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Research Article

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Study of Wear Ratio of SKD11 Steel in Titanium Abrasives Mixed Electrical Discharge Machining

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Abstract—

In the present study an attempt has been done to investigate the wear ratio of SKD11 steel in Electrical Discharge Machining process. In this study five input factors are taken too investigated by using orthogonal array L_{18}.Input machining variables are varied in sinking EDM process using copper tool electrode. Evaluation of effect of input machining variables for their percentage contribution is made using (ANOVA) technique. Experimental results are presented to display the effect of variables.

Keywords— Abrasives EDM, SKD11 Steel, Wear Ratio (WR).

I. INTRODUCTION

Ability to cut complex shapes in conductive materials irrespective of hardness and toughness and by maintaining dimensional accuracy electrical discharge machining as most efficient non conventional machining process among all other processes. Electrical Discharge Machining (EDM) is one such process which is widely used to machine electrically conductive materials. EDM is a thermo-electric process in which material removal takes place through the process of controlled spark generation. It is one of the most popular non-traditional machining processes being used today in the industry. EDM is commonly used in mould and die making industry and in manufacturing automotive, aerospace and surgical components. EDM has achieved an essential status in the industry because of its ability to machine any electrically conductive material irrespective of its mechanical strength. Despite its advantages, it has been a major drawback in concern of environment. The dielectric fluid used in EDM is the primary source of pollution from the process. Dielectric wastes generated after machining are very toxic and cannot be recycled. Also, toxic fumes are generated due to high temperature chemical breakdown of dielectric during machining. The use of oil as the dielectric fluid also makes it necessary to take extra precaution to prevent from fire hazards. Since an environment friendly alternative for replacing the EDM process is not available, changing or totally eliminating the liquid dielectric medium provides a feasible solution [1]. Around 12,000 temperatures is produced during operation by an electrical spark in the discharging gap between electrode and work piece surface. This temperature is strong enough to erode material by evaporation and also melting both the tool electrode and work piece surface. In spite of to machine very hard and tough metal its use is restricted because of its low machining efficiency and poor surface finish. To overcome of these drawbacks, some suitable foreign particles are added in powder form in the dielectric fluid of EDM. Powders in the dielectric fluid enlarge the gap between the work piece and electrode and improve the surface finish by reducing the spark energy and dispersing the discharges more uniformly throughout the surface of work piece to be machined [2, 3, and 4, 5]. Mixing of tungsten carbide, silicon powder and Aluminum oxide abrasives powder particles in EDM oil for machining. It improves the surface properties of material and the MRR increases with increases the concentration of powder particles and the time lag is decreases at high powder concentration [6, 7, 8, and 9].The surface cracking of the work piece is highly influenced by the electrode size and thermal conductivity of material. It can be avoided by using a small electrode when machining a low thermal conductivity material and machining with large pulse current and short pulse on duration [10].

II. MATERIALS AND METHODS

A. Equipment and Work piece Material

Smart ZNC die-sinking Electric Discharge machine tool with OSCARMAX S645 ZNC pulse generator having 1200 litter dielectric capacity and DC servo feed control system is used for sinking blind holes in work material. Copper tool electrode as a solid rod of 9.5 mm diameter was used in experimental work. The physical and mechanical properties of copper are density: 8.96 g/cm^3, tensile strength: 90 MPa, thermal conductivity: 401W/m/K. A piece of SKD11 steel work-piece surface was machined on shaper and finished on grinding machine. Chemical composition of SKD11 work material is C- 1.40wt%, Mn-0.4 wt%, Si-0.3wt%, V-0.3wt%, S-0.002wt%, Mo-1.0wt%, Cr-1.5wt%. Yielding stress and young modulus of SKD11 work material are 334MN/m^2 and 202GN/m^2 respectively. A mild steel sheet tank of capacity of 7 litres was made in which 6 litres dielectric fluid was filled. Titanium abrasives of 100 mesh size were used to mix in dielectric fluid to conduct abrasive mixed experiments.

TABLE I EXPERIMENTAL SETUP AND OPERATING CONDITIONS

Condition	**Description**
Work piece	SKD11steel
Tool electrode material	Copper
Dielectric fluid	EDM oil
Tool electrode diameter	9.5mm
Grain size of abrasives	100 mesh
Polarity	+ve and -ve
Peak current	6-12
Pulse on time	120-200
Gap voltage	40-80
Abrasive concentration	0-12

TABLE II DESIGN PLAN OF MACHINING VARIABLES

Symbol	**Control Variable**	**Level 1**	**Level 2**	**Level 3**
A	Polarity	+ ve	-ve	
B	Peak current (amp)	6	9	12
C	Pulse on time (μs)	120	150	200
D	Gap voltage (volt)	40	60	80

B. Experimental Design

In this study, evaluation of wear ratio of work materials is done by conducting experimental investigation. Polarity, peak current, pulse on time, gap voltage and concentration of abrasive powder were taken as input parameters in sinking EDM process. A, B, C, D and E is given below. Variable A is varied at two levels and all other variables (B, C, D and E) varied at three levels. Table I enlists experimental set up and operating conditions of this study. Table II shows design scheme of machining variables.

C. Orthogonal Design

Taguchi method uses special design of orthogonal array to study the entire parameters space with only a small number of experimental runs. This method is a powerful tool in the design of experiment methods and can optimize performance characteristics through the settings of process parameters and reduce the sensitivity of the system performance to sources of variation. In this study Taguchi method is applied to plan and analyse the experiments. A mixed orthogonal array L_{18} is used to plan the experimental runs. This array has 5 columns and 18 rows with one two-level input parameter and four three-level input parameters. Each input parameter is assigned to a column and 18 machining parameter combinations are required as per L_{18} orthogonal array.18 experiments are needed to study the entire machining parameter space using the L_{18} orthogonal array. The experimental layout using an L_{18} orthogonal array (coded levels) is shown in table III.

TABLE III DESIGN LAYOUT: L_{18} ORTHOGONAL ARRAY (CODED LEVEL VALUES)

Exp. No.	**Coded Variable Levels**				
	(A)	**(B)**	**(C)**	**(D)**	**(E)**
1	1	1	1	1	1
2	1	1	2	2	2
3	1	1	3	3	3
4	1	2	1	1	2
5	1	2	2	2	3
6	1	2	3	3	1
7	1	3	1	2	1
8	1	3	2	3	2
9	1	3	3	1	3
10	2	1	1	1	3
11	2	1	2	2	1
12	2	1	3	2	2
13	2	2	1	2	3
14	2	2	2	3	1

15	2	2	3	1	2
16	2	3	1	3	2
17	2	3	2	1	3
18	2	3	3	2	1

D. Signals to Noise Ratio

In the Taguchi methodology, the signal to noise ratio is used to find the deviation of the performance characteristic from its desired value. Usually, there are three kinds of the performance characteristics in the analysis of the S/N ratio, i.e., (a) lower-the-better, (b) higher-the-better, and (c) nominal-the-better. In machining operations the lower the wear ratio is always desirable. So, the lower-the-better wear ratio is selected. For lower-the-better category the signal-to-noise ratio for the i^{th} output performance characteristic in the j^{th} experimental run can be expressed as:

$$(S/N)_{ij} = -10*\text{Log}_{10}\left\{\frac{1}{n}\sum_{k=1}^{n} y_{ijk}^{2}\right\}$$

Where (n) stands for number of test.

Productivity of any machining process is evaluated, in general, form the lowest value of wear ratio on work material. Therefore lower the better wear ratio is selected in this work.

E. Analysis of Variance

Analysis of variance (ANOVA) technique is used to sum up the result of input machining variables parameters on the performance measures i.e. wear ratio. This technique makes use of special set of stats to evaluate results. These results are further represented using a set of tabular values for further interpretation.

III. RESULTS AND DISCUSSION

The results obtained according to values of table IV and then put in to Minitab 16.1 software for further analysis. ANOVA tables are used to sum up the results to see the impact of input machining parameters on the output measure i.e. WR This table concludes information of analysis of variance and case statistics for further interpretation. After the ANOVA procedure, further analysis was performed with graphic plots. Which is shown in fig 1 and fig 2 are main effects plots of the means for the output response parameter are obtained using Minitab 16.1 software. It is clearly visible and analysed from fig.1 that the wear ratio is minimum at 2nd level of polarity, 2nd level of peak current, 2nd level of in pulse on time, 3rd level of gap voltage, 1st level of concentration of abrasives. Therefore the optimum condition for input machining variables is $A_2B_2C_2D_3E_2$. These results are also confirmed from main effects plot for S/N ratios (fig 2).

TABLE IV DESIGN LAYOUT: L_{18} ORTHOGONAL ARRAY AND EXPERIMENTAL RESULTS

Exp Run	**Polarity**	**Peak current**	**Pulse on time**	**Gap voltage**	**Concentration abrasives**	**Values of WR**
	A	**B**	**C**	**D**	**E**	
1	Positive	6	120	40	0	0.03571
2	Positive	6	150	60	6	0.03571
3	Positive	6	200	80	12	0.03571
4	Positive	9	120	40	6	0.03226
5	Positive	9	150	60	12	0.03030
6	Positive	9	200	80	0	0.03333
7	Positive	12	120	60	0	0.03125
8	Positive	12	150	80	6	0.03125
9	Positive	12	200	40	12	0.03846
10	Negative	6	120	80	12	0.23810
11	Negative	6	150	40	0	0.25000
12	Negative	6	200	60	6	0.23810
13	Negative	9	120	60	12	0.17391
14	Negative	9	150	80	0	0.13043
15	Negative	9	200	40	6	0.22727

16	Negative	12	120	80	6	0.25000
17	Negative	12	150	40	12	0.22727
18	Negative	12	200	60	0	0.21739

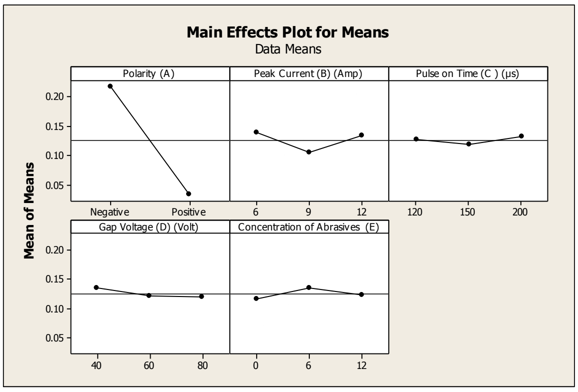

Fig. 1 Main effect plot for means for WR

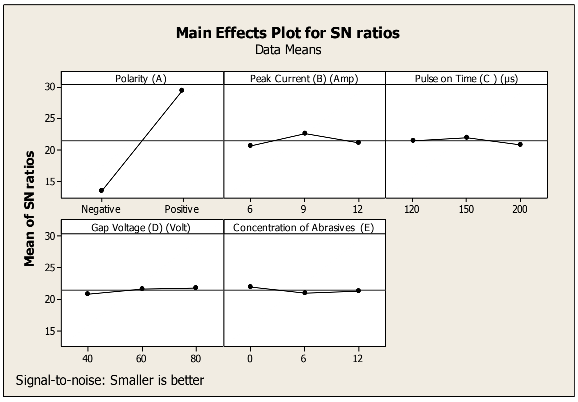

Fig. 2 Main effect plot for S/N ratio for WR

F-ratio and p-values of table V shown that polarity and peak current are main significant input process variable with contribution of 97.34% and 1.04% towards wear ratio of machined blind holes. Concentration of abrasives contributes only 0.20% which is least among all input variables. Gap voltage, peak current and pulse on time also having insignificant contribution of 0.30% and 0.31% respectively towards wear ratio of SKD11 steel. Delta value is equal to the difference of maximum S/N ratio to minimum S/N ratio for a particular input process variable. These values designate rank to an input process variable for its influence to output response characteristics. These values are shown in table VI. The higher delta value is the more effect of that input process variable. Highest delta values of polarity and lowest delta value for concentration of abrasives ranked them as most input process variable and least input process variable respectively.

TABLE V ANALYSIS OF VARIANCE RESULTS FOR WR (S/N DATA)

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution%**
Polarity (A)	1	1154.94	1154.94	1154.94	975.91	0.000	97.34
Peak current (B)	2	12.38	12.38	6.19	5.23	0.035	1.04
Pulse on time (C)	2	3.68	3.68	1.84	1.56	0.269	0.31
Gap Voltage (D)	2	3.64	3.64	1.82	1.54	0.272	0.30
Concentration of Abrasives (E)	2	2.43	2.43	1.22	1.03	0.401	0.20
Residual Error	8	9.47	9.47	1.18			0.39
Total	17	1186.54					

DF* = Degree of freedom
$F^{\#}$ = Tabulated value of F-ratio at 95% confidence level

TABLE VI RESPONSE TABLE FOR WR (S/N DATA)

Level	**Polarity (A)**	**Peak Current (B)**	**Pulse on Time (C)**	**Gap Voltage (D)**	**Concentration of Abrasive (E)**
1	13.43	20.63	21.43	20.81	21.93
2	29.45	22.58	22.00	21.72	21.04
3		21.11	20.90	21.80	21.36
Delta	16.02	1.95	1.11	0.99	0.89
Rank	1	2	3	4	5

IV. CONCLUSIONS

Following are some conclusions which can be taken:

1. Wear ratio is less at positive polarity in comparison of negative polarity because it is highly influenced by changing tool electrode polarity from positive to negative.
2. The selected range of pulse on time is decreases the wear ratio and increases the MRR and also enhances the productivity of SKD11 steel material.
3. The addition of abrasives particles in EDM oil has also put the effect on wear ratio of material. At starting addition of abrasives particles the wear ratio is increases but after more addition of abrasives it is decreases.

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