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THE PARAMETERS' INFLUENCE ON THE CHARACTERISTICS OF THE EDM PROCESS APPLIED TO G-TYPE HARD ALLOYS

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Abstract: *The final properties of G-type hard alloys, consisting especially of carbides, depend on various factors involved in the electro-discharge machining (EDM) process. This study analyses the influence of the most important such factors – the electrode wear rate and the process productivity.*
Using the random balance method, input factors are analysed and the influence of each input factor on the EDM process is studied, the impulse duration resulting as the most important one.
Key words: *electro-discharge machining, hard alloys*

1. INTRODUCTION

Carbide-based hard alloys are currently recognized as the best choice for materials for cutting tools in the machine-manufacturing industry. Hard alloys are classified into single carbide compound alloys and in multiple carbide compound alloys, respectively. Multiple carbide compound alloys are divided in types like P, M, K and G, according to ISO TC29 (Amza, 1994). G-type hard alloys are usually used for manufacturing tools for forming and cutting processes.

The EDM processing technology can generate complex and accurate surfaces for cutting tools, by copying the shape of the tool-electrode under advantageous conditions. The process' productivity process and the surface quality are technological output characteristics in many manufacturing processes and depend on a variety of input factors (Sánchez et al., 2001).

These input factors are process variables and depend on the technological equipment and other elements of the workspace.

In the following, the main parameters involved in the EDM process are described and analyzed, and output characteristics, such as process productivity, tool-electrode wear, surface precision and quality, are evaluated, based on their order of influence.

2. INFLUENCE OF INPUT PARAMETERS ON THE EDM PROCESS

Figure 1 shows the input and output parameters for the EDM process system. These parameters are separated into categories, each group of parameters having its own characteristics:

Input parameters, related to the technical equipment (TE) and to the work environment (WE), are (Amza et al., 2002):

- IG - parameters of the impulse generator;
- FRS - characteristics of the feed regulation system;
- EAE - parameters of the electrode actuation equipment;
- DLS - parameters and characteristics of the dielectric liquid system;
- PC - characteristics of the machined part;
- WEC - characteristics of working environment;
- EC - characteristics of electrode.

Output parameters, related to the part (P) and to the electrode (E), are:

- MP - machining productivity;
- DP - dimensional precision;
- SQ - surface quality.

The impulse generator (IG) introduces input parameters such as the medium impulse current intensity (i_i), the polarity, and the duration of the impulse (t_i) and of pauses between impulses (t_p). Polarity can be set at the beginning of the process and does not change during a phase.

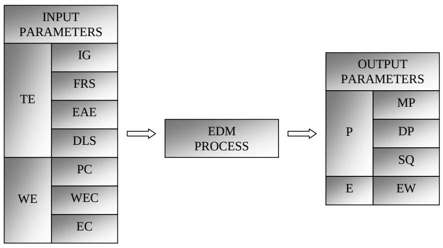

Fig. 1. Systemic approach of the EDM process

The impulse current intensity (i_i) can be varied in steps and is limited by the current density (j). During the EDM process the usual values are j = 2÷10 A/cm^2 and can reach a limit of j = 25 A/cm^2.

The current impulse duration can also be varied in steps and determines the impulse energy and the material amount extracted from the part. The lower limit of the pause (t_0) is determined by the minimum time needed to de-ionise the space affected by the previous electric discharge and to rebuild the dielectric stiffness of the electrode-part gap (Petrescu, 2000).

The characteristics of the part (PC) and electrode (EC) can influence the EDM process through its parameters: the material’s structure, chemical composition, thermo-physical constants and the mechanical properties. These can have a significant influence on the shape, dimensions, roughness and structure of the material’s superficial layer.

Based on the output parameters, the EDM process system can be analyzed either by means of volume (V_p) of extracted material or by the ratio (Q_p) between the volume and the time needed to remove the extracted material (Petrescu, 1996).

3. THEORETICAL AND EXPERIMENTAL CONDITIONS

Each of the input parameters can reach different value levels. While polarity has only two possible levels, other characteristics like the impulse current intensity, impulse duration or pause duration can have 12 different levels. In all, there are 262164 possibilities to combine these levels for assessing one single performance criterion.

Thus, a research method must be adopted to assess the influence of various parameters by means of limited number of experiments. The authors have adopted for this purpose the random balance method to determine the minimum number of experiments. It consists of several steps, as follows:

- the mean value of the analyzed performance criteria for each level of the independent variable (X) is calculated;
- the mean value for each variable is calculated (X);
- the value’s dispersion (D) must be calculated for each individual variable. The variable that shows the largest dispersion is the most important one for the analyzed criteria;
- the effects of the most important variable are removed, after which the process is restarted for the remaining variables.

It was determined that a number of 24 different experiments need to be conducted, using the above mentioned input and output parameters. Table 1 presents the variables chosen for the roughing and finishing experiments and their respective levels.

The experiments were carried out on test samples made of three different types of G-type hard alloys: G10 (6% Co, 94% WC), G40 (20% Co, 80% WC) and G60 (30% Co, 70% WC). These test samples had a square cross-section with a side length of 20 mm and 10 mm thickness. The electrodes used during the experiments were made of electrolytic copper and had a cylindrical shape, with the outer diameter of 15 ± 0.1 mm and the diameter of the inner hole of 3 ± 0.1 mm. The dielectric liquid used here was winter Diesel Oil 15A.

The machining was carried out on an electro-discharge machine ELER-01, manufactured by Electrotimis, from Timisoara - Romania, equipped with a GEP-50F impulse generator. Every experiment had a duration of 15 minutes and was repeated 3 times.

4. RESULTS

The output characteristics of the EDM process have been calculated with the help of a specially designed calculation software program, for all 24 experiments, both for roughing conditions and for finishing conditions.

Table 2 present some of the obtained results with regard to the effect produced on the analyzed performance criteria, for the roughing and finishing conditions. The table also indicates the order of importance among the input parameters.

5. CONCLUSIONS

Based on the experiments presented above, it can be concluded that under the analysed conditions, the relative wear (γ) is influenced primarily by the impulse duration (t_i) and by the washing pressure (p). For the described experiments, a maximal relative wear is obtained at the highest impulse duration t_i = 190 [μs] and for the highest washing pressure p = 0.3 [bar].

Next in the order of influence on the process is the electrode's polarity. It can be noticed that the highest relative wear is reached when machining G60 hard alloy with direct polarity. The pause has a much lower importance for the relative wear. The best relative wear is obtained when using the shortest pause t_{p4} = 139 μs. Next is the intensity of the discharge current i_i and it can be observed that best relative wear is at highest values of intensity discharge current i_i = 50 A. The impulse duration has the highest influence on the relative wear and the part material has no influence at all on the relative wear.

The presented experiments can contribute to the optimisation of the EDM processes carried out on parts made of G-type hard alloys. Further researches can be carried out in order to determine a possible influence of other input parameters, possibly with more variation levels and for the determination of further technological characteristics which might be of interest in specific applications of the EDM process.

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Curr. no.	Input parameter	Symbol	Level of the parameter				Number of levels
1.	Part material	G	G10	G40	G60	-	3
2.	Electrode polarity	Pol	(-)	(+)	-	-	2
3.	Discharge current intensity [A]	i_i	12.5	25.0	50.0	-	3
4.	Pause [μs]	t_p	139.040	184.700	158.655	-	3
5.	Impulse duration [μs]	t_i	24	48	95	190	4
6.	Washing pressure [bar]	p	0.1	0.2	0.3	-	3

Tab. 1. The values of input parameters taken into consideration for the research

Param. no.	Parameter	Level	Initial values		After the 1st correction		After the 2nd correction		After the 3rd correction		After the 4th correction	
			X	D	X	D	X	D	X	D	X	D
1.	Part material	G10	126.121		143.331		137.906		154.407		160.650	
		G40	162.056	68.096	143.520	52.214	165.020	41.564	156.769	16.812	145.096	31.57
		G60	194.218		195.545		179.470		171.220		176.659	
2.	Electrode polarity	(+)	211.841	102.085	193.801	66.005	193.801	*66.005*				
		(-)	109.756		127.796		127.796					
3.	i_i [A]	12.5	197.386		188.863		169.975		178.226		181.214	
		25	152.946	65.322	145.750	43.113	170.062	27.703	153.561	27.616	159.804	*39.93*
		50	132.063		147.783		142.358		150.609		141.378	
4.	t_p [μs]	12	184.717		163.365		147.291		139.040			
		24	158.814	45.853	168.827	18.622	184.700	37.409	184.700	*45.660*		
		48	138.864		150.204		150.405		158.655			
5.	t_i [μs]	24	160.473									
		48	240.575	*148.283*								
		95	149.860									
		190	92.286									
6.	p [bar]	0.1	131.215		139.902							
		0.2	134.697	85.357	117.39	*107.698*						
		0.3	216.573		225.096							

Tab. 2. Experimental results and parameter levels