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THE STABILITY OF WEDM

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Abstract

This paper is focused on the effect of generator´s parameters on the stability of WEDM process that is expressed by the length of time of cutting until the wire electrode breaks. This paper provides an overview of the current research articles dealing with the causes of the wire electrode´s rupture and the options of control and regulation of the process. The aim was to clarify the impact of input parameters to the cutting process, and to find those parameters making the process as fast as possible and stable. The experiment was performed on the machine of Agie Charmilles Robofil 310. As input factors were selected pulse width, time between two pulses, servo voltage, pulse current, short pulse time and frequency. Due to the fact that it is necessary to assess the impact of several input parameters, Taguchi experimental design was selected. L27 matrix was used. The Analysis of Variance (ANOVA) was used for evaluation.

Key words

stability, WEDM, Material Removal Rate, ANOVA, Taguchi

INTRODUCTION

Material Removal Rate (MRR) is generally expressed as a proportion of the volume of removed material and time for which it has been taken. Sometimes it is expressed as a weight of removed material for a time. In the case of EDM wire cutting, the following formula is the most commonly used for the calculation (1):

$$\mathrm{MRR} = v_c.B.H\ [mm^3.min^{-1}]\ , \qquad [1]$$

where: v_c -cutting speed [mm.min^{-1}],
B -width of the cut [mm],
H - height of the cut.

The following basic parameters of wire EDM can be considered: pulse on time, pulse off time, voltage, peak current, discharge current, flushing pressure of dielectric fluid, wire feed rate and wire tension. Each of these parameters (except wire tension and wire feed rate) has huge influence on the cutting process, which is explained in detail in (2).

Research of the relationship between the cutting speed and input parameters has been described in (3). The cemented carbide has been machined. It has been found that the increase of pulse duration leads to a higher cutting speed, greater duration of the pulse off time, the more cutting speed decreases and the voltage affects the cutting speed inversely, and, with increasing discharge current, cutting speed increases.

It was found that the discharge current and the discharge pulse duration have a greater impact than other observed parameters on the MRR, surface roughness and wear wire (4).

In (5) it has been proved that discharge frequency, voltage, pulse duration and wire feed rate has the greatest influence on the MRR.

S. R. NITHIN ARAVIND et al. (2012) (6) present the experimental study to select best suitable value of voltage, current, speed, pulse on/off time in order to get maximum metal removal rate (MRR) and minimum surface roughness (SR).

METHODS AND MATERIALS

There are many parameters that enter into the WEDM process. The aim of the experiment was to determine the effect of the process input parameters to break the wire electrode. In this case, it was necessary to evaluate the importance of each parameter in the cutting process. For this experiment, Taguchi experimental design was used. Six parameters were used at three levels, as can be seen in Table 1. It means L27 orthogonal array was used.

Table 1 Used parameters

Parameter	Label	Unit	Factor Level		
			Level 1	Level 2	Level 3
Pulse width	A	μs	0.5	0.7	1
Time between two pulses	B	μs	16	20	24
Servo reference mean voltage	Aj	V	30	40	50
Injection pressure	INJ	Bar	3	5	7
Wire tension	Wb	N	0.6	0.8	1
Frequency	FF	%	50	75	100

Other parameters (Voltage, Pulse current, Short pulse time, Feed rate, Wire feed speed) were the constants, and their values can be seen in Table 2.

Table 2 Constant parameters

Parameter	Label	Unit	Value
Voltage	V	V	-80
Pulse current	IAL	A	8
Short pulse time	TAC	µs	0.5
Linear feed rate	S	mm/min	5
Wire feed speed	Ws	mm/min	15

As the workpiece material, high speed molybdenum-wolfram-vanadium steel (HS6-5-2C) was used. Steel was nitrided in NH3. The width of the workpiece was 50 mm. The experiment was carried out on the Charmilles ROBOFIL 310 machine, which is a CNC machine for wire EDM. The diameter of the CuZn37 wire was 0.25 mm. Wire tensile strength Rm was 980 $N.mm^{-2}$. As dielectricum deionized water was used. Conductivity of the dielectricum was 5µS.

RESULTS

Table 3 shows the experiment results. If the electrode did not break after 5 minutes, the process was described as a stable.

Table 3 S/N Ratio for speed of cut and MRR

Experiment number	Process status	Speed of cut		MRR	
		mm/min	S/N ratio [dB]	(mm2/min)	S/N ratio [dB]
1	Stable	0.2	13.979	15	-23,522
2	Stable	0.4	7.959	25.2	-28.028
3	Unstable	0	40	0	40
4	Stable	0.1	20	4	-12.041
5	Stable	0.03	30.458	0.9	0.915
6	Stable	0.019	34.425	1.2	-1.584
7	Stable	0.1	20	4	-12.041
8	Stable	0.019	34.425	1.2	-1.584
9	Stable	0.03	30.458	0.6	4.437
10	Unstable	0	40	0	40
11	Unstable	0	40	0	40
12	Stable	0.028	31.057	1.8	-5.105
13	Stable	0.2	13.979	10.2	-20.172
14	Unstable	0	40	0	40
15	Stable	0.1	20	5.4	-14.648
16	Stable	0.3	10.458	19.8	-25.933
17	Stable	0.048	26.375	3	-9.542
18	Stable	0.019	34.425	1.2	-1.584

19	Unstable	0	40	0	40
20	Stable	0.07	23.098	2.4	-7.604
21	Stable	0.028	31.057	1.8	-5.105
22	Unstable	0	40	0	40
23	Stable	0.028	31.057	1.8	-5.105
24	Stable	0.028	31.057	1.8	-5.105
25	Unstable	0	40	0	40
26	Unstable	0	40	0	40
27	Unstable	0	40	0	40

For each measurement, the MRR values and cutting speed values were recorded, and the values of S/N ratio were calculated by [2].

$$S/N = -10.\log_{10}[\frac{1}{n}\sum_{i=1}^{n} y_i^2] \, , \qquad [2]$$

where: n - number of repetition,

y_i - the measured value of the required characteristic.

The next step was the use of analysis of variance (ANOVA) for the evaluation of the experiment. Analysis of variance (calculated from MRR) was performed to measure the significant and insignificant input parameters and also to clarify their impact on the monitored characteristics. It is necessary to determine whether the calculated S/N ratio has a normal probability distribution. Fig. 1 shows that the entire calculated S/N ratio meets the condition, and therefore it is possible to perform ANOVA.

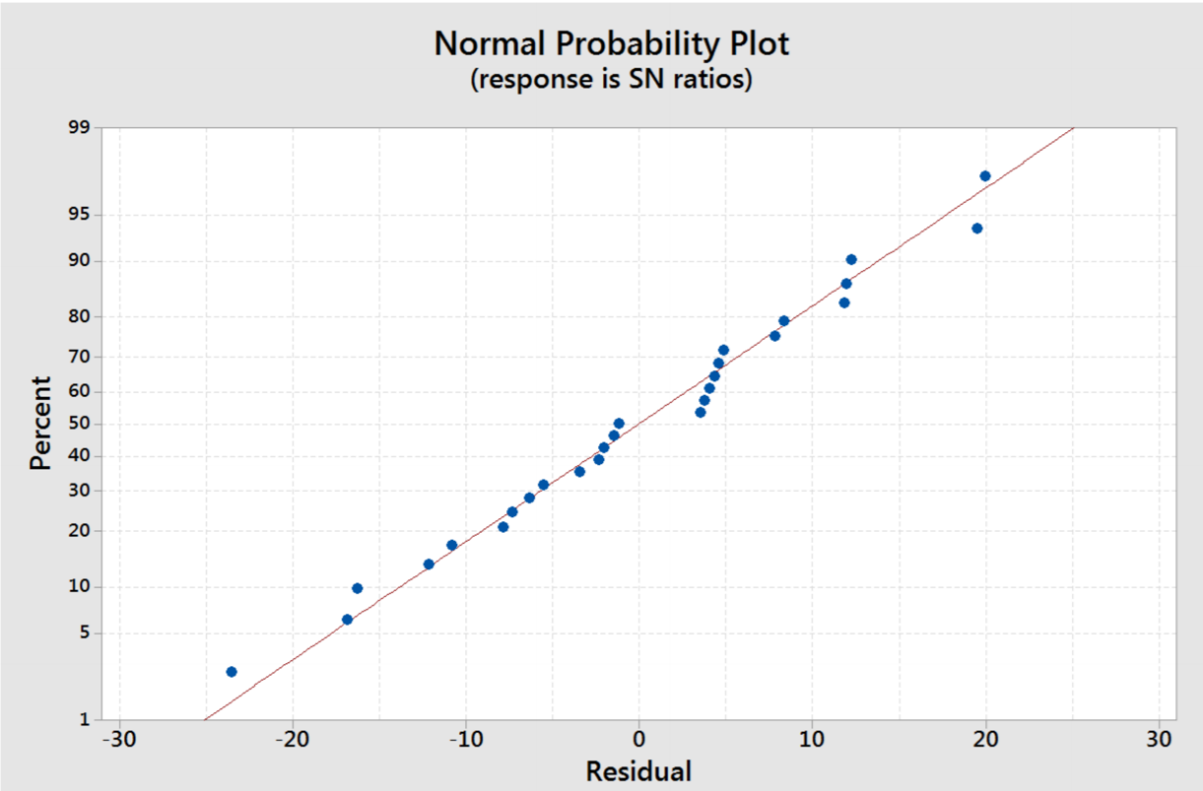

Fig. 1 *Normal probability plot for S/N ratio*

From ANOVA it was found (Table 4) that the input factors Time between two pulses (B), Injection pressure of the liquid dielectric (INJ), Wire tension (Wb) are irrelevant because the p-values are much greater than 0.05 (as it is the level of significance $\alpha = 0.05$).

Table 4 ANOVA for S/N ratio

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F - value	P - value
A	2	2523.8	15.47 %	2533.75	1261.88	3.66	0.053
B	2	281.9	1.73 %	281.9	140.96	0.41	0.672
Aj	2	2497.2	15.31 %	2497.2	1248.62	3.62	0.054
INJ	2	1213.8	7.44 %	1213.8	606.9	1.76	0.208
Wb	2	20.3	0.12 %	20.26	10.13	0.03	0.971
FF	2	4953.5	30.36 %	4953.5	2476.75	7.19	0.007
Residual Error	14	4823.3	29.57 %	4823.29	344.52		
Total	26	16313.8	100 %				

It was found that the input parameters – Pulse width (A), Servo reference mean voltage (Aj) and discharge frequency (FF) significantly influence the wire electrodes interruption, because its values are close to or smaller than p-value of 0.05 (significance level α). Parameter that significantly affects the interruption of wire electrodes is the discharge frequency (FF), because it is an input parameter with the highest net sum of squares (SEQ SSFF = 4953.5) and the lowest p-value 0.007, indicating a very strong influence on thinning wire electrodes.

Table 5 Response table for S/N ratios

Level	A	B	Aj	INJ	Wb	FF
1	-3.7164	10.0706	-2.0911	12.6256	7.3656	-4.6276
2	4.7795	2.4733	20.2428	-2.4976	7.6724	-0.5570
3	19.6755	8.1948	2.5870	10.6106	5.7006	25.9234
Delta	23.3919	7.5973	22.3339	15.1232	1.9718	30.5513
Rank	2	5	3	4	6	1

The response table for the signal to noise ratio includes the order of significance of factors based Delta Statistics that compare the relative size of each factor. The Statistics is the difference largest diameter and the smallest diameter of each factor. As can be seen from Table 5, the Discharge Frequency Parameter (FF) has the greatest impact on the wire electrodes breakage, which is also influenced by the pulse width (A) at the second place and the servo reference mean voltage (Aj) at the third place.

CONCLUSION

The following conclusions may be formulated from the experimental results:

- Increasing height of the workpiece will increase the probability of the wire electrode breakage;

- Discharge frequency (FF), pulse width (A), Servo reference mean voltage (Aj) and dielectric fluid injection pressure (INJ) have a significant impact on the wire electrode breakage;
- The time between two pulses (B) and Wire tension (Wb) is statistically insignificant.

It is probable that the interaction between the input parameters affecting the process of 30 %, as this is the value of the Residual error. Further research will examine the interaction between input parameters and their influence on the stability of the WEDM process.

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