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A Study on Influence of Discharge Current on Output Criteria While Machining With Spark Erosion Machine

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ABSTRACT

In this research, investigations are carried out on machining of Inconel 825 material using the electric discharge machining (EDM) technique with a copper as electrode. Inconel 825 material is used for aviation and high temperature applications. The Inconel 825 is difficult to machine using conventional machining techniques. However, it can be machined using a spark EDM process to obtain accurate dimensional and geometric tolerances. The machining parameters, such as the current (I), pulse on time (T-on), pulse off time (T-off), dielectric pressure (DP) and spark gap voltage (SV), were investigated using a Regression Surface Methodology (RSM). The output characteristics, such as the material removal rate (MRR), tool wear rate (TWR), wear ratio (WR) were examined during the sparking operation. The significance of the machining parameters was obtained using analysis of variance (ANOVA) which showed that the current, pulse on time and spark gap voltage were the most significant parameters. The results were further confirmed using an experiment that illustrated that the spark eroding process could effectively be improved.

Keywords:- EDM, Inconel 825, Optimization, RSM, Spark gap, MRR

I. INTRODUCTION

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive. In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining.

A thin gap about 0.025mm is maintained between the tool and work piece by a servo system shown in fig.1. Both tool and work piece are submerged in a dielectric fluid. Kerosene/EDM oil is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases.

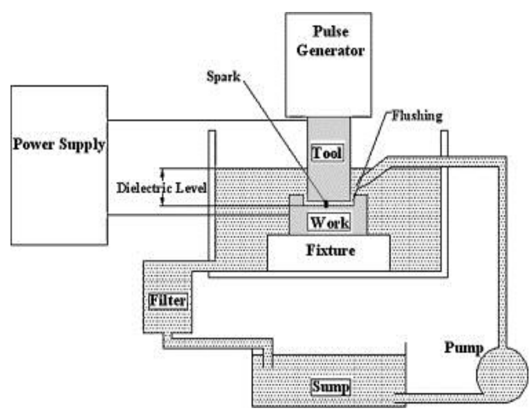


Figure1. Set up of Electric discharge machining

This fig.1 is shown the electric setup of the Electric discharge machining. The tool is made cathode and work piece as anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. And positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature that some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially.

Wang and Lin [1] discussed the optimization of W/Cu composite martial machining using Taguchi method and L18 orthogonal array to obtain the polarity, peak current, pulse duration, duty factor, rotary electrode rotational speed, and gap load voltage in order to explore the material removal rate, electrode wear rate, and surface roughness. The influence of each variable and optimal processing parameter was obtained through ANOVA analysis through experimentation to improve the process.

The parameter like MRR, TWR, gap size and SR and relevant experimental data were obtained through experimentation using the RSM, by Sameh S. Habib[2] on **Al/Sic composites** material and shown the correlations between the cutting rates, the surface finish and the physical material parameters of this process made it difficult to use. Optimal combination of these parameters was obtained for achieving controlled EDM of the workpiece and finding the MRR increases with an increase of pulse on time, peak current and gap voltage and MRR decreases with increasing of Sic%. Kunge et al. [3] evaluated the effect of MRR and EWR on the powder mixed electrical discharge machining (PMEDM) of cobalt-bonded tungsten carbide (WC-Co). In the PMEDM process, the aluminum powder particle suspended in the dielectric fluid disperses and makes the discharging energy dispersion uniform; it displays multiple discharging effects within a single input pulse. This study was made only for the finishing stages and has been carried out taking into account the four processing parameters: discharge current, pulse on time, grain size, and concentration of aluminum powder particle for the machinability evaluation of MRR and EWR. The RSM has been used to plan and analyze the experiments. Notice that the residuals generally fall on a straight line implying that the errors are normally distributed. Furthermore, this supports adequacy of the least squares fit. The MRR generally increases with an increase of Aluminum powder concentration. Torres, I. Puertas, C.J. Luis [4] worked on Hard-to-machine alloys are commonly used for industrial applications in the aeronautical, nuclear and automotive sectors, where the materials must have excellent resistance to corrosion and oxidation, high temperature resistance and high mechanical strength. In this present study the influence of different parameters of the electrical discharge machining process on surface roughness, electrode wear and material removal rate have been studied. Regression techniques are employed to model arithmetic mean deviation Ra (µm), peak count Pc (1/cm), material removal rate MRR (mm^3/min) and electrode wear EW(%). All these parameters have been studied in terms of current intensity supplied by the generator of the electrical discharge machine I (A), pulse time ti (µs), duty cycle and open-circuit voltage U (V). This modeling allows us to obtain mathematical data and models to predict that the most influential factor in MRR and Ra is the current intensity and in the case of EW and Pc is the pulse time.

Torres & C. J. Luis & I. Puertas [5] mentioned that Nickel-based alloys are attractive materials for industrial applications owing to their good mechanical properties and excellent resistance to corrosion and oxidation, even under extreme conditions. In this paper, the behavior of an INCONEL 600 alloy has been studied using electrical discharge machining (EDM). The response parameters selected are the material removal rate (MRR), the electrode wear (EW), and the surface roughness (SR). All of them have been studied in terms of current intensity supplied by the generator (I), duty cycle (η), pulse time (ti), and polarity. To carry out the experiments, design of experiment (DOE) techniques have been used in order to obtain mathematical models to predict the most influential factors by using a small number of experiments. The experimental results confirm that positive polarity leads to higher MRR whereas negative polarity leads to lower Ra values.

Harpreet Singh, Amandeep Singh [6] mentioned that Electric discharge machining is non conventional machining process. EDM is generally used for machining for those materials which are cannot processed by conventional machining process. In this article we compared the material removal rate achieved using different tool materials. Work piece used is AISI D3 and tool materials used copper and brass electrode with pulse on/pulse off as parameter. The electrolyte used is kerosene oil. Torres & C. J. Luis & I. Puertas [7] stated that Nickel-based alloys are attractive materials for industrial applications owing to their good mechanical properties and excellent resistance to corrosion and oxidation, even under extreme conditions. In this paper, the behavior of an INCONEL 600 alloy has been studied using electrical discharge machining (EDM). The response parameters selected are the material removal rate (MRR), the electrode wear (EW), and the surface roughness (SR). All of them have been studied in terms of current intensity supplied by the generator (I), duty cycle (η), pulse time (ti), and polarity. To carry out the experiments, design of experiment (DOE) techniques have been used in order to obtain mathematical models to predict the most influential factors by using a small number of experiments. The experimental results confirm that positive polarity leads to higher MRR whereas negative polarity leads to lower Ra values.

Harmanpreet1, Harvinder Lal2, Gaurav Dhuria [8] did the experimentation on EDM for the modelling and optimization of the process parameters. In this work modelling of the processes are done by artificial neural networking and optimization by genetic algorithm. For fitness function regression analysis has been performed. Design of experiment with mixed level L18 orthogonal array has been considered. All 18 experiments were performed on INCOLOY-800. Copper as an electrode considered. In this work TWR considered as the response variable. Dielectric fluid with two level; where current, pulse on time and gap voltage considered with three levels as the process parameters. 4-17-1-1 network considered in ANN by feed forward back propagation for process modeling. Two types of dielectric fluid considered as kerosene and EDM oil. For multi objective-optimization Genetic Algorithm used (GA). R.Sankara Doss, B. Kumaraguruparan [9], a series of experiments were conducted with copper electrode as a tool and Inconel 718 alloy as work piece to machine small depth on the work piece. The combination of gap voltage, pulse ON time, pulse OFF time and peak current setting were considered for maximum Material Removal Rate (MRR), Surface Roughness (Ra) & Tool Wear Rate (TWR). This work emphasized to optimization of the electrode which could enhance the production quality and to have a significant contribution for modern industrial requirements.

P. Kuppan & A. Rajadurai & S. Narayanan [10]: This paper reports on an experimental investigation of small deep hole drilling of Inconel 718 using the EDM process. The parameters such as peak current, pulse on-time, duty factor and electrode speed were chosen to study the machining characteristics. An electrolytic copper tube of 3 mm diameter was selected as a tool electrode. The experiments were planned using central composite design (CCD) procedure. The output responses measured were material removal rate (MRR) and depth averaged surface roughness (DASR). Mathematical models were derived for the above responses using response surface methodology (RSM). The results revealed that MRR is more influenced by peak current, duty factor and electrode rotation, whereas DASR is strongly influenced by peak current and pulse on-time. Finally, the parameters were optimized for maximum MRR with the desired surface roughness value using desirability function approach.

A. Torres & C. J. Luis & I. Puertas [11] worked and stated that Nickel-based alloys are attractive materials for industrial applications owing to their good mechanical properties and excellent resistance to corrosion and oxidation, even under extreme conditions. In this paper, the behavior of an INCONEL 600 alloy has been studied using electrical discharge machining (EDM). The response parameters selected are the material removal rate (MRR), the electrode wear (EW), and the surface roughness (SR). All of them have been studied in terms of current intensity supplied by the generator (I), duty cycle (η), pulse time (ti), and polarity. To carry out the experiments, design of experiment (DOE) techniques have been used in order to obtain mathematical models to predict the most influential factors by using a small number of experiments. The experimental results confirm that positive polarity leads to higher MRR whereas negative polarity leads to lower Ra values.

II. EXPERIMENTATION

Figure 2 EDM machine

The main objective of experimental design is studying the relations between the response as a dependent variable and the various parameter levels. It provides an opportunity to study not only the individual effects of each factor but also their interactions. Design of experiments is a method used for minimizing the number of experiments to achieve the optimum conditions. The design of experiments for exploring the influence of various predominant EDM process parameters (e.g. pulse on time, peak current, average gap voltage and the percent volume fraction of SiC present in the aluminum matrix) on the machining characteristics (e.g. the material removal rate, electrode wear ratio, gap size and the surface finish), were modeled. In the present work experiments were designed on the basis of experimental design technique using response surface design method. In order to determine the equation of the response surface, experimental design has been developed with the attempt to approximate this equation using the smallest number of experiments possible. In this investigation, experimental design was established on the basis of 2*k* factorial, where k is the number of variables, with central composite-second-order rotatable design to improve the reliability of results and to reduce the size of experimentation without loss of accuracy. The experiments were carried out on S35 model EDM of Sparkonics make which is shown in Fig.2. The specimen after machining at different parameters were shown in Fig.3

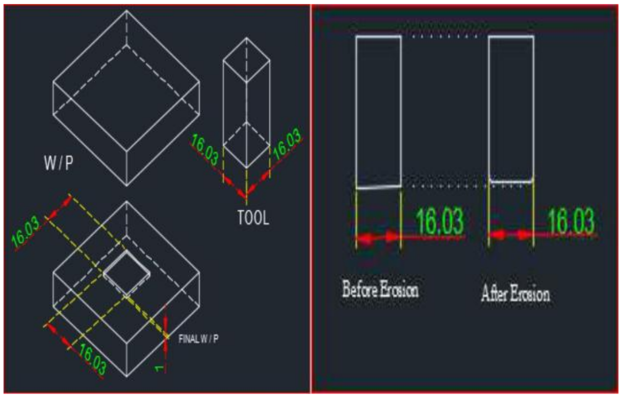


Figure 3 After machining on EDM

III. RESULTS AND DISCUSSIONS

Optimization of process parameter for Inconel 825 is shown in fig.4

MRR=volume of material removed from work piece / Time

Where volume in mm^3, time in minutes

MRR = 256.9609/ 8.5147= 30.1786 mm^3/min.

TWR= (Tool mass before machining-Tool mass after machining)/Time.

TWR = (68.54-68.46)/8.5147= 0.009395516 gm/min

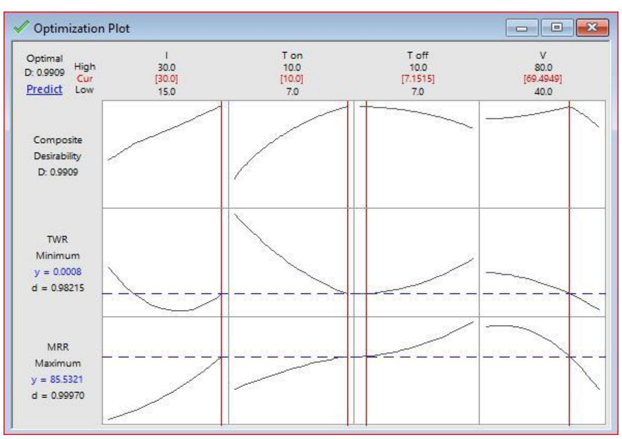
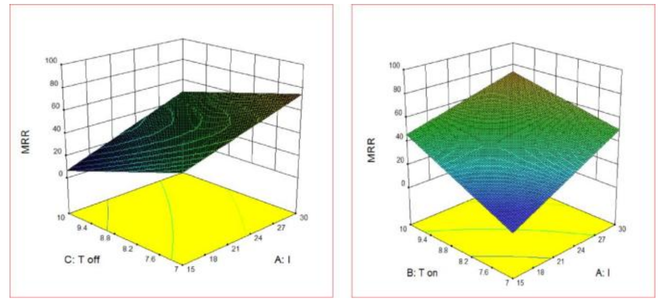


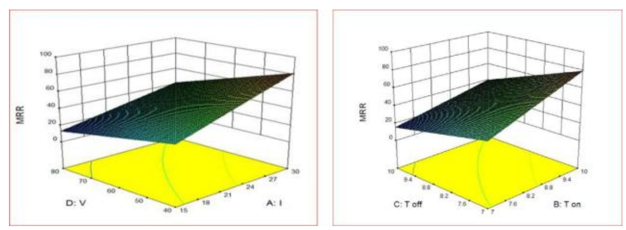
Fig.4. Optimization of process parameter for machining Inconel 825

Effect of parameters on MRR:

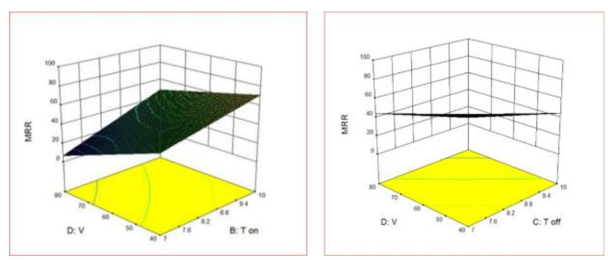


A ***B***

From the fig.5, it is observed that the MRR is increasing with increase in Current, T-on time and decreasing with increase in T-off time. This may be due to the energy dispensed at the sparking zone as it increases with increase in current and T-on time.



C D



E F

Figure 5 Two factor interaction on MRR

From the above ANOVA table we can say that Current, T on, T off, voltage all are significant effective on the material removal rate because of p value of current ,T on, T off and voltage are 0.0043, 0.0095, 0.0146 and 0.0046 respectively.

There is no significant effect of T on and T off on material removal rate.

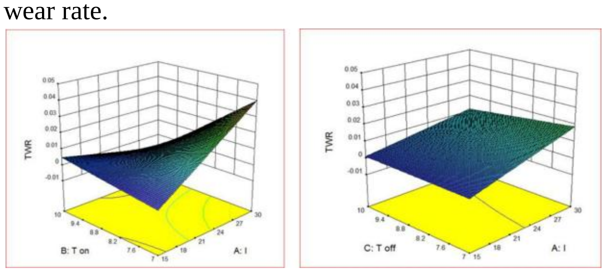
Figure a: Interaction effect of T on and I on MRR.

As shown in the figure A, the time was found to be high at 30amp and 10ms of T on. It was found to be less 15amp and7ms o f T on.

Figure b: interaction effect of T off and I on MRR.
As shown in the figure B, the processing MRR was found to be high at 15 amp and 10ms of Toff. It was found to be less at 30amp and 7ms of T off.
Figure C: interaction effect of V and I on MRR.
As shown in the figure C, the MRR was found to be high at 30amp and 40V. It was found to be less at 15amp and 80 V.
Figure D: Interaction effect of T off and Ton MRR
As shown in the figure D, the MRR was found to be high at Ton of 7ms and 10ms of T off. It was found to be less at Ton of 10ms and T off 7ms.
Figure E: Interaction effect of V and Ton on MRR
As shown in the Figure E, the MRR was found to be high at Ton of 7ms and 40 V of voltage. It was found to be less at Ton of 7ms and 80V.
Figure F: Interaction effect of V and T off on MRR.
As shown in the figure F, the MRR was found to be high at T off of 7ms and 40 voltage. It was found to be less at T off on 10ms and 40V.
The mathematical correlation generated using RSM is as a multiple parametric optimization in terms of thickness, T-on, T-off and current, I is

MRR = -119.0025 +5.83145 * I +26.9512 * T on +2.05553 * T off -1.09224 * V -0.43474 * I * T on +0.2302 * I * T off -0.0271 * I * V -1.7839 * T on * T off +0.1486 * T on * V - 0.0409 * T off * V

Effect of process parameter on TWR: From the above ANOVA table we can say that Current and voltage are significant effective on the material removal rate because the P value of T on is 0.0450. There is no significant effect of Current, T off and voltage on tool wear rate.



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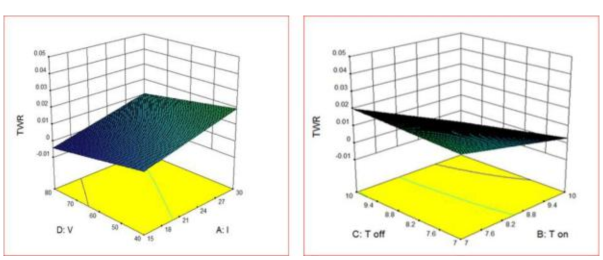

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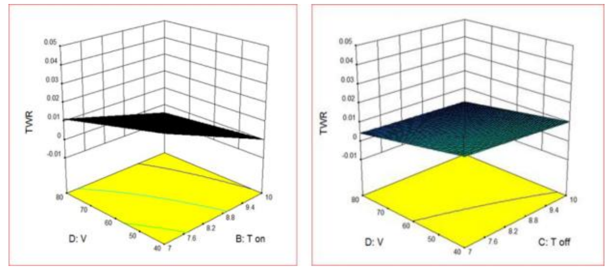

E F

Figure 6: Interaction effect of Ton and I processing TWR.
Figure A: Interaction effect of T on and I on TWR.
As shown in the figure A, the processing time was found to be high at 30amp and 7ms of T on. It was found to be less 30amp of I and 10ms of T on.
Figure B: interaction effect of T off and I on TWR.
As shown in the figure B, the TWR was found to be high at 30 V and 7ms of T off. It was found to be less at 15amp of I and 7ms of T off.
Figure C: interaction effect of V and I on TWR.
As shown in the figure C, the TWR was found to be high at 30amp and 40 V. It was found to be less at 15amp of I and 80 V.
Figure D: Interaction effect of T off and Ton TWR
As shown in the figure D, the TWR was found to be high at Ton of 7ms and 10ms of T off. It was found to be less at T on of 10ms and T off 10ms.
Figure E: Interaction effect of V and Ton on TWR
As shown in the Figure E, the TWR was found to be high at Ton of 7ms and 40 V of voltage. It was found to be less at Ton of 10ms and 80V.
Figure F: Interaction effect of V and T off on TWR.
As shown in the figure F, the TWR was found to be high at T off of 7ms and 40 voltage. It was found to be less at T off on 10ms and 80V.
The mathematical correlation generated using RSM as a multiple parametric optimization in terms of thickness, T-on, T-off and current, I is

TWR = -0.2848 +0.01331 * I +0.03199 * T on +0.01595* T off -1.019457E-003* V
-1.285291E-003 * I * T on -1.78408E-004 * I * T off +1.69767E-006 * I * V -1.660141E-003* T on * T off +6.98023E-005* T on * V +1.8058E-005 * T off * V

IV. CONCLUSIONS

The optimization of process parameters namely discharge current, pulse on time, pulse off time and voltage can be done by using RSM for eroding of Inconel 825. The conclusions are drawn from this work is as follows.

The empirical relationship was developed for material removal rate, tool wear rate on EDM with eroding parameter.

ANOVA was used to identify significant parameters on the out variables in ANOVA for material removal rate voltage and current were found to be significant. In ANOVA for tool wear rate no one was found to be significant.
The RSM was used for multi response optimization of process parameters. Current of 30amp, pulse on time of 10ms, pulse off time of 7ms and voltage of 69 volts are optimum erosion parameters.
MRR and TWR with process parameter

MRR = -119.0025 +5.83145 * I +26.9512 * T on +2.05553 * T off -1.09224 * V -0.43474 * I * T on +0.2302 * I * T off -0.0271 * I * V -1.7839 * T on * T off +0.1486 * T on * V - 0.0409 * T off * V
TWR = -0.2848 +0.01331 * I +0.03199 * T on +0.01595* T off -1.019457E-003* V
-1.285291E-003 * I * T on -1.78408E-004 * I * T off +1.69767E-006 * I * V -1.660141E-003* T on * T off +6.98023E-005* T on * V +1.8058E-005 * T off * V

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