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ELECTRICAL DISCHARGE MACHINING OF INCONEL X-750 USING ONE FACTOR APPROACH

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ABSTRACT

Inconel X-750, a precipitation hardenable nickel-chromium alloy used especially in rotor blades and wheels, rocket engine thrust chambers, gas turbines, nuclear reactors and large pressure vessels due to its excellent properties like corrosion, oxidation, creep rupture and high strength at temperature of 1300^{0}F. The rapid work hardening, poor thermal conductivity of Inconel made very difficult to machine using traditional techniques. Machining with traditional machinery to hard materials causes effective tool wear. Electrical discharge machining (EDM) is having better capability for cutting intricate cavities and complex shapes with extraordinary precision for these kind of hard materials. The paper presents, an experimental study of parameters optimization using one factor approach. The considered input parameters like pulse peak current, pulse on time and type of electrode. The performance parameters like Material Removal Rate (MRR), and Surface Roughness (Ra). It was observed that MRR increases with increasing peak current and pulse-on-time up to the finest points and drops significantly thereafter

KEYWORDS: Inconel X-750,one factor approach,EDM oil,Copper electrode.

INTRODUCTION

A Nickel -chromium alloy X-750 is a precipitation hardenable material extensively used in aircraft structures, rocket engine thrust chambers, gas turbines, nuclear reactors due to its excellent properties like high mechanical strength and high temperature resistance. Because of rapid work hardening, poor thermal conductivity, it is very difficult to machine using traditional techniques. For Inconel alloy EDM is preferred as best material removal process due to its advantages like reduced machining stresses lesser work hardening effects and less metallurgical damage. In this process Copper was used as an electrode because of its excellent thermal properties and high thermal conductivity of copper component and low thermal expansion. EDM is an unconventional machining process used to produce dies, moulds, ceramics, etc. Hard materials which are difficult- to-cut materials like nickel, titanium, hastelloy, kovar can be effectively machined using EDM. The materials which are electrically conductive can be machined using EDM as well. The spark eroding process can cut intricate (complex) contours or cavities in hardened steel without the need for heat treatment to soften and re-harden them. In this Machining, material is removed with a number of electrical discharges between tool (electrode) and the work piece which is immersed in the dielectric fluid. The selection of process parameters plays an important role in machining. The effective selection of parameters gives the better results of machining. It has been noticed that most of the authors focused on reducing the surface roughness and increasing the material removal rate using different materials like copper, graphite, brass. However, very few authors have been experimental investigated on Inconel X-750 with Cu electrode.

LITERATURE

E.Uhlmann et al. investigated regarding the development and optimization of EDM for machining MAR-M247 a nickel based alloy using graphite electrodes of three dissimilar dimensions. They reached a total machining time reduction of more than 50 % in comparison to the technology currently employed in the industry.[1]

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P. Balasubramanian et al. identified the optimum parameters of Electrical discharge machining of EN8 and D3 steel materials using cast copper and sintered powder metallurgy copper electrodes. They noticed that, for EN-8 material mean value of MRR is high and low TWR value for Cast electrode compared with Sintered electrode. Moreover the SR value is slightly less for Sintered electrode compared with Cast electrode. RSM is used to analyses the parameters and significant parameters are obtained using ANOVA [2]. Payal et al. investigated the machining of EN31 tool steel with three different electrodes like copper, graphite and brass. Experimental results concluded that at high levels of current intensity, the copper electrodes reached higher MRR compared to other two electrodes [3]. Kupan et al. Investigated the EDM characteristics in deep hole drilling of Inconel 718. The input parameters are peak current, pulse on time, electrode rotation and duty factor as the considered performance parameters are MRR, SR, TWR and through hole. They mentioned that higher MRR and lower SR obtained at lower conditions of tool electrode [4]. Sandhu et al. observed that the graphite electrodes with negative polarity gives higher MRR and low tool wear rate [5].

Agarwal et al. utilized RSM method to create empirical models for anticipating the cutting rate and surface hardness while machining of Inconel 718 [6]. Muthu Kumar et al. studied response surface methodology for prediction of ROC in electrical discharge machining of Inconel 800 with copper electrode. They concluded that ANOVA results show that current and voltage gives the significant parameters, while pulse-on time and pulse-off time are non-significant parameters by considering ROC response [7]. Syed asghar Husain rizvi et al. attempted the surface integrity of EDM process with a copper-tungsten electrode. They observed that at a constant pulse on duration MRR increases with increase in peak current .The surface crack density increases with a low pulse current and the pulse-on duration effects the severity of crack opening [8]. M Sreenivasa Rao et al. has done experimental investigations on surface integrity issues of Inconel-690 with wire-cut electrical discharge machining process. They observed that the hardness of machined surface is less compared to the hardness of base metal due to movement of Zn and Cu from wire electrode to machining surface [9].

EXPERIMENTAL PROCEDURE

Selection of tool and work-piece materials

The experiments are done with the material INCONEL X-750.The dimension of the material 100×42×10m.An electrode made of electrolytic copper of diameter 16mm is used because it is one of the most common electrode materials in EDM having high melting temperature.

The experiments are carried out on a die sinking EDM machine of model EMS-5535 of axis specification X-750 Y-200 Z-200.The machine conditions are of max peak current is 50A, pulse on 3000µs and Gap voltage of max 30. A dielectric fluid of EDM-30 oil is used. The material was clamped on the vice and tool is fixed to the tool holder. The tool and work piece are connected with mono polarity. The tool and work piece are submerged in the EDM 30 oil at a flushing pressure of 0.5kg/cm^2. Each experiment was conducted for 15 minutes. The weight of the work piece and electrode are measured before and after experiments using an electronically digital weighing balance having a maximum capacity of 300grams with a resolution of 0.001grams was used. The weight loss is calculated to find the MRR and TWR as follows

$$MRR = \frac{\text{Workpiece weight loss}}{\text{Workpiece density*machining time}}$$

$$TWR = \frac{\text{Tool weight loss}}{\text{Tool density*machining time}}$$

The density of the material Inconel X750 is 8.28g/cm^3.
In this experimental study considered the input process parameters such as pulse current (A), Pulse-on time, duty factor and gap voltage are used to measure the performance parameters like Material removal rate(MRR), electrode wear rate(EWR), surface roughness(Ra).

RESULTS AND DISCUSSIONS

MRR in EDM is an important factor to estimate the time of finishing the workpiece.In this paper the effect of controlling parameters such as peak current, pulse on-time on material removal rate, surface roughness and depth of cut are presented. In this trials, current was varied from 10A to 50A and all other input parameters Ton=2000, Duty factor=11, Gap voltage=25 are kept constant.

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Effect of peak current

Figure 1(a) displays the relationship between MRR and peak current. It can be shown from the figure that the MRR increases with the increase in current. Increasing the peak current at a constant frequency increases the energy of the pulse and results in higher MRR. At lower peak current values, low intensity is produced that effect a small amount of material is heated and melted, results in Lower MRR.

Table 1 Results of MRR, R_a and depth of cut varying the peak current

S.no	Current(A)	MRR(mm^3/min)	Ra(µm)	Depth of cut(mm)
1	10	6.50	5	0.36
2	20	8.94	5.2	0.54
3	30	8.94	5.5	0.58
4	40	8.13	5.6	0.67
5	50	12	5.4	0.65

Table 2 Results of MRR, R_a and depth of cut varying the Pulse-on time

S.no	Pulse-on time	MRR(mm^3/min)	Ra(µm)	Depth of cut(mm)
1	100	19.51	3.5	1.4
2	500	22.76	3.8	1.58
3	1000	19.51	4	1.33
4	1500	13.82	5.6	0.94
5	2000	12	5.4	0.65

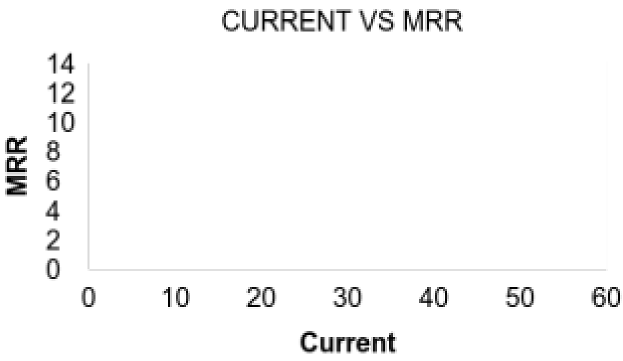

Fig 1(a):Current vs MRR

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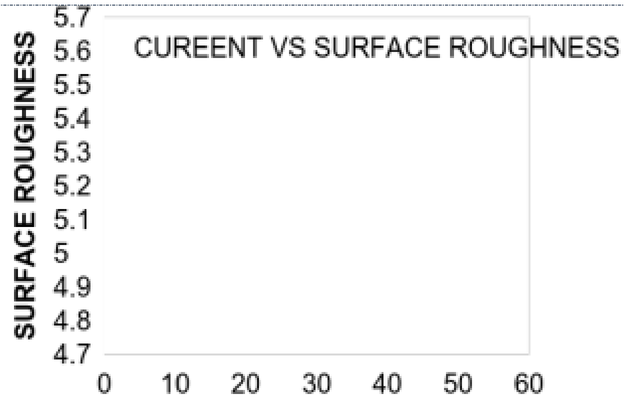

Fig 1(b):Current vs Surface roughness

The Figure 1(b) indicated that when peak current is increased surface roughness is increases due to more amount of material is removed surface is generated deeper crater and wider structure.

The Figure 1(c) shows that depth of cut increases with increase in peak current.

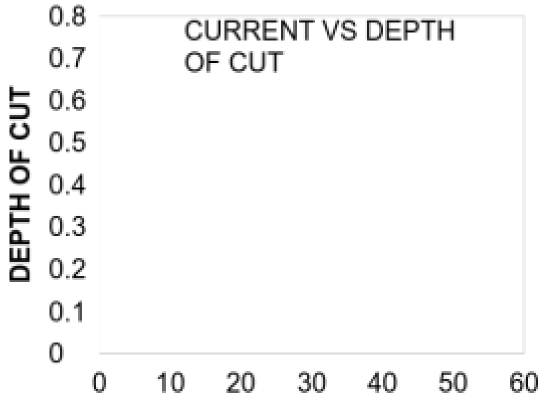

Fig 1(c):Current vs Depth of cut

Effect of pulse on-time

The relationship between the MRR and pulse on-time is shown in Fig.2(a) .The Figure reveals that pulse-on time is increases MRR is increased at initial conditions. Furthermore pulse-on time is increased decreasing the MRR because of less amount of material is expelled.When high amount of pulse-on time is generated more amount of material is heated and melted but not expelled through the machined surface.

Thus MRR was maximum at ton around 500 μs for the range of investigation carried out.

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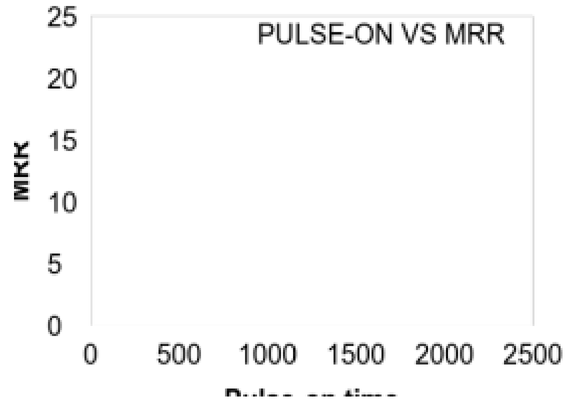

Fig 2(a):Pulse-on time vs MRR

The influence of pulse-on time vs. SR is shown in the Figure 2(b).The Figure depicts that pulse-on time is increases SR is increased at certain conditions. After that pulse-on time is increased decreasing the SR because of less amount of material is removed

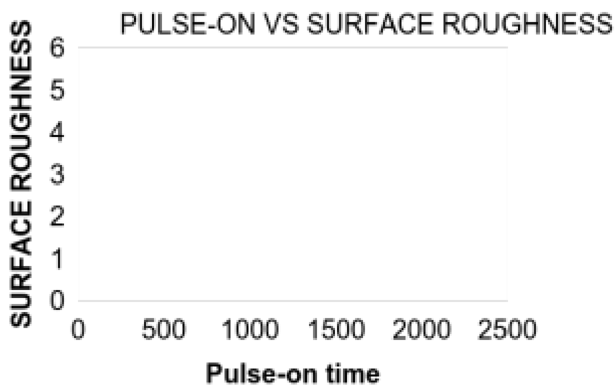

Fig 2(b):Pulse-on time vs Surface roughness

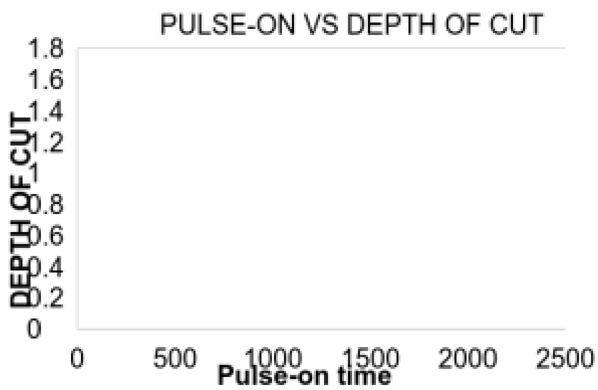

Fig 2(c):Pulse-on time vs Depth of cut

CONCLUSION

The following conclusions are given based on the experimentation results on Inconel X-750 material with copper electrode in the investigated range.

- The MRR is increased with increase in the discharge current .
- The lower surface roughness is obtained at initial conditions of discharge current and pulse-on time.

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For Inconel X-750, the effect of pulse on-time is insignificant on MRR. Hence to achieve better surface roughness low value of pulse on-time is to be selected

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