Stainless Steel Optimal Debiting using the Computer-Aided Complex Erosion

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ABSTRACT: The paper focuses on the improving of the processing parameters using computers and expert software. Nowadays, all over the world, the non-conventional processing techniques are used in cases where traditional techniques are too complex or too expensive. In such situations, non-conventional methods like electro-erosion, electrochemical erosion, complex electrochemical erosion (EEC) and laser erosion could be the best solution.
KEYWORDS: complex electrochemical erosion, method of least squares, polynomial functions.

1. Theoretical considerations

In order to develop a program that automatically performs the functions' settling of the dependence of the technological output parameters on the influencing factors, we have considered some mathematical patterns with polynomial functions ([Kar04, Kar07, Lan86]).

Concretely, let us consider the dependences as being of one (1, 2, and 3) and two variables (4, 5) only, namely:

$$Q_p = a_0 + a_1 \cdot P \tag{1}$$

$$Q_p = a_0 + a_1 \cdot P + a_2 \cdot P^2 \tag{2}$$

$$Q_p = a_0 + a_1 \cdot P + a_2 \cdot P^2 + a_3 \cdot P^3 \tag{3}$$

$$Q_p = a_0 + a_1 \cdot U + a_2 \cdot I \tag{4}$$

$$Q_p = a_0 + a_1 \cdot U + a_2 \cdot I + a_3 \cdot U^2 + a_4 \cdot I^2 + a_5 \cdot U \cdot I \tag{5}$$

the establishing of the coefficients a_0, a_1, … being based on the method of least squares ([Kil97]).

2. Input Data

In order to determine the mathematical pattern of the productivity (Q_p) dependency on the induced power (P), respectively on the voltage (U) and current (I) in the working space, there were developed more debiting experiments of some stainless steel PO with the thickness of 45, 50, 65, 90 and 100 mm, in a solution of soluble sodium silicate, with M=3 and ρ=1.25 kg/dm^3, with the TO of 1,5 mm thickness and advance speed of 25m/s, on a MEC 100 non-conventional device, as displayed in the following table.

Table 1. Experimental results for the processing productivity ([HLM99])

No.	Voltage U [V]	Current I [A]	Induced power P [W]	Measured productivity Q_p [mm^3/min]
1st Experiment – PO thickness of 45 mm				
1	26	45	1170	386.24
2	22	120	2640	1081.49
3	24	130	3120	1081.49
4	22	150	3300	1081.49
5	24	150	3600	1287.49
6	24	200	4800	1160.39
7	26	200	5200	2032.87
2nd Experiment – PO thickness of 50 mm				
1	26	45	1170	417.26
2	24	140	3360	1383.82
3	24	150	3600	1112.64
4	26	170	4680	1668.97
3rd Experiment – PO thickness of 65 mm				
1	26	40	1040	296.90
2	24	80	1920	805.87
3	24	120	2880	1253.58
4	24	150	3600	1327.32
5	26	180	4680	1128.22
4th Experiment 3 – PO thickness of 90 mm				
1	28	130	3640	1411.87
2	24	160	3840	1169.18
3	24	170	4080	1172.93
4	28	150	4200	1253.22
5	24	180	4320	1663.83
6	28	240	6720	2544.68
7	26	270	7560	2276.82
8	24	340	8160	2703.73

Table 1. Experimental results for the processing productivity (continued)

No.	Voltage U [V]	Current I [A]	Induced power P [W]	Measured productivity Q_p [mm^3/min]
5th Experiment – PO thickness of 100 mm				
1	30	60	1800	387.01
2	25	150	3750	953.69
3	26	160	4160	1405.44
4	24	220	5720	1513.80
5	25	240	6000	1668.97
6	30	320	9600	2225.29

3. Results

We have obtained the following mathematical patterns of the dependence of the EEC processing productivity (Q_p) on the induced power (P) at the debiting, using the experimental data presented in the table above:

- Experiment 1 (best fit for the 3rd rank function, medium error is 11.9%):

$$Q_p = 90.4239 + 3.1372 \cdot 10^{-1} \cdot P \quad (6)$$

$$Q_p = 46.3642 + 3.4544 \cdot 10^{-1} \cdot P - 4.8617 \cdot 10^{-6} \cdot P^2 \quad (7)$$

$$Q_p = -2654.0708 + 3.9011 \cdot P - 1.2835 \cdot 10^{-3} \cdot P^2 + 1.3488 \cdot 10^{-7} \cdot P^3 \quad (8)$$

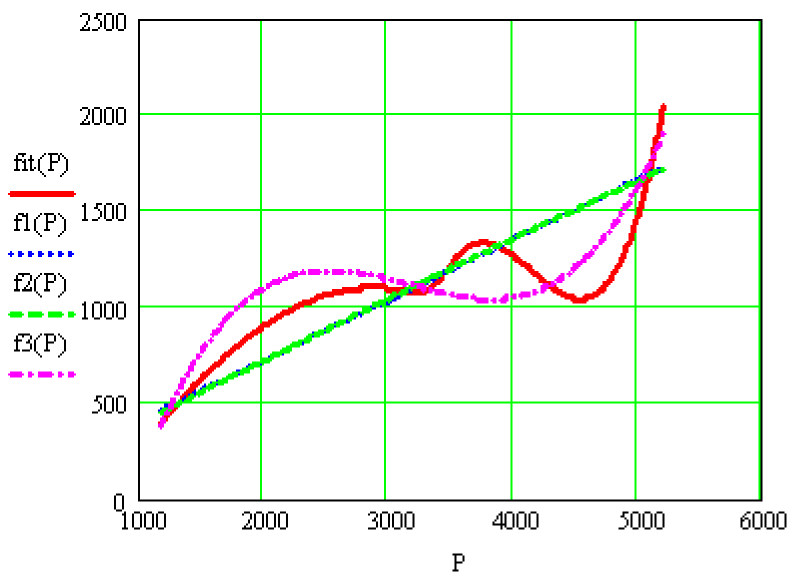

Figure 1. Graphical representation of fitting functions in experiment 1 (using Mathcad 2000 Professional software)

- Experiment 2 (best fit for the 3rd rank function, medium error is 0%):

$$Q_p = 22.4664 + 3.5075 \cdot 10^{-1} \cdot P \quad (9)$$

$$Q_p = -42.2459 + 4.1021 \cdot 10^{-1} \cdot P - 1.0581 \cdot 10^{-5} \cdot P^2 \quad (10)$$

$$Q_p = -10268.5375 + 14.2782 \cdot P - 5.0283 \cdot 10^{-3} \cdot P^2 + 5.3898 \cdot 10^{-7} \cdot P^3 \quad (11)$$

- Experiment 3 (best fit for the 3rd rank function, medium error is 1.6%):

$$Q_p = 283.5556 + 2.4038 \cdot 10^{-1} \cdot P \quad (12)$$

$$Q_p = -730.4515 + 1.1272 \cdot P - 1.555 \cdot 10^{-4} \cdot P^2 \quad (13)$$

$$Q_p = -413.4774 + 6.8027 \cdot 10^{-1} \cdot P + 1.9962 \cdot 10^{-5} \cdot P^2 - 2.0318 \cdot 10^{-8} \cdot P^3 \quad (14)$$

- Experiment 4 (best fit for the 3rd rank function, medium error is 11.4%):

$$Q_p = 38.529 + 3.2664 \cdot 10^{-1} \cdot P \quad (15)$$

$$Q_p = -1160.2646 + 7.8067 \cdot 10^{-1} \cdot P - 3.8885 \cdot 10^{-5} \cdot P^2 \quad (16)$$

$$Q_p = 2400.4666 - 1.1507 \cdot P + 2.9488 \cdot 10^{-4} \cdot P^2 - 1.852 \cdot 10^{-8} \cdot P^3 \quad (17)$$

- Experiment 5 (best fit for the 2nd rank function, medium error is 8.4%):

$$Q_p = 179.712 + 2.2803 \cdot 10^{-1} \cdot P \quad (18)$$

$$Q_p = -349.5587 + 4.5114 \cdot 10^{-1} \cdot P - 1.9171 \cdot 10^{-5} \cdot P^2 \quad (19)$$

$$Q_p = -631.7964 + 6.6854 \cdot 10^{-1} \cdot P - 6.4714 \cdot 10^{-5} \cdot P^2 + 2.7147 \cdot 10^{-9} \cdot P^3 \quad (20)$$

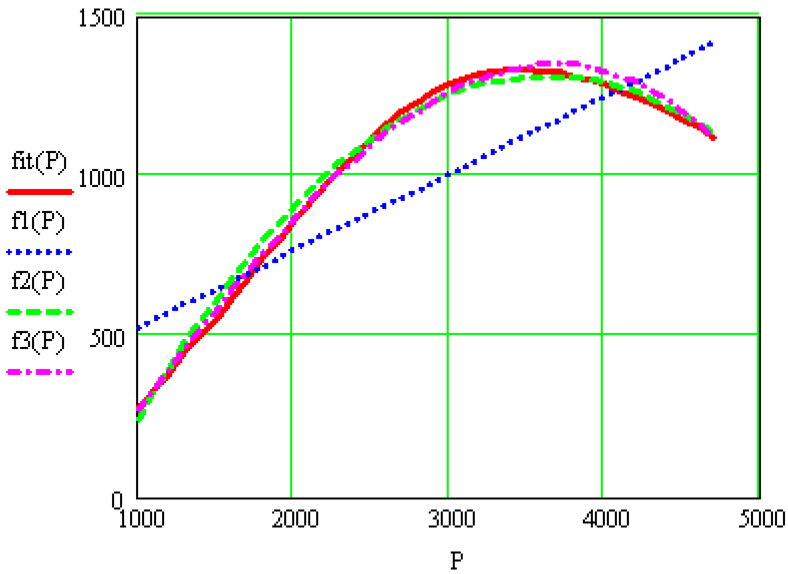

Figure 3. Graphical representation of fitting functions in experiment 3

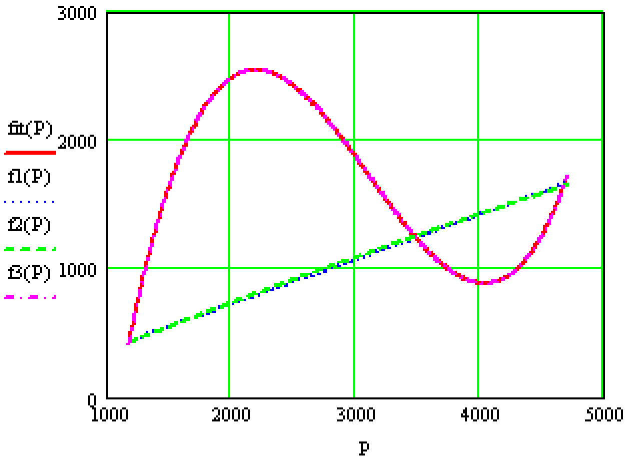

Figure 2. Graphical representation of fitting functions in experiment 2

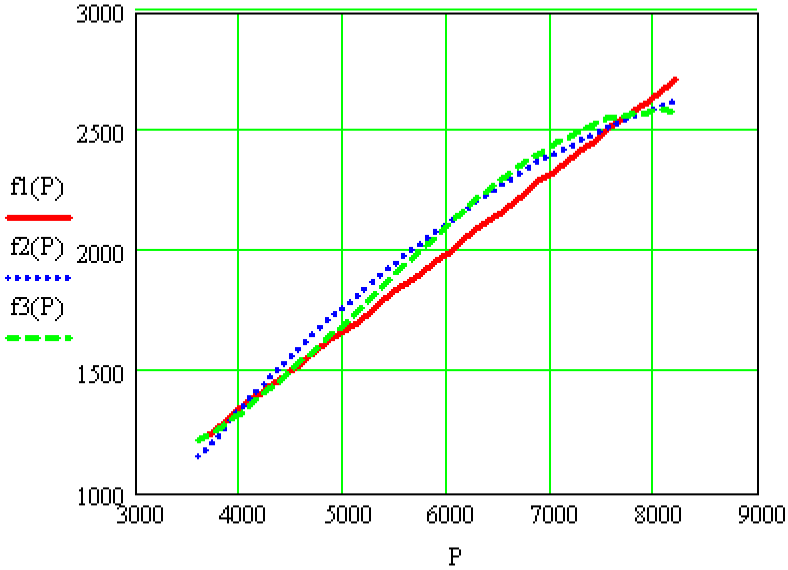

Figure 4. Graphical representation of fitting functions in experiment 4

In the above figures, the fit(P) represents the input data, and the f1(P), f2(P), f3(P) functions are the polynomial 1st, 2nd and 3rd degree approximation functions.

Next, we have obtained the following mathematical patterns of the dependence of the EEC processing productivity (Q_p) on the voltage (U) and current (I) at the debiting, using the experimental data presented in Table 1:

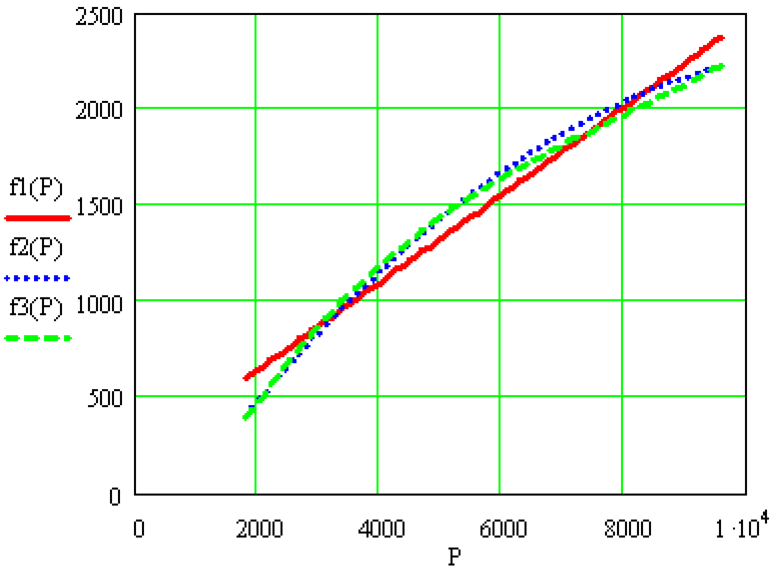

Figure 5. Graphical representation of fitting functions in experiment 5

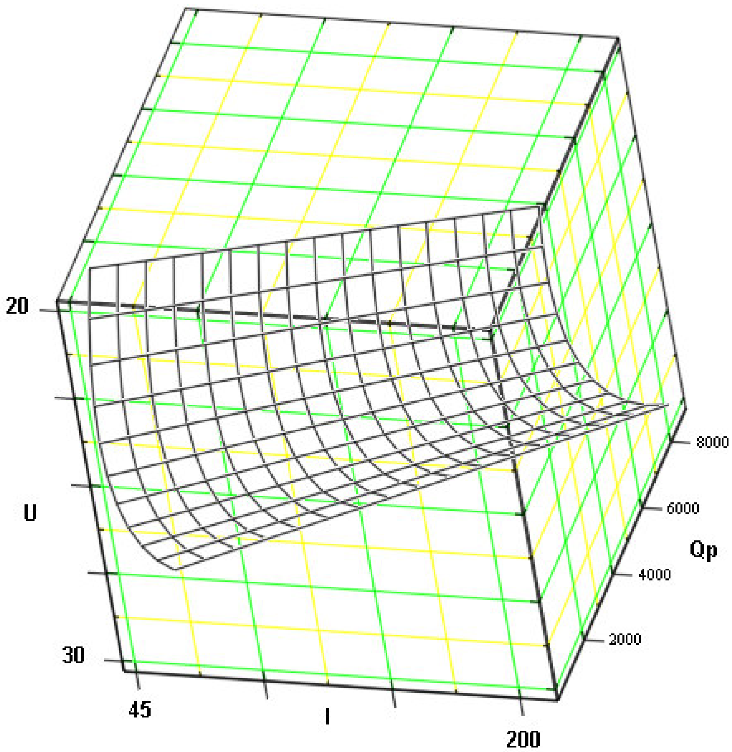

Figure 6. Graphical representation of fitting functions in experiment 1

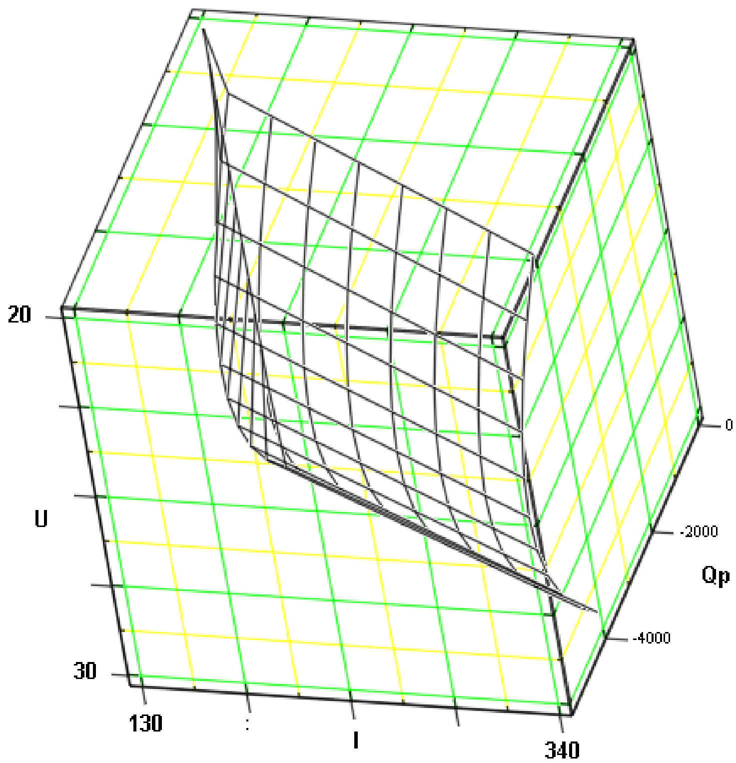

Figure 7. Graphical representation of fitting functions in experiment 5

- Experiment 1 (best fit for the 2nd rank function, medium error is 2.9%):

$$Q_p = -1301 + 56.3579 \cdot U + 7.7893 \cdot I \quad (21)$$

$$Q_p = 40812 - 3381.35 \cdot U - 21.53 \cdot I + 68.53 \cdot U^2 + 1.95 \cdot U \cdot I \quad (22)$$

- Experiment 5 (best fit for the 2nd rank function, medium error is 10.7%):

$$Q_p = -2583 + 99.55 \cdot U + 8.75 \cdot I \quad (23)$$

$$Q_p = 39213 - 3199 \cdot U + 15.34 \cdot I + 63.03 \cdot U^2 + 0.14 \cdot U \cdot I \quad (24)$$

Conclusions

By analyzing the determined functions, regarding the Q_p = f(P) dependency, there can be observed that:

- the Q_p dependence on P using the 3 rank functions is correct with an minimum of 0% and a maximum of 11.9% error;

- increasing the P will improve the Q_p, but the excess of tension or current over limit leads to the instability of the process and to unexpected bad results (productivity or quality of the surface).

By analyzing the determined functions, regarding the $Q_p = f(U, I)$ dependency, there can be observed that:

- the Q_p dependence on U and I using the 2 rank functions is correct with an maximum 10.7% error;
- Qp dependency is more accurately expressed by U, I and U^2, and less by the multiplication U x I;
- Q_p can be expressed both depending on P, U and I.

In all cases, the mathematical approximation can be automatically set by a computer program which will determine the selection of the optimal values of the process parameters. This result also improves manufacturing, save materials and energy, emphasize the advantages and the benefits of using the non-conventional processing method.

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