MODELLING SURFACE FINISH IN THE INNER CIRCLE MACHINING OF 90CrSi TOOL STEEL USING WIRE CUT EDM

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ABSTRACT

This paper introduces a study on modelling surface finish in the inner circle machining of 90CrSi tool steel using wire cut electrical discharge machining (EDM). In this study, experiments were performed with full factorial design with a total of 32 experiments. Also, the input parameters including the cutting radius, the cutting voltage, the pulse on time, the pulse off time, the server voltage, the wire feed and the cutting speed were carefully selected. The influence of this parameters on the surface roughness were examined by analysing variance. Additionally, from the experimental results, a regression model to calculate the surface roughness is proposed.

KEYWORDS: WEDM, Surface Roughness, Full Factorial Design & Tool Steel Machining

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INTRODUCTION

Wire electrical discharge machining (WEDM) is a non-traditional machining process, which is commonly used for machining electrically conducting materials. It is one of the most effective machining methods for machining difficult-to-machine materials and parts with small-radius inside corners or narrow slots. Therefore, there have been many studies in order to optimize the EDM process for finding the optimum input parameters.

To recognize the tasks in optimization of WEDM process, Yushi Takayama et al. [1] presented the latest technology in this area. The researches on WEDM optimization have been done for many work piece materials. M. Durairaj and his colleagues [2] introduced a study on determining the optimum process parameters for wire cut EDM of Stainless Steel SS304 with the use of the Grey relational theory and Taguchi technique. Also, G. Ugrasen et al. [3] carried out an optimization study on the influence of process parameters on the accuracy, the surface roughness and the volumetric material removal rate in WEDM with molybdenum wire. In addition, Parameswara Rao and M Sarcar [4] estimated the optimum input parameters in wire cut EDM brass. Besides, there have been several studies on determining optimum process parameters in WEDM [5, 6, 7 and 8]. In addition, many methods have been used for the investigation of wire cut EDM process. The method can be Genetic Algorithm method [10], simulation method [11] or experimental method [12, 13].

This paper presents a study on modelling surface finish in wirecut EDM of 90CrSi tool steel. In this study, the effect of the input factors including the cutting voltage, the pulse on time, the pulse off time, the gap voltage,

the wire feed and the cutting speed on the surface roughness were estimated. Also, a regression equation for calculation of the surface roughness when WEDM tool steel 90CrSi was suggested.

EXPERIMENTAL WORK

To weigh the effect of the process parameters on the surface roughness, 7 input factors were carefully chosen (Table 1). Also, a 2-levels full factorial experimental design was selected. Therefore, a number of $2^7=128$ experiments will be tested. The explanation of experimental machine and equipment is presented in Table 2.

Table 1: Input Parameters and their Levels

Parameter	Code	Unit	Low	High
Cutting voltage	VM		3	9
Pulse on time	T _{on}		8	12
Pulse off time	T _{off}		13	18
Server voltage	SV		25	35
Wire feed	WF		8	12
Cutting speed	SPD		2.5	4.5
Cutting radius	R	mm	3	9

Table 2: Experimental Machine and Equipment

Machine and Equipment	Specifications
Machine	Fanuc Robocut α -1 iA (Figure 1)
Wire	Brass wire of diameter 0.25 mm (Taiwan)
Work-piece material	90CrSi
Dielectric fluid	Deionised water
Roughness measurement	Mitutoyo 178-923-2A, SJ-201 (Japan)

Figure 1: Wire-Cut Electrical Discharge Machine

After experimental cutting, the surface roughness of the workpieces was measured. The various levels of input factors and the output response results (the surface roughness Ra) are presented in Table 3.

RESULTS AND DISCUSSIONS

Table 3: Experimental Plans and Output Response

Std Order	Run Order	Center Pt	Blocks	VM	Ton		Toff	SV	WF	SPD	R (mm)	Ra (μm)
30	1	1	1	9	8		18	35	12	2.5	3	3.22
2	2	1	1	9	8		13	25	8	2.5	3	2.88
6	3	1	1	9	8		18	25	8	4.5	3	3.41
10	4	1	1	9	8		13	35	8	4.5	9	2.80
25	5	1	1	3	8		13	35	12	2.5	9	3.45
13	6	1	1	3	8		18	35	8	4.5	3	5.44
...												
9	31	1	1	3	8		13	35	8	2.5	3	5.28
22	32	1	1	9	8		18	25	12	4.5	9	2.87

To imagine the influences of input factors on the response and to evaluate the relative strength of the influence, figure 2 shows a graph of the main effect of each factor. From the figure, with the growth of the cutting voltage VM and the cutting radius R, the surface roughness R_a reduces considerably. Besides, the surface roughness is effected by the pulse off time Toff, the serve voltage SV, the cutting speed SPD and the wire feed WF.

Figure 2: Main Effects Plot for Surface Roughness

To evaluate the effects of increasing or decreasing the response, the Normal Plot is shown in Figure 3. It can be seen from the figure that, the cutting radius (factor G), the cutting voltage (factor A), the cutting speed (factor F), the pulse on time (factor B), the pulse of time (factor C), the wire feed (factor E) and the interactions BD, BG, BCE and BCG are the significant effects factors. In addition, the pulse on time (factor B), the pulse off time (factor C) and the wire feed (factor E) have a positive standardized effect. That means, if their values rise the surface roughness growths. Besides, the cutting radius (factor G), the cutting voltage (factor A), the cutting speed (factor F) and the interactions BD and BCE have negative standardized effects. If their values grow, the surface roughness drops.

Figure 4 presents the Pareto chart of the standardized effects. From the chart, the bars that represent three factors including the cutting radius (factor G), the cutting voltage (factor A), the pulse on time (factor B), the cutting speed (factor F), the pulse off time (factor C), the wire feed (factor E) and the interactions BG, BD, BCE, BCG cross the reference line. Hence, these factors are statistically significant at the 0.05 level with the response model.

Figure 3: Normal Plot for R_a

Figure 4: Pareto Chart of the Standardized Effects

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		3.4881	0.0139	250.24	0.000	
VM	-0.3756	-0.1878	0.0139	-13.47	0.000	1.00
Ton	0.2195	0.1097	0.0139	7.87	0.000	1.00
Toff	0.1221	0.0611	0.0139	4.38	0.000	1.00
SV	-0.0325	-0.0163	0.0139	-1.17	0.260	1.00
WF	0.0607	0.0303	0.0139	2.18	0.045	1.00
SPD	-0.1761	-0.0880	0.0139	-6.32	0.000	1.00
R	-0.5494	-0.2747	0.0139	-19.71	0.000	1.00
Ton*Toff	0.0045	0.0023	0.0139	0.16	0.873	1.00
Ton*SV	-0.1415	-0.0707	0.0139	-5.07	0.000	1.00
Ton*WF	-0.0542	-0.0271	0.0139	-1.94	0.070	1.00
Ton*R	0.1530	0.0765	0.0139	5.49	0.000	1.00
Toff*WF	-0.0081	-0.0041	0.0139	-0.29	0.775	1.00
Toff*R	-0.0416	-0.0208	0.0139	-1.49	0.155	1.00
Ton*Toff*WF	-0.1189	-0.0594	0.0139	-4.26	0.001	1.00
Ton*Toff*R	0.1149	0.0574	0.0139	4.12	0.001	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0788524	98.03%	96.17%	92.10%

Figure 5: Estimated Effects and Coefficients for R_a

The estimated effects and coefficients for R_a after ignoring insignificant effects is described in figure 5. It can be seen from the figure that, factors which have a significant effect on a response have P-values lower than 0.05 are the cutting radius, the cutting voltage, the pulse on time, the cutting speed, the pulse off time, the wire feed and the interactions BC, BD, BE, BG, CE, CG, BCE, BCG (Figure 5). Consequently, the surface roughness can be determined by the following equation.

$$R_a = 4.91 - 0.0626 \cdot VM - 0.074 \cdot T_{on} - 0.1641 \cdot T_{off} + 0.04391 \cdot SV - 0.328 \cdot WF - 0.088 \cdot SPD + 0.1065 \cdot R + \\ + 0.02051 \cdot T_{on} \cdot T_{off} - 0.004716 \cdot T_{on} \cdot SV + 0.03512 \cdot T_{on} \cdot WF - 0.01703 \cdot T_{on} \cdot R + 0.03235 \cdot T_{off} \cdot WF - \\ - 0.02359 \cdot T_{off} \cdot R - 0.003303 \cdot T_{on} \cdot T_{off} \cdot WF + 0.002128 \cdot T_{on} \cdot T_{off} \cdot R \quad (1)$$

CONCLUSIONS

A study on modelling surface finish in wire electrical discharge machining tool steel 90CrSi was presented. The effects of the input WEDM and many process parameters including cutting voltage, pulse on time, pulse off time, server voltage, wire feed and cutting on the surface roughness were investigated in experiments. The experiments were conducted in two levels full factorial design. From the results of the study, a regression equation for calculating the surface roughness has been proposed.

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