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Analysis of the Effect of Process parameters in Electric Discharge Machining of Inconel X750 using brass Electrode

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Abstract— Inconel X-750, a high strength, age-hardenable, Ni-base super alloy, finds wide range of applications in aerospace engineering on the basis of its excellent high-temperature and cryogenic properties. Electrical discharge machining (EDM) is a process for shaping hard metals and forming deep complex shaped holes by arc erosion in all kinds of electro-conductive materials irrespective of their hardness, shape and toughness such as Inconel X750. The objective of this paper is to study the influence of operating parameters of brass electrode on the machining characteristics such as material removal rate (MRR), Electrode wear rate (EWR) and surface roughness (Ra). In the present work, Inconel X-750 is used as a work piece for investigation using with input parameters like pulse peak current, pulse on time, gap voltage. The experiments were performed based on Box- Behnken design of experiments and influence ranking was done using the analysis of means technique.

Keywords— Box Behnken design of experiments,Inconel X-750,MRR,EWR.Surface roughess.

INTRODUCTION

Electrical discharge machining (EDM) is a unconventional machining process based on removing material from a metal by means of a series of repeated electrical discharge between the tool called electrode and the part being machined in the presence of a dielectric fluid medium .

The high strength, good corrosion resistance, excellent high-temperature and cryogenic properties and weld ability attributed by Inconel alloys find wide range applications in aerospace, automobile, nuclear reactors, gas turbines and other major industrial applications [1]. Inconel X750 is one of the most difficult-to-cut nickel based alloys. Formation of complex shapes along with reasonable speed and surface finish is very difficult by traditional machining. Electric discharge machining (EDM) is one of the most suitable non-conventional material removal processes to shape this alloy.

The selection of machining parameters is one of the most important aspects t take into consideration in the die sinking electric machining of nickel based alloys such as Inconel X -750 as these conditions are the ones that are to determine such important characteristics: Material removal rate, electrode wear rate, and surface roughness. In this paper, an attempt is made to study the influence of the input parameters of pulse peak current, pulse on time and gap voltage while machining the Inconel X-750 by using brass as a electrode material.

EXPERIMENTAL METHOD

A. Material Used- Inconel X-750

Inconel X750 has been selected as the work piece for this experiment, which means that it has a composition of nickel of 72%. Inconel alloy X-750 is used extensively in rocket-engine thrust chambers. Airframe applications include thrust reversers and hot-air ducting systems. Large pressure vessels are formed from Inconel alloy X-750. In gas turbines, it is used for rotor blades and wheels, bolts, and other structural members. Other applications are heat-treating fixtures, forming tools; extrusion dies, and test machine grips. For springs and fasteners, INCONEL alloy X-750 is used from sub-zero to 1200°F and table 1 shows the work piece material properties.

TABLE I : Work piece material properties

Property	Metric
Density	8.28 g/cm3
Melting point	1430°C
Yield strength	916 Mpa
Tensile Strength	1296 Mpa
Hardness	336 HB

B. Tool electrode material- Brass

In this experiment, brass is used as a tool electrode material. The tool tip diameter has been taken as17 mm. The length of the electrode has been kept at 70 mm so that maximum transfer of heat is possible away from the tool tip. All these electrodes were machined to its dimension with EMCO CNC machines to maintain the accuracy. Figure 1 shows the electrode tool.

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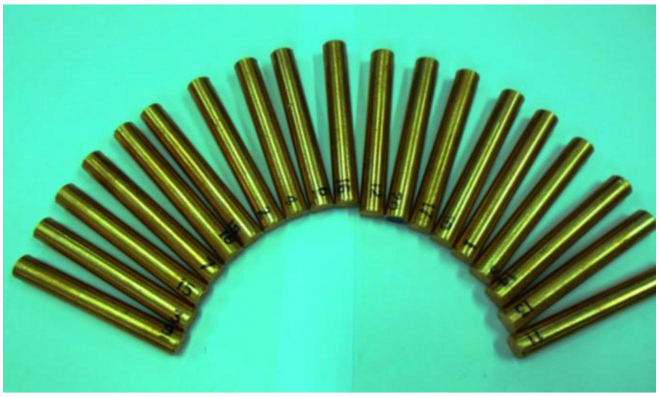

Figure. 1 Brass Electrodes

C. Parameters and its range:

In total three experimental parameters were considered. All are electrical parameters which are pulse peak current, pulse on time, gap voltage. Table II shows the details of the parameters and its three level values. The levels of these parameters were decided based on the work done by literature [2].

TABLE II PARAMETERS WITH THEIR RANGES

Parameters	**Level 1**	**Level 2**	**Level 3**
Pulse peak current (Ip)	3	5	7
Pulse on time (Ton)	100	300	500
Gap voltage (V)	50	60	70

D. Design of experiment :

The experiments were performed using Box- Behnken design. The pilot experimentation was done for the selected of process parameters levels during machining. Total 15 experiments were conducted as per the design [4]. Table III presents the experimental matrix.

TABLE III DESIGN OF EXPERIMENTS MATRIX

Experiment Number	Pulse peak current (Ip) (Amps)	Pulse on time (Ton) (μs)	Gap voltage (Vg) (V)
1	5	100	70
2	7	300	50
3	5	300	60
4	5	500	70
5	7	300	70
6	5	300	60
7	5	500	50
8	7	500	60
9	5	300	60
10	3	500	60
11	3	300	50
12	3	300	70
13	7	100	60
14	3	100	60
15	5	100	50

The experiments were conducted in a Smart ZNC Electric discharge machine manufactured by Electronica Machine tools of India. In all experiments, kerosene oil was used as dielectric fluid medium. The dielectric side flushing pressure is maintained as 0.6MPa. The work piece top and bottom surfaces were ground to a surface finish using a surface grinding machine before conducting the experiments. The initial weights of the work piece and electrode were weighed using a electronic balance. A special fixture was used to hold the work.

RESPONSE MEASUREMENTS

A. Material removal rate measurement :

The material removal rate has been defined as the ratio of the wear weight of work piece to machining time [5], Material removal rate (mg/ min) = wear weight of work piece time of machining

$$MRR(mg/\ min)= \frac{WWBM - WWAM}{T} \quad (1)$$

Where WWBM is weight of work piece before machining, WWAM is weight of work piece after machining and T is the total time during which machining was performed. After completing of each machining process, the work piece was blown by compressed air using air gun to ensure no debris and dielectrics were present. A precise balance was used to measure the weight of the work piece after machining.

B. Electrode wear rate measurement :

The concept of electrode wear rate can be defined in many ways. The present study defines the ratio of the wear weight of electrode to the wear weight of work piece after machining .

$$EWR\ (\%) = \frac{WEBM - WEAM}{WWBM - WWAM} \times 100 \quad (2)$$

Where WEBM is weight of electrode before machining, WEAM is weight of electrode after machining, WWBM is weight of work piece before machining, and WWAM is weight of work piece after machining.

C. Surface roughness measurement :

The surface finish after machining was measured using Mitutoyo surftest SJ-201P.A traverse length of 3 mm with a cut-off evaluation length of 2 mm was used. The centre line average value of the surface roughness (Ra) is the most widely used surface roughness parameter in industry was selected in this study.

RESULTS AND DISCUSSION

A. Material removal rate, MRR analysis:

The experiment results were analyzed using Minitab software version 14. Taguchi analysis based on analysis of means (ANOM) and analysis of variance (ANOVA) was used to find out the influence over the machining responses. Figure 2 to 4 shows the main effects plots for MRR.

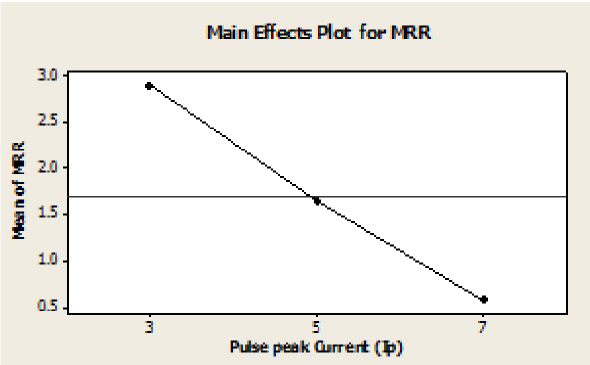

Figure. 2 : Graph of material removal rate verses pulse peak current.

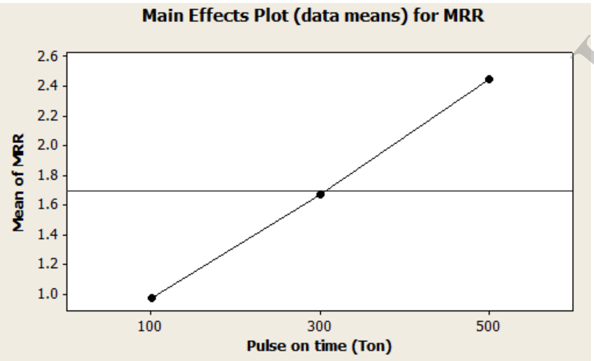

Figure. 3 : Graph of material removal rate verses Pulse on time.

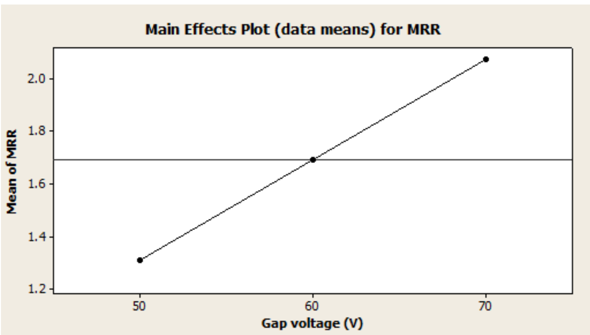

Figure. 4 : Graph of material removal rate verses gap voltage

Figure 5 represents a three dimensional surface plot of the data for pulse peak current and gap voltage with hold values of pulse on time (Ton) 300 µs. It is observed that the effect of the interaction between pulse peak current (Ip) and gap voltage (V) in the data is twist planes that there is curvature in the response function to the material removal rate.

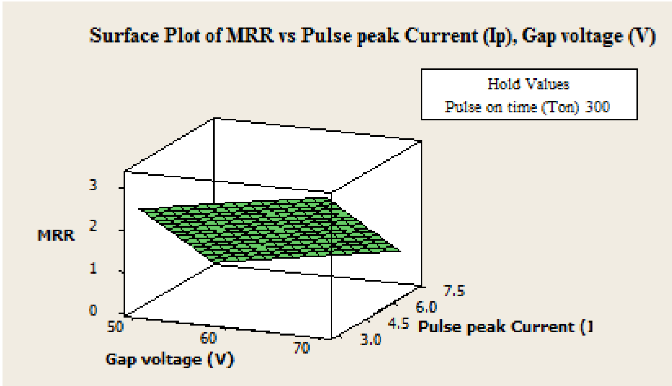

Figure. 5 : 3D surface plots of the main effects of the pulse peak current and gap voltage.

B. Electrode wear rate, EWR analysis:

Pulse on time is the single most important factor that has direct relationship with EWR as shown in fig 6. Where as other fators are showing similar tendencies as in the case of MRR. Pulse on time is again proving in significant.

Fig 7 shows the influence of pulse on time with EWR. As the pulse on time increases, the value of EWR decreases. The single most influential factor here is pulse current which is followed at distance by tool cross sectional area and pulse on time.

Figure 9 represents a three dimensional surface plot of the data for pulse peak current and gap voltage with hold values of pulse on time (Ton) 300 µs. It is observed that the effect of the interaction between pulse peak current (Ip) and gap voltage (V) in the data is twist planes that there is curvature in the response function to the electrode wear rate.

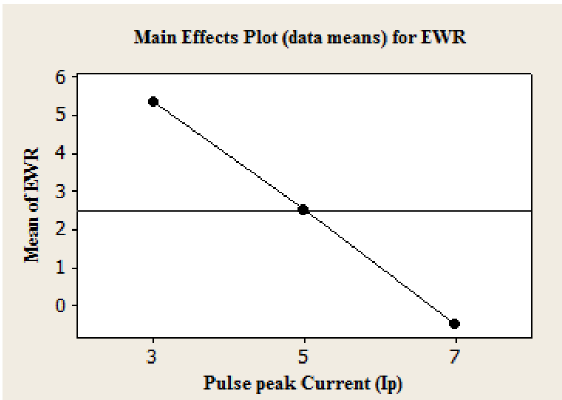

Figure. 6 : Graph of electrode wear rate verses pulse peak current

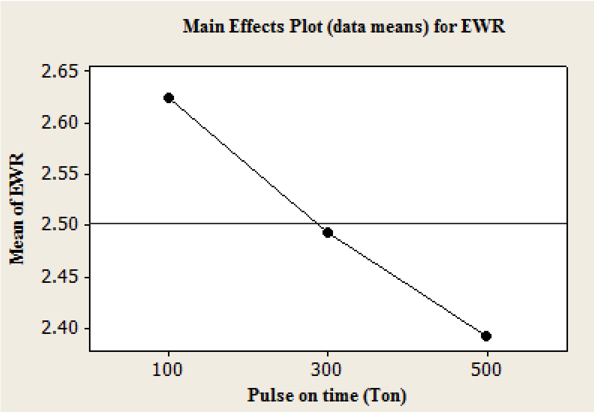

Figure. 7 : Graph of electrode wear rate verses Pulse on time.

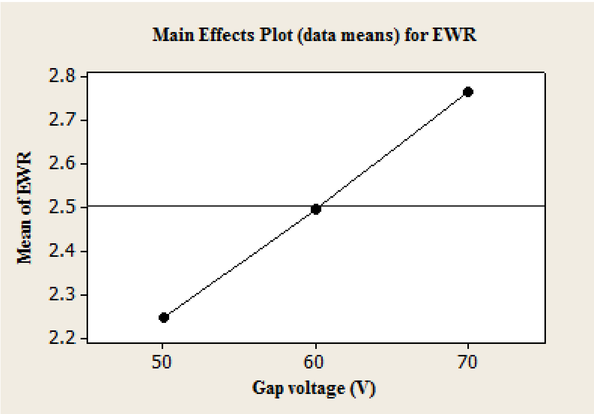

Figure. 8 : Graph of electrode wear rate verses gap voltage

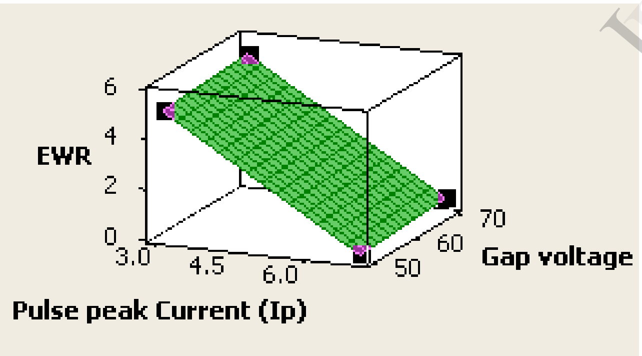

Figure. 9 : 3D surface plots of the main effects of the pulse peak current and gap voltage.

A. Surface roughness, Ra analysis:

As shown in figure 10, when pulse peak current increases from 3amps to 5amps, the surface roughness increases the surface roughness value also increases. After that, it increases dramatically till 7amps. The roughness of the machined surface increases as the energy of the pulse increases. In other words, at higher pulse energy the metal removal rate increases and the surface will be rough [7]. Gap voltage shows the opposite trend to the pulse peak current in figure 12. From 60v to 70v, the surface roughness reduces very fast.

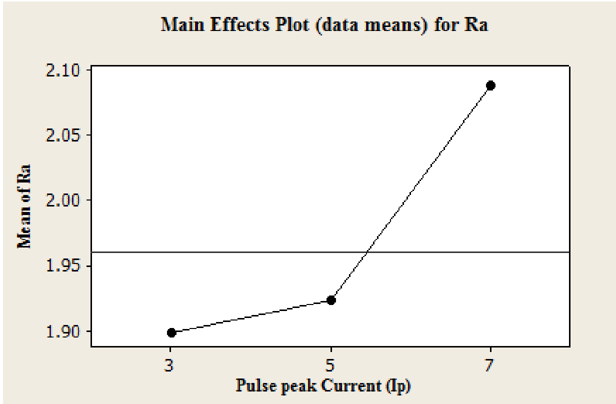

Figure. 10 : Graph of surface roughness verses pulse peak current

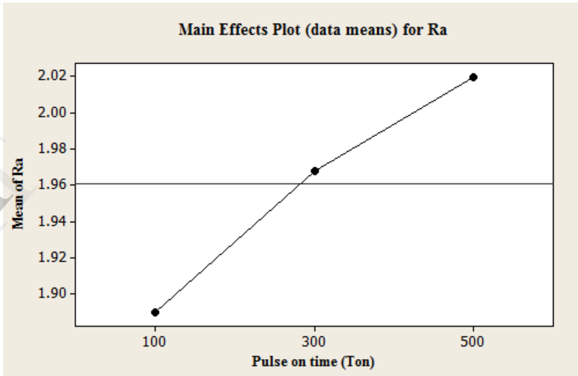

Figure. 11 : Graph of surface roughness verses Pulse on time.

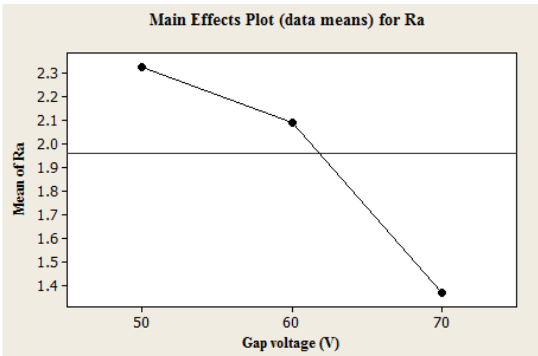

Figure. 12 : Graph of surface roughness verses gap voltage

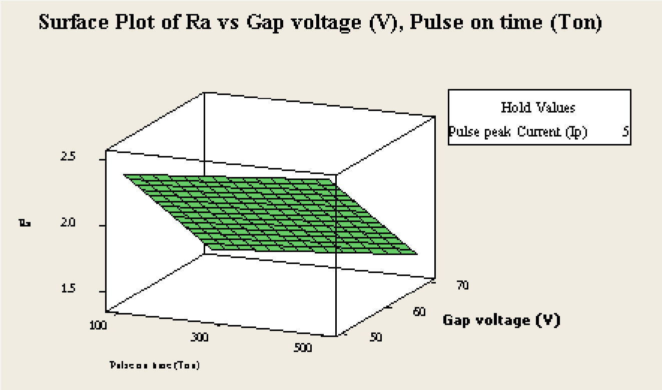

Figure. 13 : 3D surface plots of the main effects of the pulse peak current and gap voltage.

CONCLUSIONS:

The analysis of the experimental observations highlights that the metal removal rate, electrode wear rate, and surface roughness in electrical discharge machining are greatly influenced by the various dominant process parameters considered in the present study. In fact, the metal removal rate increases with an increase of pulse on time, and relatively with gap voltage. Metal removal rate decreases with increase of pulse peak current. Electrode wear rate decreases with an increase of both pulse on time and peak current and decreases with increase of pulse peak current. Finally, the surface roughness increases with the increase of pulse on time, peak current and decreases with increase of gap voltage.

In order to obtain high value of metal removal rate for brass, with in the parameter range in this work, one should use, higher value of gap voltage. In the case of the electrode wear rate, it is found that most influenced factor were gap voltage and then pulse peak current. In the case of surface roughness, the most influential factors were gap voltage followed by the pulse current and pulse on time.

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