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EDMed M2 steel Surface Quality Evaluation with Cu-Ti PM Processed Electrode

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Abstract

Cutting tool steels are amongst the very hard to machine materials by conventional machining processes outstanding to their strength. This type of laborious to machine materials is comfortably being machined by a non contact action Electric Discharge Machining (EDM). In this research an effort has been made to examine and compare surface quality of EDMed M2 tool steel with Cu-Ti powder metallurgy (PM) shaped electrodes and established copper electrode. Parametric quantity like polarity, abrasive concentration, conductor type, peak current, gap voltage and duty cycle were varied. Taguchi technique was adopted to conduct a series of experimentations using L36 mixed orthogonal array. Experimental results of surface roughness (SR) were statistically assessed with analysis of variance (ANOVA). In addition, the substantial machining parametric quantity and the optimum compounding levels linked with SR were also depicted. Scanning electron microscopy (SEM) and Energy dispersion spectrum (EDS) depth psychology of the operated surface at the best parametric level setting confirmed downfall of tool electrode material on the operated surface thereby improving the surface quality.

Keywords: Surface quality; electrode; EDM; powder metallurgy; Taguchi; ANOVA; EDS;

INTRODUCTION

EDM has been widely used for material removal due to immediate heating, melting and vaporization of the materials after migration from the positive electrode towards negative electrode and vice-versa [1]. The erosion of the workpiece material in a form of debris by occurrence of series of distinct electric discharge between the electrodes broke by a constant flow of dielectric fluid [2]. The advanced EDMing operated round the clock for machining very hard alloys in all manufacturing sectors with best performance and the efficiency having control monitoring systems for stability of the process to improve by better throwing out debris from machining gap. A rotational external magnetic field was introduced to make a new hybrid technique for EDMing of hard material parts [4]. To improve the microhardness and other surface characteristics the composite electrodes manufactured through powder metallurgy process with the aim of inducing manganese, carbon, Ti and Nb oxides into the machined surface as a the recast layer with a SR of 1 μm, for oral implants in biocompatible materials [5-6]. In hybrid machining process a small-amplitude vibrations of specific frequency are applied to the tool or work- piece for machining improvement [7]. Surface characteristics are degraded when water is considered as the dielectric fluid. SR is lowered and the addition of surfactant to dielectric fluid improved material removal rate and SR [8]. Plasma treatment is also useful method for altering the metallic and non-metallic surfaces of tool steel [9]. With the addition of abrasive powder particles in dielectric fluid modifies to achieve a better surface quality in prominent machined areas [10]. NiTi, Al & TiC based alloys with controlled microstructures are having various range of applications to fabricate net shape geometries at elevated temperatures, low thermal conductivity and resistance to corrosion [11-13]. For selection of abrasive powder material properties and their possible correlation plays an important role in PMEDM utmost significance [14]. The influence of different tool electrode materials such as titanium, copper, chromium, brass and graphite and various process input parameters on EDMed work piece material white layer, surface cracks, and surface roughness (SR) predominantly influence surface integrity [15]. The compaction for low die wear, vacuum sintering, less power consumption and mechanical behavior with high production rate in M2 high speed steel surface modification using powder-mixed electrical discharge machining (PMEDM) process. The workpiece material were examined by X-ray diffraction (XRD) followed by scanning electron microscope (SEM) for surface integrity and material deposition [17]. Therefore, from the literature it is noticed that Taguchi technique and ANOVA is very useful to optimize the process parametric quantity and there is a possibility of improving the surface quality after EDMing on M2 steel with Cu-Ti powder metallurgy (PM) shaped electrodes.

MATERIALS AND METHODS

The Taguchi technique uses particular designed mixed orthogonal array (OA) depicting lesser experiment count and signal-to-noise (S/N) ratio for experimental data quantification. Table 1 laid the parameters with levels picked up for the present experimental effort. All other parameters were kept ceaseless. Experimentations were performed as per L36 (2^1 x 3^6) Taguchi design of mixed orthogonal array, on Electronica make (S50) SMART ZNC EDM.

Based upon the desirability lower-the-better criterion is picked up for SR within the 17 version of Minitab statistical software. Average arithmetic roughness Ra was employed to assess the quality of the machine surface quantitatively. The average values of SR (Ra value) were measured by digital roughness tester, Surftest SJ-401 (MITUTOYO make) and are shown in Table 2. All surface roughness value was found by averaging three measures at various perspectives of work piece surface for each experimental condition and constant depth of cut.

RESULTS AND DISCUSSION

The main effect plots of S/N ratios for SR was found using Minitab 17 statically software (Fig. 1). A plot having a steeper slope along with longer line means significant impact of that factor on the output parameter. Data was analyzed using ANOVA and to judgement of the amount of significance of the input parameters on SR (Table 3).

From ANOVA (Table 3) and main effect plots, it was observed that polarity, electrode type, peak current and duty cycle are the most influencing factors for SR.

It is clear from Fig. 1 that A2-B2-C3-D1-E2-F1 is the best parametric combination for minimum SR obtained by minimizing the SN ratio. Minimal SR assess is obtained at reverse polarity with CuTi1 (PM) electrode at 4 amperes current and maximum gap voltage. At lower current smaller craters are formed on M2 tool steel surface thereby decreasing SR. The available energy per spark during discharge is enough for breaking the PM electrode binding energy. Owing to this separation of titanium particles from the electrode occur and within no time get deposited on the surface with in the machining zone during cyclic discharge cycle causing betterment of surface quality (SR).

SEM and EDS analysis of the surface obtained at best parametric setting was done using Cu and CuTi1 (PM) electrode SEM is shown in Fig. 2 (a) and 2 (b) and EDS analysis in Fig. 3 (a) and (b). This affirms the downfall of titanium on the operated surface as evident from the EDS analysis.

CONCLUSIONS

The present data-based study showed betterment in outcome characters being operated M2 tool steel. Within the experimentation array, the most beneficial parameter preferred as SR is reverse polarity, CuTi1 (PM) tool, minimum current value, average duty cycle, maximum gap voltage (A2-B2-C3-D1-E2-F1) as per Fig 1. It was further remarked that surface quality of the worked surface has improved as evident from the SEM and EDS analysis done at best parametric level settings. Detachment of titanium particles from the CuTi1 (PM) electrode and subsequent deposit of the same on the operatedM2 work surface has occurred, which caused betterment of surface quality.

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Table 1: Levels of Machining Parameters

Factor Identification	Machining Parameters (units)	Levels and their values		
		1st Level	2nd Level	3rd Level
A	Polarity	Straight (+)	Reverse (-)	
B	Electrode	Cu	Cu-Ti1 PM Electrode	Cu-Ti1 PM Electrode
C	Concentration of Al abrasive (g/l)	0	3	6
D	Peak Current (A)	4	7	10
E	Gap Voltage (V)	40	50	60
F	Duty cycle	0.7	0.8	0.9

Table 2: Observational Layout of Mixed Orthogonal Array L36 (2^1 x 3^6) and results Ra

Expt No.	Polarity (A)	Electrode Type (B)	Concentration of Al Abrasive (C)	Current (D)	Voltage (E)	Duty Cycle (F)	Surface Roughness Ra
1	-ve	Cu	0	4	40	0.7	0.15
2	-ve	CuTi1	3	7	50	0.8	1.71
3	-ve	CuTi2	6	10	60	0.9	0.55
4	-ve	Cu	0	4	40	0.8	0.51
5	-ve	CuTi1	3	7	50	0.9	0.6
6	-ve	CuTi2	6	10	60	0.7	2.16
7	-ve	Cu	0	7	60	0.7	0.16
8	-ve	CuTi1	3	10	40	0.8	2.96
9	-ve	CuTi2	6	4	50	0.9	0.78
10	-ve	Cu	0	10	50	0.7	0.11
11	-ve	CuTi1	3	4	60	0.8	0.79
12	-ve	CuTi2	6	7	40	0.9	2.66
13	-ve	Cu	3	10	40	0.9	0.92
14	-ve	CuTi1	6	4	50	0.7	1.75
15	-ve	CuTi2	0	7	60	0.8	2.21
16	-ve	Cu	3	10	50	0.7	0.35
17	-ve	CuTi1	6	4	60	0.8	0.06
18	-ve	CuTi2	0	7	40	0.9	2.13
19	+ve	Cu	3	4	60	0.9	0.11
20	+ve	CuTi1	6	7	40	0.7	0.59
21	+ve	CuTi2	0	10	50	0.8	1.24
22	+ve	Cu	3	7	60	0.9	1.36
23	+ve	CuTi1	6	10	40	0.7	1.91
24	+ve	CuTi2	0	4	50	0.8	0.27
25	+ve	Cu	6	7	40	0.8	1.19
26	+ve	CuTi1	0	10	50	0.9	1.59
27	+ve	CuTi2	3	4	60	0.7	0.09
28	+ve	Cu	6	7	50	0.8	0.11
29	+ve	CuTi1	0	10	60	0.9	1.7
30	+ve	CuTi2	3	4	40	0.7	0.66
31	+ve	Cu	6	10	60	0.8	0.94
32	+ve	CuTi1	0	4	40	0.9	2.56
33	+ve	CuTi2	3	7	50	0.7	0.51
34	+ve	Cu	6	4	50	0.9	0.15
35	+ve	CuTi1	0	7	60	0.7	0.08
36	+ve	CuTi2	3	10	40	0.8	0.75

Table 3. ANOVA for Signal to Noise ratio for SR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	68.29	41.47	41.471	7.64	0.051
B	2	108.48	142.95	71.476	13.18	0.017
C	2	366.95	366.95	183.475	33.82	0.003
D	2	808.39	117.61	58.807	10.84	0.024
E	2	364.98	371.48	185.742	34.24	0.003
F	2	183.46	258.71	129.354	23.85	0.006
AXC	2	241.67	59.55	29.774	5.49	0.071
BXC	4	72.68	158.55	39.637	7.31	0.040
CXD	4	418.11	451.71	112.927	20.82	0.006
CXE	4	247.60	235.74	58.936	10.86	0.020
CXF	4	113.01	113.01	28.253	5.21	0.069
Residual Error	4	21.70	21.70	5.425		
Total	33	3015.34				

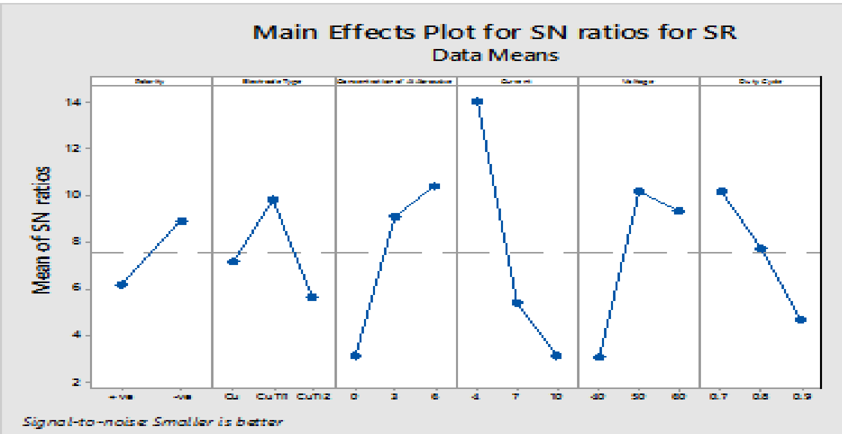
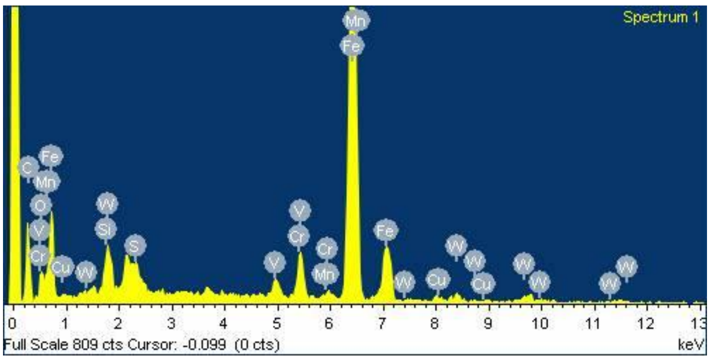
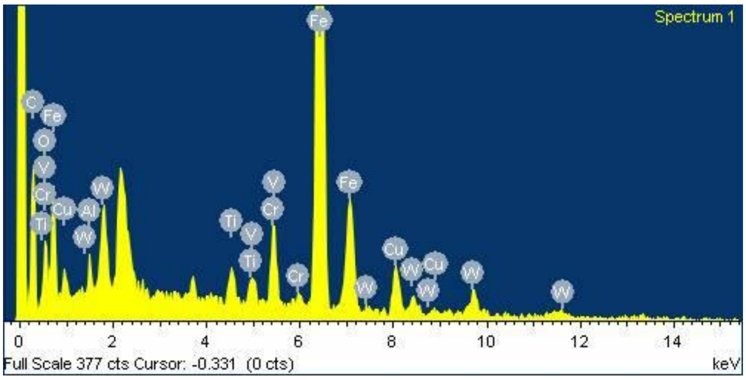


Fig. 1: Main effects plots for SN ratios for SR

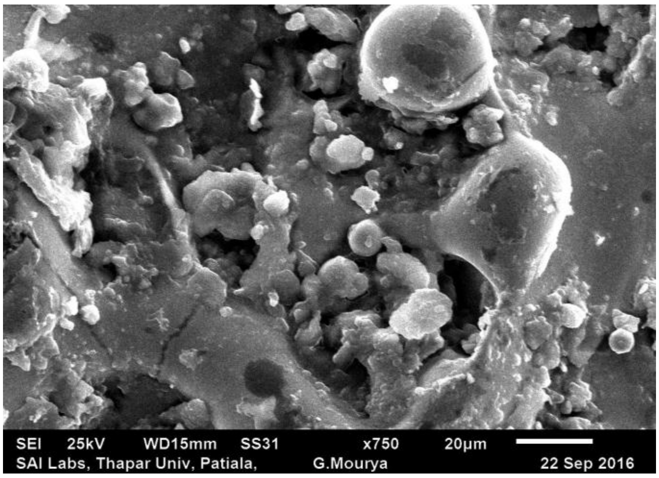


(a)

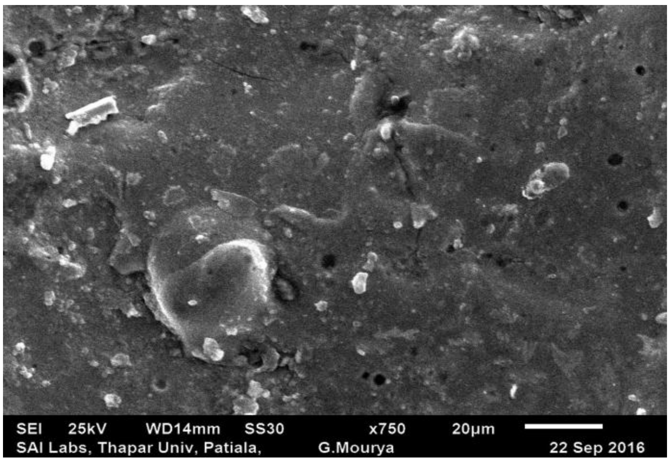


(b)

Fig. 2 EDS of specimen surface machined with: (a) Cu (b) CuTi1 electrodes



(a)



(b)

Fig.3 SEM of the specimen surface machined with: (a) Cu (b) CuTi1, electrodes

REFERENCES

[1] Assarzadeh, S., and Ghoreishi, M., 2015, “Electro-thermal-based finite element simulation and experimental validation of material removal in static gap single- machining process,” Proc IMechE Part B: J Engineering Manufacture, pp. 1-20.

[2] Raj, S., and Kumar, K., 2015, “Optimization and Prediction of Material Removing Rate in Die Sinking Electro Discharge Machining of EN45 Steel Tool,” Materials Today: Proceedings, vol. 2, no. 4–5, pp. 2346–2352.

[3] Banh, T., Nguyen, H., and Ngo, C., 2017, “Characteristics optimization of powder mixed electric discharge machining using titanium powder for die steel materials”, Proc IMechE Part E: J Engineering Manufacture, pp. 1–18.

[4] Unses, E., and Cogun, C., 2015, “Improvement of Electric Discharge Machining (EDM) Performance of Ti-6Al-4V Alloy with Added Graphite Powder to Dielectric,” Journal of Mechanical Engineering, vol. 61, no. 6, pp. 409–418.

[5] Gohil, V., and Puri, Y.M., 2016, “Statistical analysis of material removal rate and surface roughness in electrical discharge turning of titanium alloy,” Proc IMechE Part B: J Engineering Manufacture, pp. 1–12.

[6] Bobbili R., Madhu, V., and Gogia, A. K., 2015, “Engineering Science and Technology , an International Journal Multi response optimization of wire-EDM process parameters of ballistic grade aluminium alloy,” Engineering Science and Technology, an International Journal, vol. 18, no. 4, pp. 720–726.

[7] Khatri, B. C., Rathod, P., and Valaki, J. B., 2015, “Ultrasonic vibration–assisted electric discharge machining : A research review,” Proc IMechE Part B: J Engineering Manufacture, pp. 1–12.

[8] Kolli, M., and Kumar, A., 2015, “Surfactant and graphite powder–assisted electrical discharge machining of titanium alloy,” Proc IMechE Part B: J Engineering Manufacture, pp. 1–17.

[9] Meena, V. K., Azad, M. S., Singh, S., and Singh N., 2016, “Micro-EDM multiple parameter optimization for Cp titanium,” The International Journal of Advanced Manufacturing Technology.

[10] Peças, P., and Henriques, E., 2008, “Effect of the powder concentration and dielectric flow in the surface morphology in electrical discharge machining with powder-mixed dielectric (PMD-EDM),” Int. J. Adv. Manuf. Technol, vol. 37, pp. 1120–1132.

[11] Rao, M. S., and Venkaiah, N., 2016, “Experimental investigations on surface integrity issues of Inconel-690 during wire-cut electrical discharge machining

process," Proc IMechE Part B: J Engineering Manufacture, pp. 1–11.

[12] Sharma, N., Raj, T., and Jangra, K.K., 2015, "Parameter optimization and experimental study on wire electrical discharge machining of porous Ni 40 Ti 60 alloy," Proc IMechE Part B:J Engineering Manufacture, pp. 1–15.

[13] Kolli, M., and Kumar, A., 2015, "Surfactant and graphite powder – assisted electrical discharge machining of titanium alloy," Proc IMechE Part B: J Engineering Manufacture, pp. 1–17.

[14] Gaikwad, V., and Jatti V. S., 2016, "Optimization of material removal rate during electrical discharge machining of cryo-treated NiTi alloys using Taguchi's method," Journal of King Saud University - Engineering Sciences, pp. 0–6.

[15] Kumar, S., Singh, R., Batish, A., and Singh, T.P., 2015, "Modeling the tool wear rate in powder mixed electro-discharge machining of titanium alloys using dimensional analysis of cryogenically treated electrodes and workpiece," Proc IMechE Part E:J Engineering Manufacture, pp. 1–12.

[16] Talla, G., and Gangopadhyay, S., 2016, "Effect of impregnated powder materials on surface integrity aspects of Inconel 625 during electrical discharge machining," Proc IMechE Part B: J Engineering Manufacture, pp. 1–14.

[17] Yildiz, Y., and Rajurkar, K.P., 2015, "Correlation of surface roughness and recast layer thickness in electrical discharge machining," Proc IMechE Part E: J Process Mechanical Engineering, pp. 1–11.