Modelling Surface Finish in Electrical Discharge Machining Tablet Shape Punches using Response Surface Methodology

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Abstract

This paper presents a study on modelling surface finish in Electrical Discharge Machining of tablet shape punches. In the study, experiments were conducted based on Box-Behnken design and the work-piece material was 9CrSi steel. A total of 27 experiments were done. The input parameters including current, pulse on time, pulse off time and voltage were selected. The influence of input parameters on the surface finish were investigated by analysing variance. In addition, based on the results of the experiments, a regression equation for determining the surface roughness is introduced. Also, the optimum input parameter values were found in order to get the minimum surface roughness.

Keywords — *EDM, EDM sinking, Surface Roughness, Response Surface Methodology, Box-Behnken Design.*

I. INTRODUCTION

[1] Electrical Discharge Machining is the process for removing electrically conductive materials by using precisely controlled sparks that occur between an electrode and a work-piece in a dielectric fluid. It is one of the most effective non-traditional machining processes for working with difficult-to-machine materials as well as for producing blank cavities in products. Therefore, many researches have been done for optimizing the EDM process in order to find the optimum input parameters.

Until now, there are many studies on the modeling of EDM process as well as on the finding optimum input parameters. Reza Vantakhah et al. [1] carried out an optimum study to optimize the material removal rate and tool wear ratio when EDM AISI D6 tool steel. To maintain the stability of the EDM process, Tsutomu Kaneko and Tomomasa Onodera [2] suggested using fuzzy control. The Physical and Electrical Characteristics of EDM Debris were also investigated by J. W. Murray et al [3]. S. Thiyagarajan [4] conducted an experimentally investigation on the influences of three different work-piece materials on the aerosol emission rate and the material removal rate. A. Torres et al. [5] conducted a study on the effect of input parameters of the EDM process on the surface roughness, the electrode wear and the material removal rate. N. Annamalai et al. [6] investigated the effect of process parameters when machining AISI 4340 steel by electrolytic copper electrode. The authors also found that the material removal rate and the surface roughness are mainly effected by pulse on time, peak current and pulse off time. It can be seen from previous researches that there were many studies on EDM processes. However, the previous studies usually done with work-pieces in the types of blank cavities or shaped holes. This study investigated the modelling surface finish in EDM tablet shape punches using response surface methodology (RSM). In the study, the influence of input parameters on the surface finish of 9CrSi steel were investigated by analysing variance. In addition, a regression equation for determining the surface roughness is proposed. Also, the optimum input parameter values for getting the minimum surface roughness were found.

II. EXPERIMENTAL WORK

The experiments were designed based on the response surface method. Four input parameters were selected and three levels of each factors were considered in the experiments. Besides, the Box-Behnken Design of RSM is chosen for the experiments. The details of the experimental set-up are described below:

- Machine: sinker EDM model CNC-AG40L from Sodick Europe Ltd. (UK);
- Work-piece material: 9CrSi steel;
- Electrode materials: Copper;

TABLE I - INPUT PARAMETERS AND THEIR LEVELS

Parameter	Level 1	Level 2	Level 3
Pulse on time	30	35	40
Pulse off time	15	20	25
Gap voltage	40	45	50
Pulse current	4	6	8

- Dielectric fluid: EDM oil HD-1;
- Input parameters: Gap voltage (U); pulse on time (Ton); pulse off time (Toff); pulse current (I); the level of the input parameters were shown in Table I.
- Number of experiments: 27;

After processing, the surface roughness of the work-pieces 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 given in table 2.

III. RESULTS AND DISCUSSIONS

TABLE III-INPUT PARAMETERS AND THEIR LEVELS

No.	T_{on} (µ/s)	T_{off} (µ/s)	U (V)	I (A)	Ra (µm)
1	35	20	40	8	7.33
2	30	20	50	6	4.04
3	35	15	45	8	3.90
4	35	20	40	4	4.31
5	40	20	50	6	3.90
6	35	15	40	6	3.76
7	35	20	50	4	5.61
8	35	25	45	8	4.36
9	30	20	45	4	2.97
10	30	20	45	8	3.02
11	40	25	45	6	3.42
12	30	20	40	6	3.89
13	40	15	45	6	3.14
14	35	25	45	4	2.90
15	35	25	40	6	3.24
16	40	20	40	6	2.81
17	40	20	45	4	2.73
18	40	20	45	8	2.74
19	35	15	50	6	2.57
20	35	20	45	6	2.78
21	30	15	45	6	3.14
22	35	20	50	8	2.70
23	35	20	45	6	2.76
24	35	20	45	6	2.40
25	35	25	50	6	2.56
26	35	15	45	4	2.43
27	30	25	45	6	2.37

The results of regression analysis for the surface roughness was shown in Fig. 1. Observing the results of the analysis of variance, it was found that the highest composition of the regression model was statistically significant (p value was 0.051). Since the p value of the lack-of-fit (0.871) in RSM is much larger than the normal value 0.05, the second order is suitable and the model fit well.

Response Surface Regression: Y (Ra) versus Ton, Tof, U, I

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The analysis was done using coded units.

Estimated Regression Coefficients for Y (Ra)

Term          Coef  SE Coef        T      P
Constant   2.55444   0.2488   10.265  0.000
Ton       -0.05750   0.2155   -0.267  0.093
Tof       -0.00750   0.2155   -0.035  0.073
U         -0.33000   0.2155   -1.531  0.043
I          0.25833   0.2155    1.199  0.046
U*U        1.05792   0.2951    3.585  0.002
I*I        0.84292   0.2951    2.856  0.010
Ton*U      0.23500   0.3733    0.630  0.037
U*I       -1.48250   0.3733   -3.972  0.001


S = 0.746520    PRESS = 31.6242
R-Sq = 67.65%   R-Sq(pred) = 0.00%   R-Sq(adj) = 93.28%


Analysis of Variance for Y (Ra)

Source          DF   Seq SS   Adj SS    Adj MS      F      P
Regression       8  20.9801  20.9801  2.62252   4.71  0.003
  Linear         4   2.1480   2.1480  0.53700   0.96  0.051
    Ton          1   0.0397   0.0397  0.03967   0.07  0.093
    Tof          1   0.0007   0.0007  0.00067   0.00  0.073
    U            1   1.3068   1.3068  1.30680   2.34  0.043
    I            1   0.8008   0.8008  0.80083   1.44  0.046
  Square         2   9.8200   9.8200  4.91001   8.81  0.002
    U*U          1   5.2728   7.1628  7.16280  12.85  0.002
    I*I          1   4.5473   4.5473  4.54725   8.16  0.010
  Interaction    2   9.0121   9.0121  4.50606   8.09  0.003
    Ton*U        1   0.2209   0.2209  0.22090   0.40  0.037
    U*I          1   8.7912   8.7912  8.79123  15.77  0.001
Residual Error  18  10.0313  10.0313  0.55729
  Lack-of-Fit   16   9.9398   9.9398  0.62124  13.58  0.871
  Pure Error     2   0.0915   0.0915  0.04573
Total           26  31.0114
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Fig 1: Anova results for Surface Roughness

The regression equation for the surface roughness as follows:

$$R_a = 2.55444 - 0.0575 \cdot T_{on} - 0.0075 \cdot T_{off} - 0.33 \cdot U + $$
$$+0.25833 \cdot I + 0.235 \cdot T_{on} \cdot U - 1.4825 \cdot U \cdot I + $$
$$+1.05792 \cdot U^2 + 0.842922 \cdot I^2$$

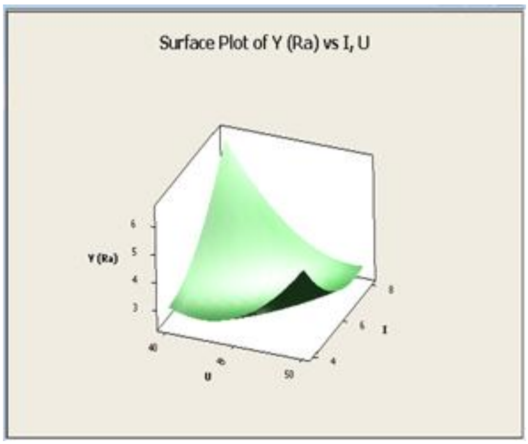

Fig 2: Surface roughness versus I and U

Fig. 2 shows the relation between the surface roughness with the pulse current and the gap voltage. In addition, the contour plot of the surface roughness and the pulse current and the gap voltage is described in Fig. 3. From the contour plot, it was found that the minimum value of the surface roughness was Ra=2.52935 when the gap voltage was 45.6002 and the pulse current was 5.82945.

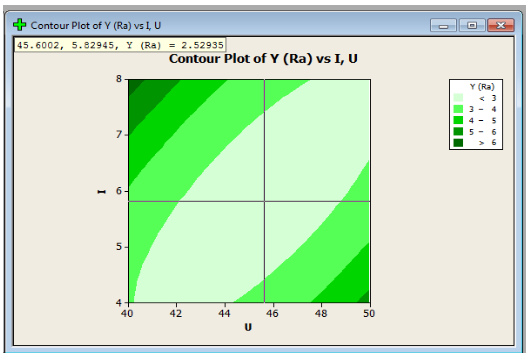

Fig 3: Contour Plot of Surface roughness versus I and U

IV. CONCLUSIONS

A study on modelling surface finish in Electrical Discharge Machining of tablet shape punches was carried out. The input parameters of the EDM process which effects on the surface roughness were investigated by experiments which were designed by BBD. From the results of the experiments, a regression equation for determining the surface roughness was proposed. In addition, the optimum values of input parameters for getting the minimum surface roughness were given.

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