STUDY OF THE INFLUENCE SOME TECHNOLOGICAL FACTORS ON JOINING RADIUS BETWEEN TWO CONSECUTIV SIDES TO THE ELECTROHYDRAULIC PERFORATION OF THE POLYGONAL HOLES

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Abstract: *The paper deals with the influence of technological factors such as discharge energy, angle between sides and thickness of the semi-finished products, on joining radius that obtained to the electro hydraulic perforation of the polygonal holes.*
Keywords: *perforation, holes, statistics.*

1. Introduction

For study these factors have made experimental measurements used semi-finished product from aluminum and carbon steel OLC 10. In the paper, are presented results perforation holes in the case semi-finished products from aluminum perform without energy concentrator! [1], [2], [3]..

To analyze the results, using method of the experiences plans development by G. Taguchi [4].

After the experimental determinations, was calculated the average values for each experiment and the result are given in table 1

Tabele 1

Nr. exp.	Factors			Values
	A	B	C	
1	1	1	1	2,5
2	1	1	2	3,0
3	1	2	1	0,7
4	1	2	2	1,3
5	2	1	1	0,8
6	2	1	2	1,6
7	2	2	1	0,2
8	2	2	2	0,5

2. Elaboration of the experiences plan

For study, was used a factorial plan with three factors and two levels of form $2 \cdot 2 \cdot 2 = 2^3 = 8$ experiences.

Factors taken in the study were:

A – Discharge energy, in J;

B – Angle between sides of the polygon, in degrees;;

C - Thickness of the semi-finished products, in mm

Levels of the three factors are date in table 2.

Table 2

Factor	Level 1 (minimum)	Level 2 (maximum)
A	650	1260
B	60	120
C	0.5	1,0

Matrix effects of the plan are presented table 3.

Table3

Nr. exp.	Factori			Interacţiuni			
	A	B	C	AB	AC	BC	ABC
1	-	-	-	+	+	+	-
2	-	-	+	+	-	-	+
3	-	+	-	-	+	-	+
4	-	+	+	-	-	+	-
5	+	-	-	-	-	+	+
6	+	-	+	-	+	-	-
7	+	+	-	+	-	-	-
8	+	+	+	+	+	+	+

3. Calculation of the average effects

The general average of the values:

$$M = \frac{1}{n}\sum_{i=1}^{n}\overline{Y_i} = \frac{10,6}{8} = 1,325mm \quad (1)$$

Calculation of effect factor A

$$E_{A1} = \frac{1}{4}\sum_{i=1}^{4}Y_i - M = 0,55mm \quad (2)$$

$$E_{A2} = \frac{1}{4}\sum_{i=5}^{8}Y_i - M = -0,55mm \quad (3)$$

In figure 1 is the effect factor A

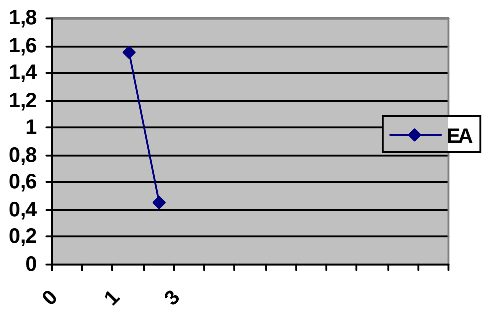

Figure 1.

Calculation of effect factor B

$$E_{B1} = \frac{1}{4}\left(\sum_{i=1}^{2}Y_i + \sum_{5}^{6}Y_i\right) - M = 0,65mm$$

$$E_{B2} = \frac{1}{4}\left(\sum_{3}^{4}Y_i + \sum_{7}^{8}Y_i\right) - M = -0,65mm$$

In figure 2 is the effect factor B

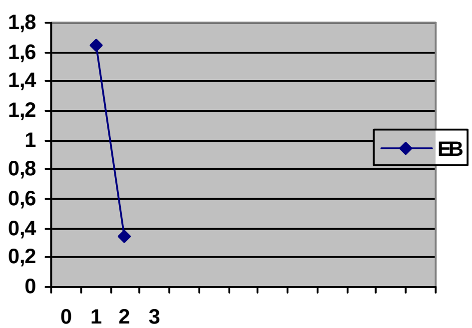

Figure 2

Calculation of effect factor C

$$E_{C1} = \frac{1}{4}\sum_{i=1}^{7}Y_i - M = -0,275mm(i - impar)$$

$$E_{C2} = \frac{1}{4}\sum_{i=2}^{8}Y_i - M = 0,275mm(i - par)$$

In figure 2 is the effect factor C

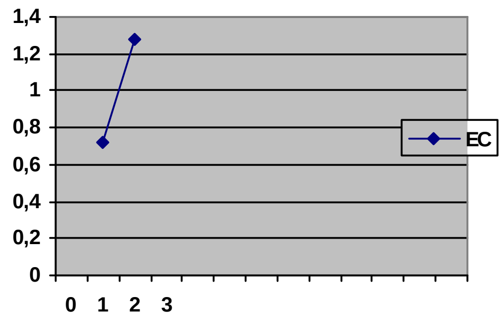

Figure 3

Figure 4 are present the effect of factor A, B and C on the joining radius.

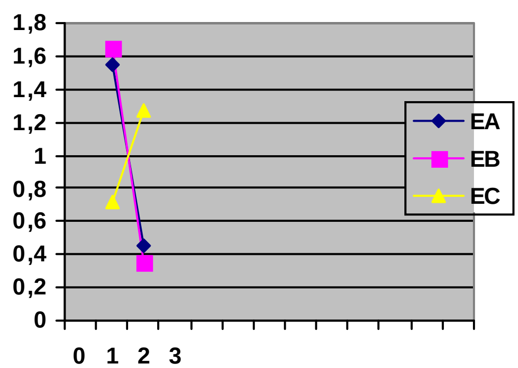

Figure 4

The values of interactions

The average values of factors A and B

$$M_{A1B1} = \frac{Y_1 + Y_2}{2} = 2,75; \quad (4)$$

$$M_{A1B2} = \frac{Y_3 + Y_4}{2} = 1,0; \quad (5)$$

$$M_{A2B1} = \frac{Y_5 + Y_6}{2} = 1,2; \quad (6)$$

$$M_{A2B2} = \frac{Y_7 + Y_8}{2} = 0,35 \quad (7)$$

Interaction AB

$$E_{A1B1} = M_{A1B1} - M - E_{A1} - E_{B1} = +0,225mm$$

$$E_{A1B2} = M_{A1B2} - M - E_{A1} - E_{B2} = -0,225mm$$

$$E_{A2B1} = M_{A2B1} - M - E_{A2} - E_{B1} = -0{,}225mm$$
$$E_{A2B2} = M_{A2B2} - M - E_{A2} - E_{B2} = +0{,}225mm$$

Values of the interaction A and B are presented in the table 4.

Table 4

		B	
		1	2
A	1	0,225	-0,225
	2	-0,225	0,225

The average values of factors A and C

$$M_{A1C1} = \frac{Y_1 + Y_3}{2} = 1{,}6; \quad (8)$$
$$M_{A1B2} = \frac{Y_2 + Y_4}{2} = 2{,}15; \quad (9)$$
$$M_{A2C1} = \frac{Y_5 + Y_7}{2} = 0{,}5; \quad (10)$$
$$M_{A2C2} = \frac{Y_6 + Y_8}{2} = 1{,}05 \quad (11)$$

Interaction AC

$$E_{A1C1} = M_{A1C1} - M - E_{A1} - E_{C1} = 0{,}0mm$$
$$E_{A1C2} = M_{A1C2} - M - E_{A1} - E_{C2} = 0{,}0mm$$
$$E_{A2C1} = M_{A2C1} - M - E_{A2} - E_{C1} = 0{,}0mm$$
$$E_{A2C2} = M_{A2C2} - M - E_{A2} - E_{C2} = 0{,}0mm$$

Values of the interaction A and C are presented in the table 5.

Table 5

		C	
		1	2
A	1	0,0	0,0
	2	0,0	0,0

The average values of factors B and C

$$M_{B1C1} = \frac{Y_1 + Y_5}{2} = 1{,}65; \quad (12)$$
$$M_{B1B2} = \frac{Y_2 + Y_4}{2} = 2{,}3; \quad (13)$$
$$M_{B2C1} = \frac{Y_3 + Y_7}{2} = 0{,}45; \quad (14)$$
$$M_{B2C2} = \frac{Y_4 + Y_8}{2} = 0{,}9 \quad (15)$$

Interaction BC

$$E_{B1C1} = M_{C1B1} - M - E_{C1} - E_{B1} = -0{,}05mm$$
$$E_{B1C2} = M_{C2B1} - M - E_{C2} - E_{B1} = +0{,}05mm$$
$$E_{B2C1} = M_{C1B2} - M - E_{C1} - E_{B2} = +0{,}05mm$$
$$E_{B2C2} = M_{C2B2} - M - E_{C2} - E_{B2} = -0{,}05mm$$

Values of the interaction B and C are presented in table 6.

Table 6

		C	
		1	2
B	1	-0,05	+0,05
	2	+0,05	-0,05

4. Values calculated and values of the residues

$$Y_{C1} = M + E_{A1} + E_{B1} + E_{C1} + + E_{A1B1} + E_{A1C1} + E_{C1B1} = 2{,}425mm$$
$$Y_{C2} = M + E_{A1} + E_{B1} + E_{C2} + + E_{A1B1} + E_{A1C2} + E_{C2B1} = 3{,}075mm$$
$$Y_{C3} = M + E_{A1} + E_{B2} + E_{C1} + + E_{A1B2} + E_{A1C1} + E_{C1B2} = 0{,}775mm$$
$$Y_{C4} = M + E_{A1} + E_{B2} + E_{C2} + + E_{A1B2} + E_{A1C2} + E_{C2B2} = 1{,}225mm$$
$$Y_{C5} = M + E_{A2} + E_{B1} + E_{C1} + + E_{A2B1} + E_{A2C1} + E_{C1B1} = 0{,}875mm$$
$$Y_{C6} = M + E_{A2} + E_{B1} + E_{C2} + + E_{A2B1} + E_{A2C2} + E_{C2B1} = 1{,}525mm$$
$$Y_{C7} = M + E_{A2} + E_{B2} + E_{C1} + + E_{A2B2} + E_{A2C1} + E_{C1B2} = 0{,}125mm$$
$$Y_{C8} = M + E_{A2} + E_{B2} + E_{C2} + + E_{A2B2} + E_{A2C2} + E_{C2B2} = 575mm$$

Figure 5 depicts the values measured Y_i and calculated values Y_{Ci} in experimental plan

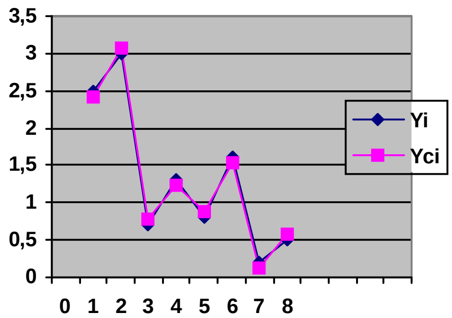

Figure 5

5. 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 lines from the plane experiences

n_a , number of levels of A factor;

n_b , number of levels of B factor;

n_c , number of levels of C factor;

v_1 - Degree of freedom for the numerator of the Fisher-Snedecor test;

v_2 - Degree of freedom for the denominator of the Fisher-Snedecor test;

n_R , number of residues

$$v_{1A} = n_a - 1 = 2 - 1 = 1$$

$$v_{1B} = n_b - 1 = 2 - 1 = 1$$

$$v_{1C} = n_c - 1 = 2 - 1 = 1$$

$$v_{1AB} = (n_a - 1)(n_b - 1) = 1$$

$$v_{1AC} = (n_a - 1)(n_c - 1) = 1$$

$$v_{1CB} = (n_c - 1)(n_b - 1) = 1^1$$

$$v_2 = n_R - 1 = 8 - 1 = 7$$

Degree of freedom of the model is shown in table 7.

Table 7

Model	Y_{Ci}=M+A+B+C+AB+AC+CB
n	7= 1+1+1+1+1+1+1

Table 8 are presents values measured and values calculated and residues.

Table 8

Nr. exp.	Factors			Y_i	Y_{Ci}	Residues r_i
	A	B	C			
1	1	1	1	2,5	2,425	+0,075
2	1	1	2	3,0	3,075	-0,075
3	1	2	1	0,7	0,775	-0,075
4	1	2	2	1,3	1,225	+0,075
5	2	1	1	0,8	0,875	-0,075
6	2	1	2	1,6	1,525	+0,075
7	2	2	1	0,2	0,125	+0,075
8	2	2	2	0,5	0,575	-0,075

$$S_A = \frac{N \cdot \sum_{i=1}^{n_a} E_{Ai}^2}{n_a} = \frac{8 \cdot 2 \cdot (0,55)^2}{2} = \frac{8 \cdot 2 \cdot 0,925}{2} = 2,42mm^2$$

$$V_A = \frac{S_A}{n_a - 1} = \frac{7,62}{2-1} = 2,42mm^2$$

$$F_A = \frac{V_A}{V_R} = \frac{2,42}{0,005625} = 430,22$$

$$S_B = \frac{N \cdot \sum_{i=1}^{n_b} E_{Bi}^2}{n_b} = \frac{8 \cdot 2 \cdot (0,65)^2}{2} = 3,38mm^2$$

$$V_B = \frac{S_B}{n_b - 1} = \frac{2,38}{2-1} = 3,38mm^2$$

$$F_B = \frac{V_B}{V_R} = \frac{3,38}{0,005625} = 643,8$$

$$S_C = \frac{N \cdot \sum_{i=1}^{n_c} E_{Ci}^2}{n_c} = \frac{8 \cdot 2 \cdot (0,275)^2}{2} = 0,605mm^2$$

$$V_C = \frac{S_C}{n_C - 1} = \frac{0,605}{2-1} = 0,605mm^2$$

$$F_C = \frac{V_C}{V_R} = \frac{0,605}{0,005625} = 107,55$$

$$S_{AB} = \frac{N \cdot \sum_{i=1}^{n_a} \sum_{j=1}^{n_b} E_{AiBj}^2}{n_a \cdot n_b} = 0,405mm^2$$

$$V_{AB} = \frac{S_{AB}}{(n_a - 1)(n_b - 1)} = \frac{0,405}{(2-1)(2-1)} = 0,405mm^2$$

$$F_{AB} = \frac{V_{AB}}{V_R} = \frac{0,405}{0,005625} = 72$$

$$S_{AC} = \frac{N \cdot \sum_{i=1}^{n_a} \sum_{j=1}^{n_c} E_{AiCj}^2}{n_a \cdot n_c} = 0,0mm^2$$

$$V_{AC} = \frac{S_{AC}}{(n_a - 1)(n_c - 1)} = \frac{0,0}{(2-1)(2-1)} = 0,0$$

$$F_{AC} = \frac{V_{AC}}{V_R} = \frac{0,0}{0,005625} = 0,0$$

$$S_{CB} = \frac{N \cdot \sum_{i=1}^{n_c} \sum_{j=1}^{n_b} E_{CiBj}^2}{n_c \cdot n_b} = 0,02mm^2$$

$$V_{CB} = \frac{S_{CB}}{(n_a - 1)(n_c - 1)} = \frac{0,02}{(2-1)(2-1)} = 0,02$$

$$F_{CB} = \frac{V_{CB}}{V_R} = \frac{0,02}{0,005625} = 3,55$$

$$S_R = 8 \cdot (0,075)^2 = 0,045mm^2$$

$$V_R = \frac{S_R}{n_R} = \frac{0,045}{7} = 0,005625$$

$$n_R = 8$$

Table 9 presents synthetic situation of the variation.

Table 9

Source	F_C	$F_T = F_{v1;v2;\alpha}$	Influence YES/NOT
A	430,22	5,59	$F_C \rangle F_T$ YES
B	643,8		$F_C \rangle F_T$ YES
C	107,55		$F \rangle F_T$ YES
AB	72		$F_C \rangle F_T$ YES
AC	0,0		$F_C \langle F_T$ NOT
BC	3,55		$F_C \langle F_T$ NOT

6. Conclusions

Because

$$F_{CA} = 430,22 \rangle F_T = F_{v1;v2;\alpha} = F_{1,7,0,05} = 5,59;$$

$$F_{CB} = 643,8 \rangle F_T = F_{v1;v2;\alpha} = F_{1,7,0,05} = 5,59;$$

$$F_{CC} = 107,55 \rangle F_T = F_{v1;v2;\alpha} = F_{1,7,0,05} = 5,59;$$

$$F_{CC} = 72 \rangle F_T = F_{v1;v2;\alpha} = F_{1,7,0,05} = 5,59$$

one can say with probability

$P = 1 - \alpha = 1 - 0,05 = 0,95 = 95\%$, that energy, angle between sides, thickness of the material and interaction between discharge energy and angle between sides, influence significantly the values joining radius.

Interactions between discharge energy and the thickness, between angle of the sides and the thickness, do not affect significantly the radius value of the joining radius.

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