Modelling Surface Finish in Wire Electrical Discharge Machining of 9CrSi Tool Steel

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Abstract
This paper presents a study on modelling surface finish in Wire Electrical Discharge Machining of 9CrSi tool steel. In the study, experiments were conducted based on full factorial design and the work-piece material was 9CrSi steel. A total of 32 experiments were conducted. The input parameters including cutting voltage, pulse on time, pulse off time,servervoltage, wire feed and cutting speed were selected. The effect of input parameters on the surface roughness were investigated by analysing variance. Furthermore, based on the results of the experiments, a regression equation for determining the surface roughness is proposed.

Keywords: *WEDM, Surface Roughness, Full Factorial Design, tool steel machining.*

I. INTRODUCTION

Wire electrical discharge machining (WEDM) is a non-traditional machining process which widely used for machining electrically conducting materials. It is one of the most effective machining processes for cutting difficult-to-machine materials as well as for machiningparts which with small-radius inside corners or narrow slots. Therefore, many researches have been done to understand the influence of process parameters as well as to optimize the EDM process in order to find the optimum input parameters.M. Durairaj et al. [1] presented a study on selection optimum process parameters for WEDM of Stainless Steel (SS304) by using the Grey relational theory and Taguchi technique. G. Ugrasen and his colleages [2] conducted an optimization research using the Taguchi's technique which is based on the robust design. In their study, the effect of machining parameters on accuracy, surface roughness and volumetric material removal rate when WEDM with molybdenum wire. Parameswara Rao and M Sarcar [3] evaluated optimum parameters including discharge current, wire speed, gap votage when machining brass.Basil Kuriachen et al. [4] determining optimum process parameters when machining Ti-6Al-4V alloy by using full factorial design of experiments. M. Panner Selvam and P. Ranjith Kumar [5] proposed empirical models for determining the surface roughness and the kerf width when WEDM Hastelloy –C-276 by using Genetic Algorithm method. Anurag Joshi [6] carried out a study on defining optimum process parameters for getting maximum metal removal rate when machining tool steel EN 31. F. Klocke et al. [7] evaluated the capabilities of advanced WEDM for manufacturing fir tree slots in Inconel 718. D. Amrish Raj and T. Senthilvelan [8] introduced a study on optimization of the cutting conditions of Wire-EDM while machining titanium alloy in order to get better surface roughness and material removal rate.

This paper introduces a study on modelling surface finish in Wire Electrical Discharge Machining of 9CrSi tool steel. In the study, the influence of input parameters including cutting voltage, pulse on time, pulse off time, gap voltage, wire feed and cutting speed on the surface roughness were evaluated. In addition, a model for determining the surface roughness when WEDM tool steel 9CrSi was proposed.

II. EXPERIMENTAL WORK

In order to evaluate the influence of WEDM process parameters, a two levels full factorial experimental design was applied because this gives all possible combinations of machine parameters. The experimental set-up is as:

-Machine: Fanuc Robocut α-1 iA (Figure 1);

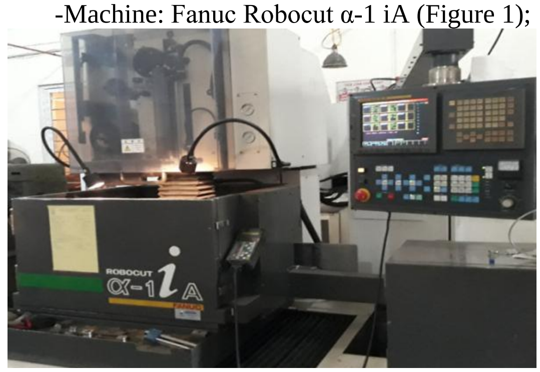

Fig. 1: Wire-cut electrical discharge machine

Parameter	Level 1	Level 2
Cutting voltage	3	9
Pulse on time	7	13
Pulse off time	9	15
Server voltage	25	35
Wire feed	8	12
Cutting speed	4.5	5.5

Table 1: Input parameters and their levels

Std Or der	Ru n Or	Cent er Pt	Blo cks	V M	T o n	Tof f	S V	W F	SP D
24	1	1	1	9	13	15	25	12	4.5
20	2	1	1	9	13	9	25	12	5.5
3	3	1	1	3	13	9	25	8	5.5
10	4	1	1	9	7	9	35	8	4.5
4	5	1	1	9	13	9	25	8	4.5
21	6	1	1	3	7	15	25	12	4.5
…									
17	31	1	1	3	7	9	25	12	5.5
26	32	1	1	9	7	9	35	12	5.5

Table 2: Experimental plans and output response

Std Orde r	Run Orde r	Cent erPt	Blo cks	V M	T on	To ff	S V	W F	SP D
24	1	1	1	9	13	15	2	12	4.
20	2	1	1	9	13	9	2	12	5.
3	3	1	1	3	13	9	2	8	5.
10	4	1	1	9	7	9	3	8	4.
4	5	1	1	9	13	9	2	8	4.
21	6	1	1	3	7	15	2	12	4.
…									
17	31	1	1	3	7	9	2	12	5.
26	32	1	1	9	7	9	3 5	12	5. 5

Table 3: Experimental plans and output response.

-Work-piece material: 9CrSi steel;

-Wire used: Brass wire of diameter 0.25 mm;

-Dielectric fluid: Deionised water;

-Input parameters: cutting voltage (VM); pulse on time (T_{on}); pulse off time (T_{off}); serve voltage (SV); wire feed (WF); cutting speed (SPD). (The levels of the input parameters were shown in Table 1);

-Number of experiments: 32.

After processing, the surface roughness was measured by a strain gage transducer contact SJ-301 (Mitutoyo, Japan). The various levels of input parameters and the results of the output response (the surface roughness Ra) are described in Table 2.

III. RESULTS AND DISCUSSIONS

For visualizing the effect of factors on the response and for evaluation of the relative strength of the effect, a graph of the main effect of each factor is plotted in Figure 2. As in the Fig. 2, the value of surface roughness Ra increases significantly with the increase of the cutting voltage and the pulse on time. In addition, it is effected by the pulse off time, the serve voltage, the wire feed and the cutting speed.

Fig. 3 shows the Pareto chart of the standardized effects from the largest effect to the smallest effect. According to in this chart, the bars that represent three factors including the cutting voltage (factor A), the pulse on time (factor B) and the interaction between the pulse off time and the serve voltage (factor CD) cross the reference line. Therefore, these factors are statistically significant at the 0.05 level with the response model.

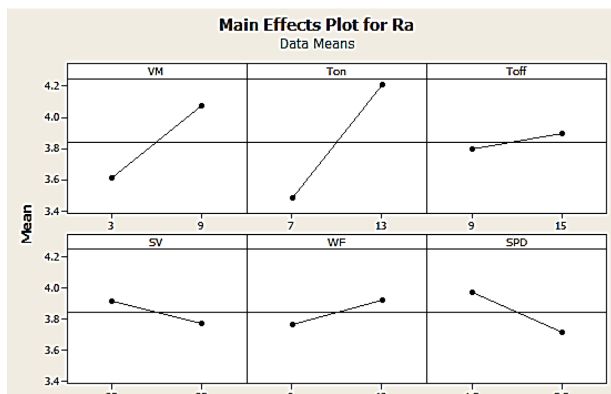

Fig. 2: Main effects plot for surface roughness

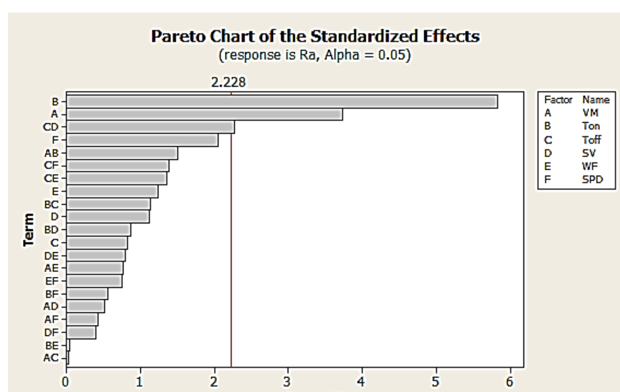

Fig. 3: Pareto Chart of the Standardized Effects

Figure 4 reports the Normal Plot of the standardized effects. From this Figure, it is seen that, the cutting voltage (factor A), the pulse on time (factor B) andthe interaction between the pulse off time and the serve voltage (factor CD) are the significant effects factors. Also, all the effects which lie along the line (including C, D, E, F and their interactions) are negligible. In addition, the cutting voltage (factor A) and the pulse on time (factor B) have a positive standardized effect. When theychange from the low level to the high level of the factor, the surface roughness increases.

Figure 5 describes the estimated effects and coefficients for *Ra* after ignoring insignificant effects. It was found that factors which have a significant effect on a response have P-values lower than 0.05 are the cutting voltage, the pulse on time and the interaction between the pulse off time and the serve voltage (Figure 5). Therefore, the following equation can be used for describing the relation between the surface roughness and significant effect factors:

$$Ra = 3.8425 + 0.2319V_M + 0.3619t_{on} + 0.0515t_{off} - 0.07SV - 0.1413t_{off}\,SV \quad (1)$$

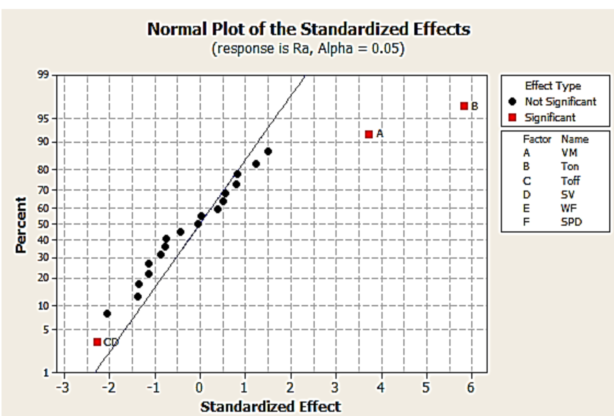

Fig. 4: Normal Plot for

Estimated Effects and Coefficients for Ra (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		3.8425	0.06267	61.31	0.000
VM	0.4637	0.2319	0.06267	3.70	0.001
Ton	0.7238	0.3619	0.06267	5.77	0.000
Toff	0.1025	0.0512	0.06267	0.82	0.421
SV	-0.1400	-0.0700	0.06267	-1.12	0.274
Toff*SV	-0.2825	-0.1413	0.06267	-2.25	0.033

S = 0.354513 PRESS = 4.94985

R-Sq = 67.51% R-Sq(pred) = 50.79% R-Sq(adj) = 61.26%

Fig. 5: Estimated Effects and Coefficients for Ra

IV. CONCLUSION

A study on modelling surface finish in wire electrical discharge machining tool steel 9CrSi was presented. The effects of the input WEDM many process parameters including cutting voltage, pulse on time, pulse off time, server voltage, wire feed and cutting on the surface roughness were investigated by 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 was proposed.

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