

To Study the Effect of Polarity and Current during Electric Discharge Machining of Inconel 718 with CuW Powder Metallurgy Electrode

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Abstract

Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes which have been widely used to produce dies, molds and finishing parts for aerospace and automotive industry. In recent years, powder metallurgy processed electrodes have found wide application as an alternative tooling for EDM. In the present experimental study an attempt has been made to study the effect of electrode polarity and current during electrical discharge machining of Inconel 718 alloy steel with copper tungsten (PM) processed electrode. The response parameters selected for the study are material removal rate (MRR) surface roughness (SR) Ra Value, tool wear rate (TWR) and Change in Surface Roughness (SR) Ra Value of electrode before and after machining.

Keywords : Electrical discharge machining (EDM), powder metallurgy (PM), material removal rate (MRR), surface roughness and tool wear rate (TWR)

1. Introduction

Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes which have been widely used to produce dies, molds and finishing parts for aerospace and automotive industry and surgical components [1]. With the use of this excellent process one can achieve highly accurate complex shapes on a wide range of conductive and difficult-to-machine materials. Inconel 718 alloy steel is one of the most difficult-to-machine nickel based alloy and is widely used in aircraft, gas turbines, space vehicles, rocket engines, nuclear reactors, submarines, and other high-temperature applications [2]. In EDM process the material is removed through the action of an electrical discharge of short duration between the electrode (tool) and the work piece in the presence of a dielectric fluid [3].

Recently, EDM tool electrode manufacturing has become the focus of many studies in paralleling the development of EDM process and machine complexity. Tools manufacturing through powder metallurgy process is one of the alternative tooling option for EDM electrodes where the desirable properties of different materials can be combined and a large number of tool electrodes can be made from a single die and punch assembly, resulting in an overall reduction of EDM tooling cost [4].

2. Literature review

Marafona and Wykes [5] performed experimental study to optimise material removal rate (MRR) during EDM with copper-tungsten electrodes using Taguchi L18 orthogonal array and they achieved improvement of MRR for a given tool wear ratio. Shu and Tu [6] performed EDM with Cu-SiCp composite electrode made by the PM method. Tsai et al. [7] performed blending of copper powders containing resin with chromium powders to form tool electrode. The machined surface showed good corrosion resistance with fewer cracks. Moro et al. [8] applied the technology of electrical discharge coating (EDC) and reported improvement in working life of the die by three to seven times.

Beri et al. [9] performed experimentation on electric discharge machining of AISID2 steel in kerosene with copper tungsten electrode made through PM technique and conventional Cu electrode and recommended to use conventional Cu electrode for higher MRR and CuW electrode made through PM for higher surface finish. Kumar et al. [10] reported the results of experimental investigations during EDM of OHNS die steel with Inconel electrode under machining conditions favoring high electrode wear. Ashokan and Senthilkumaar [11] illustrated a new approach of selecting machining parameters during turning of Inconel 718 using the multi-objective optimization coupled with multiple attribute decision-making method. Beri et al. [12] made an attempt to correlate the usefulness of powder metallurgy (PM) electrodes in electrical discharge machining (EDM). It is found that copper tungsten PM electrode gives better multi-objective performance than conventional copper electrode. Beri et al. [13] evaluated

surface quality measured in terms of surface roughness (Ra value) during electric discharge machining using orthogonal array L36 (21X 37) based on Taguchi methodology. Experimental data was statistically analyzed using analysis of variance (ANOVA) and optimum condition was achieved for evaluation criteria. It was concluded minimum Ra is obtained with CuW2080 electrode at minimum current and negative polarity and polarity, electrode type, peak current, have significant effect on surface quality of the machined surface.

From the reviewed literature it is observed that PM electrodes are widely acceptable as an EDM electrode and they significantly contribute for machining and surface quality improvement during the electric discharge machining process. Polarity and current are significant parameter that effects the machining performance of the EDM process. Thus a need is felt to study the effect of electrode polarity and current during electrical discharge machining of Inconel 718 alloy steel with copper tungsten powder metallurgy (PM) processed electrode with a view to study their effect on selected response parameters. The response parameters selected for the study are material removal rate (MRR), surface roughness (SR) Ra value, tool wear rate (TWR) and Change in Surface Roughness (SR) Ra value of electrode before and after machining. EDM oil is used as dielectric during the experimentation.

3. Experimentation

Polarity and current are important parameters which have significant effects on the machining performance of the EDM process. The experimental parameters and their values selected for the study are tabulated in Table 1 all of the other parameters are kept constant.

3.1 Experimental procedure

Experiments were carried out on Electronica make EDM machine; model SMART ZNC (S50). Inconel 718 alloy steel was used as work piece material with EDM oil as the dielectric medium. Cylindrical powder metallurgy processed CuW (Cu20%W80%) electrode is used for the experimentation. Electrode was rubbed on a fine grade emery paper and surface roughness (Ra value in microns) was measured using Mitutoyo make surface roughness tester (SJ400). Work piece and electrode were then weighed on Citizen make digital balance with an accuracy of 1 mg to get the initial weight of work piece and electrode before machining. Then erosion was switched on for a depth of cut of 0.65mm and time taken to complete the operation was noted and the work piece and electrode were then weighed again to get the final weight after machining. The surface roughness of the work piece and electrode were then was also measure again after each machining operation.

Table 1. Machining Parameters

Parameter (Symbol)	Units	Level 1	Level 2	Level 3
Electrode Type (B)	-	Copper Tungsten (Cu 20%W 80%)		(constant Parameter)
Polarity (A)	-	+ve	-ve	
Current (C)	(Amps.)	4.0	8.0	12.0
Pulse on Time (D)	(μ sec)	50		(constant Parameter)
Duty Cycle (E)	-	0.7		(constant Parameter)
Gap Voltage (F)	(Volts)	40		(constant Parameter)
Retract Distance (G)	(mm)	1		(constant Parameter)
Flushing Pressure (H)	(Kg/cm ²)	0.3		(constant Parameter)

Material removal rate and tool wear rate were obtained using weight loss method and are calculated using equations 1 and 2 respectively. Experiments were performed as per Table 2. Three set of experiments were performed and the average was taken for each output parameter. The experimental results (average values) are tabulated in Table 2.

$$\text{Material removal rate (mg/min)} = \frac{\text{Work piece weight loss (mg)}}{\text{Machining time (min)}} \quad (1)$$

$$\text{Tool wear rate (mg/min)} = \frac{\text{Electrode weight loss (mg)}}{\text{Machining time (min)}} \quad (2)$$

Table 2. Experimental Plan and Results

Exp. No.	Polarity	Current (amps.)	Material Removal Rate (MRR) (mg/min)	Tool Wear Rate (TWR) (mg/min)	Surface Roughness (SR) (μm)	Change in SR of electrode (μm)
1	-ve	04.0	00.140	1.75	0.79	0.68
2	-ve	08.0	00.489	1.66	0.93	0.80
3	-ve	12.0	01.967	2.09	2.43	0.89
4	+ve	04.0	01.235	0.55	4.34	0.43
5	+ve	08.0	38.200	0.50	5.84	0.81
6	+ve	12.0	97.000	1.00	6.30	0.97

4. Results and Discussions

The experimental results tabulated in Table 2 were used to study the effect of input parameters on the selected output parameters.

Figure 1 shows the effect of polarity and current on MRR. From figure 1 it is clear that MRR increases with the increase in current with both +ve and -ve polarity the slope of the curve shows that MRR increases drastically with the increase in current with +ve polarity as compared to -ve polarity. With an increase in current the available spark energy during discharge increases leading to higher MRR and in positive polarity the positively charged ions are emitted from the electrodes which impinge on the work piece. Due to higher mass the momentum of these positively charged ions is greater than that of negatively charged electrons this results in more material removal from the work piece in comparison with the electrodes. Maximum MRR is obtained at 12 amps current with +ve polarity.

Figure 2 shows the effect of polarity and current on TWR. TWR decrease slightly with the increase in current for both +ve and -ve polarity and then it starts increasing. The slight decrease in TWR in the beginning may be due to the formation of carbide layers on the tool surface and less energy associated with the spark at low current. As current increases the energy associated with the spark increases and the carbide layers gets broken and the TWR increases. TWR is more with -ve polarity as compared to +ve polarity because of lower binding energy of the electrode constituent. Minimum TWR is obtained at 8 amps current with +ve polarity.

Figure 3 shows the effect of polarity and current on SR of the machined surface. SR increases with the increase in current with both +ve and -ve polarity. SR obtained with -ve polarity is drastically lower as compared with the SR obtained with +ve polarity. Lower current values gives lower SR. Increase in SR with increase in current may be attributed to the increase in energy contents of the spark. Minimum SR is obtained at 4 amps current (lower current) with -ve polarity. At lower current the available spark energy during discharge is less but is enough to break the binding energy within the constituent of the electrode this may lead to the detachment of tungsten from the electrode which may further get deposited on the work surface causing an appreciable reduction in the R_a value.

Figure 4 shows the effect of polarity and current on change in SR of electrode before and after machining. It increases with increase in current with both +ve and -ve polarity. In the beginning it is less for the +ve polarity and

more for -ve polarity i.e at 4 amps current and +ve polarity because of the formation of carbide layers at lower current values and at higher current values the carbide layers gets broken due to increases in energy content associated with the spark. Minimum value of change in SR of electrode before and after machining is obtained at 4 amps current with +ve polarity.

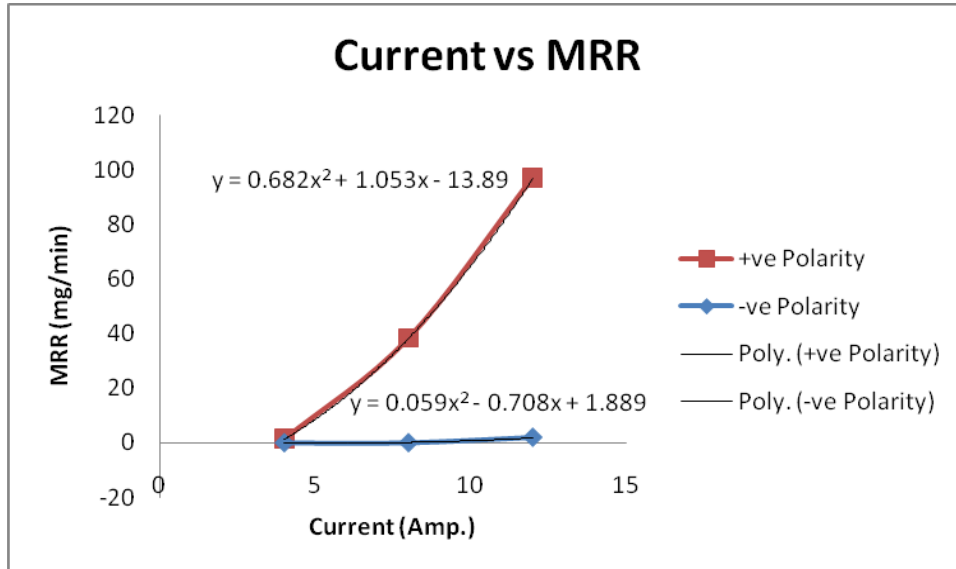


Figure 1 Effect of current on MRR

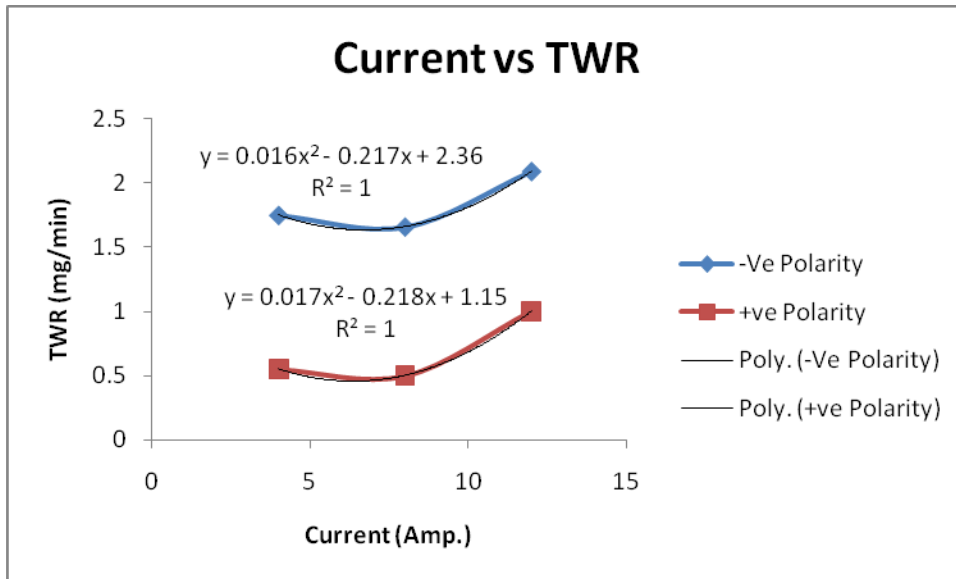


Figure 2 Effect of current on TWR

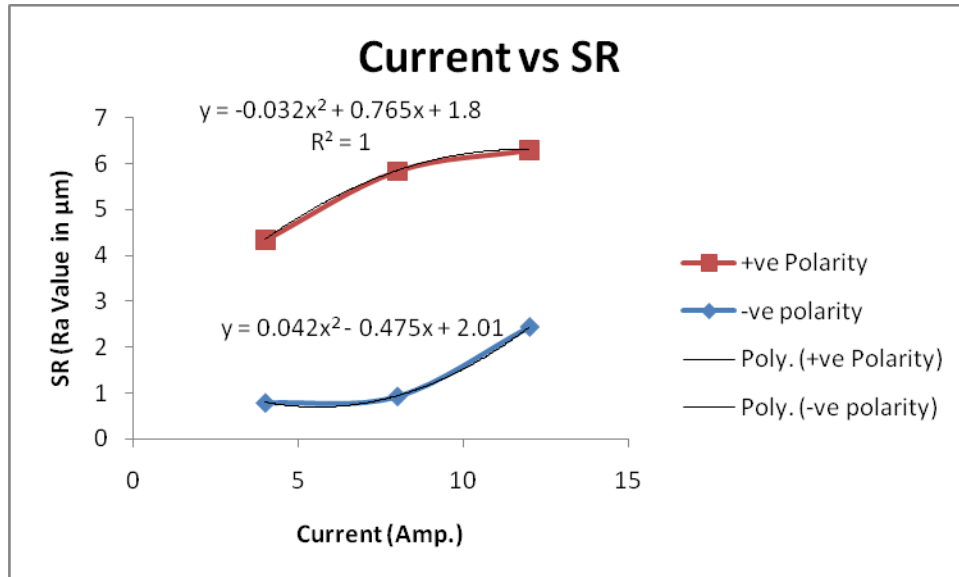


Figure 3 Effect of current on SR

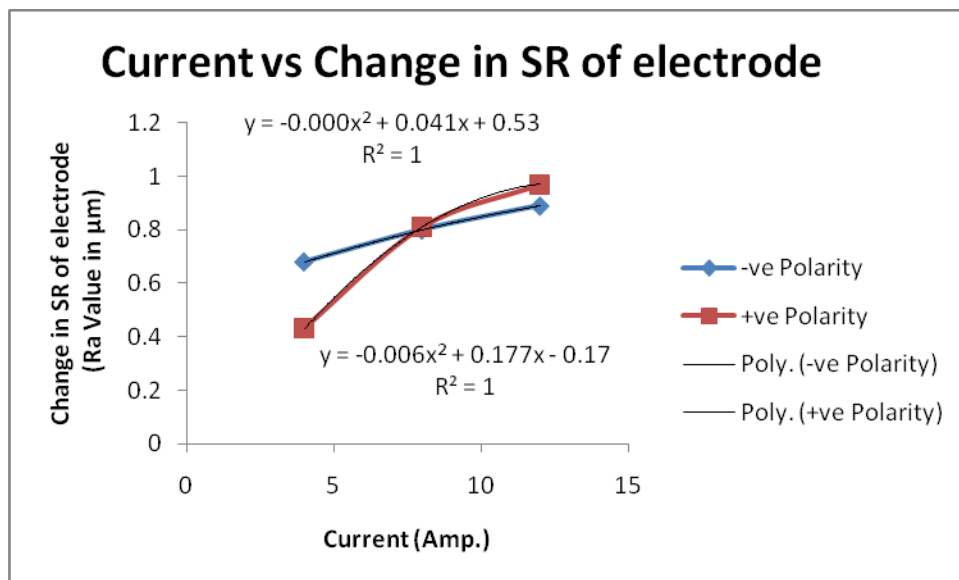


Figure 4 Effect of current on change in SR of electrode

4. Conclusions

Based on the present experimental results following conclusions can be drawn:

1. MRR increases with the increase in current with both +ve and -ve polarity and this increase is higher with +ve polarity as compared to -ve polarity. Maximum MRR is obtained at 12 amps current with +ve polarity.
2. TWR decrease slightly with the increase in current for both +ve and -ve polarity and then it starts increasing. This is due to the formation of carbide layers on the tool surface and less energy associated with

the spark at lower current and break down of the formed carbide layers at higher current values. TWR is obtained at 8 amps current with +ve polarity.

3. SR increases with the increase in current with both +ve and –ve polarity. SR obtained with –ve polarity is drastically lower as compared with the SR obtained with +ve polarity. Minimum SR is obtained at 4 amps current with -ve polarity.
4. Minimum value of change in SR of electrode before and after machining is obtained at 4 amps current with +ve polarity. It increases with increase in current with both +ve and –ve polarity.
5. It is recommended to use +ve polarity to obtain maximum MRR and Minimum TWR whereas –ve polarity is recommended for Minimum SR.

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