,81 mm^2 \quad (77)$$

$$F_{AD} = \frac{V_{AD}}{V_R} = \frac{63,81}{189,22} = 0,337 \quad (78)$$

$$S_{BC} = \frac{n \cdot \sum_{i=1}^{n_b} \sum_{j=1}^{n_c} E_{AiDj}^2}{n_b \cdot n_c} = 210 mm^2 \quad (79)$$

$$V_{BC} = \frac{S_{BC}}{(n_b - 1)(n_c - 1)} = 210 mm^2 \quad (80)$$

$$F_{BC} = \frac{V_{BC}}{V_R} = \frac{210}{189,22} = 1,109 \quad (81)$$

$$S_{BD} = \frac{n \cdot \sum_{i=1}^{n_b} \sum_{j=1}^{n_d} E_{BiDj}^2}{n_b \cdot n_d} = 68,36 \quad (82)$$

$$V_{BD} = \frac{S_{BD}}{(n_a - 1)(n_b - 1)} = 68,36 mm^2 \quad (83)$$

$$F_{BD} = \frac{V_{AB}}{V_R} = \frac{68,36}{189,22} = 0,361 \quad (84)$$

$$S_{CD} = \frac{n \cdot \sum_{i=1}^{n_c} \sum_{j=1}^{n_d} E_{CiDj}^2}{n_c \cdot n_d} = 268,05 \quad (85)$$

$$V_{CD} = \frac{S_{CD}}{(n_a - 1)(n_b - 1)} = 268,05 mm^2 \quad (86)$$

$$F_{CD} = \frac{V_{CD}}{V_R} = \frac{268,05}{189,22} = 1,416 \quad (87)$$

$$S_R = \sum_{i=1}^{16} R_i^2 = 2838,44881 \quad (88)$$

Residual dispersion is:

$$V_R = \frac{S_R}{\nu_R} = \frac{2838,44881}{15} = 189,22 \qquad (89)$$

In table 10 are summarized final results of the work.

Table 10

Factor	Calculated value F_C	Table value $F_T = F_{1;15;0,05}$	influence YES/NOT
A	0,26	4,54	$F_C \langle F_T$ NOT
B	0,109		$F_C \langle F_T$ NOT
C	4,69		$F_C \rangle F_T$ YES
D	1,33		$F_C \langle F_T$ NOT
AB	0,093		$F_C \langle F_T$ NOT
AC	1,149		$F_C \langle F_T$ NOT
AD	0,337		$F_C \langle F_T$ NOT
BC	1,109		$F_C \langle F_T$ NOT
BD	0,361		$F_C \langle F_T$ NOT
CD	1,416		$F_C \langle F_T$ NOT

8. Conclusions

From the table 8, result as the factor that has a significant influence on the drawing depth is discharge tension of the battery capacitors.

So we can say that in the closed rooms and with small volume and discharge energies smaller than 1,5 *KJ*, electrical parameter of the circuit, which acts mainly on the growth of material deformation and the operating pressure, is discharge tension of the battery capacitors, work which is also found experimentally [2] [4].

If in the rooms with large volume, all four factors have a significant role, in low rooms, the pressure must be made solely to the discharge voltage.

In rooms with low volume, is not recommended to use priming discharge wires, because reduce productivity and swell cost of the processing.

In these cases, must use free download with adjustable electrodes or mobile electrodes, to meet the optimal distance between electrodes [6] [7] [8].

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