EXPERIMENTAL ANALYSIS OF GRAPHITE ELECTRODE BOTTOM PROFILES WHILE MACHINING INCONEL 718 THROUGH EDM PROCESS

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Abstract : The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, in processes related to Electrical Discharge Machining (EDM).It is a capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Inconel 718 is a precipitation-hardened nickel-chromium alloy. It contains substantial levels of iron, molybdenum, and niobium and trace amounts of titanium and aluminum, possessing high strength and temperature-resistance combined together. Establishing the process capabilities of EDM for machining Inconel 718 and optimizing the process is important, since it has wide specialized engineering applications, like components of nuclear reactor, spacecraft, steam turbine and propulsion systems. Experiment will be performed on profile such as Flat, Concave, Convex of Inconel 718. Tangible observation will be analyzed with parameters like MRR, TWR, Recast layer thickness test, Surface roughness test. Conclusion will be displayed in durability of Inconel 718 with respect to Electric Discharge Machine.

***IndexTerms* - EDM, MRR, SR,Electrode bottom profile, Inconel 718.**

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 has ability to machine structurally complex or high strength material, the materials which are difficult to machine like tools of steel which are heat treated with heat, composite materials, super alloys, Ceramics, carbides, Heat resistant steels etc. The only condition for EDM is the material should be electrically conductive.

1.1 Principle of EDM

The figure depicts the setup of whole EDM process, which includes mechanical and electrical circuit setup. Basic process occurring is rapidly and continuously of electric spark through the tool to the work piece which results in erosion of material from the work piece. A gap of 0.025 mm is continuously maintained by the servo system indicated in fig. 1. A dielectric fluid is used for immersion of both tool and work piece during the process. Mostly dielectric fluid used are Kerosene/EDM oil/Deionized water but in some special cases Gaseous dielectric fluids are also used.

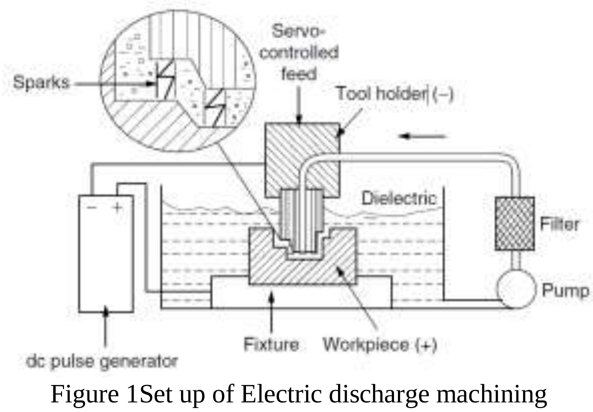

Figure 1Set up of Electric discharge machining

The Fig. 1 depicts the layout of the electric discharge machine. The cathode and anode are tool and work piece respectively. After sufficient high voltage, process of discharge starts in spark form at regular interval of 10 micro seconds, by conduction positive ions and electron starts moving. When discharged spark creates disturbance between electrons and ions and generate plasma channel. Instant loss of electric resistance of the previous channel allows high current density which creates ionization and strong magnetic field. The spark creates pressure between work and tool which ultimately reaches high temperature and melting and eradication of metal happens. This rise in temperature results in removal of metal. Instant vaporization and melting are the ways of removal of materials. Molten metal can be remove partially not totally. Plasma Channel will collapse after removal of potential difference as indicated in fig. 2. This collapsing generates pressure or shock waves, which forms a crater of unwanted metal around impacted spark area.

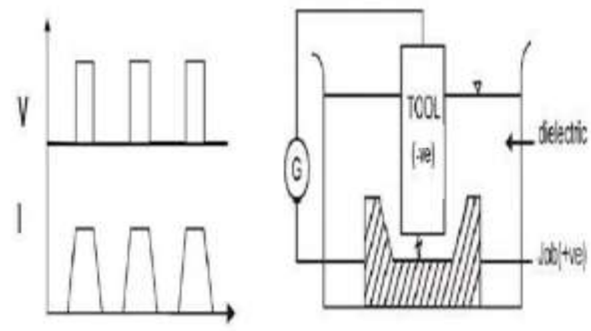

Figure 2 Working principle of EDM process

1.2 Application

- EDM is broadly used in mould manufacturing and Die industries. However it is widely common in production of prototype and parts more vividly in Automobile, Aerospace and Electronics industries. Certainly in industries where production quantity is low.
- Hard materials like alloys, steel, tungsten and carbide are machined by EDM.
- EDM is used in forging, extrusion, wire drawing, thread cutting.
- Curved holes are drilled by EDM.
- EDM is used for internal thread cutting and helical gear cutting.
- It resolves the limitation of other machining processes by machining sharp edges and corners.
- High surface accuracy can be achieved due to high tolerance limit in EDM.
- Ceramic materials that are too brittle for machining can also be machined by EDM.
- EDM is wide spread in many new field like Sports, medical, surgical instruments and optical instruments also in R&D fields.
- EDM is also useful in highly complicated areas, multifunctional parts up to micro level in micro-electronics.

II. LITERATURE REVIEW

P Kuppan et al. the purpose of this paper,electric discharge deep hole drilling of Inconel 718 was experimented with three different industrial tube electrodes viz., copper, copper-tungsten and graphite.The result indicates that MRR will increase with the rise in current no matter electrodes and also the relationship is nearly directly proportional for all 3 electrodes. Analysis of results indicates that copper conductor created the most effective MRR with increasing current followed by graphite and copper-tungsten electrodes. Further, it's to be noted that once machining exploitation the copper conductor, machining speed is increasing around over seven times than the copper-tungsten conductor and over 2 and a 0.5 times than the graphite conductor at high current (10 A). The pulse on-time is a smaller amount vital on MRR for copper and copper-tungsten conductors however vital for graphite electrode.The EWR is high in copper electrode and followed by copper-tungsten and graphite electrodes. The graphite electrode shows minimum conductor wear (no wear vary < one %) in the least values of current. It shows that because the pulse on-time will increase EWR decreases for all the 3 electrodes. it's seen from the trend that for copper electrode, EWR decreases sharply because the pulse on-time will increase (up to eighty µs) then nearly stable. In copper-tungsten and graphite electrodes, EWR is a smaller amount sensitive to pulse on-time.The result shows the impact of peak current on SR for copper, copper-tungsten and graphite electrodes. The SR will increase with will increase in current no matter electrode materials and also the increase in SR is proportional to this high for all the 3 electrodes. The analysis of results indicates that, copper exhibits the most effective performance with reference to SR whereas graphite shows the poorest. The copper-tungsten produces SR in between copper and graphite electrodes. Because the pulse on-time will increase, SR will increase for copper conductor and also the increase in SR is a smaller amount sensitive at extended pulse on-time (>60 µs). While for copper-tungsten and graphite electrodes SR step by step will increase with the rise in pulse on-time up to sixty µs then it starts decreasing.[1]

M. Kliuevet al. In this study concerning machining capabilities of recent EDM drilling machines for drilling cooling holes and diffusers in rotary engine blades square measure delineated. For up the method capability and machining potency of part alloys, drilling of cooling holes and formation of diffusers is combined into one method by exploitation constant electrode for each processes.Particular attention is given to the method parameters analysis like discharge current and discharge time, their influence on the heat-affected zone and also the influence of relative tool decline the form accuracy. Thereby the material removal rate reached seventy seven mm3/min, relative tool wear was reduced right down to twenty try to the typical recast layer thickness was reduced to eight µm. the most effective results were achieved singly with totally different sets of parameters.The combination of EDM drilling and shaping processes demonstrates the likelihood to supply cooling holes with diffusors while not electrode amendment. Once diffusor shaping the roughness SA of the interior surface is a smaller amount than one µm. explicit attention is given to the RLT. It's found that the thickness once shaping is even below once drilling and considerably lower as compared with laser drilling.[2]

M Manohar et al. This analysis paper, to grasp the impact of the electrode bottom profile and additionally its extent of influence on machining metal alloy, experimental study was dole out through EDM. Electrodes of various bottom profiles were used and also the machined surfaces were analyzed in terms of recast layer, surface topology, kind tolerance and MRR. Electrodes having convexo-convex and Flat profile at their bottom surface were chosen for the experimental study; electrodes were fabricated from copper rod of twelve metric linear unit diameter with convexo-convex or flat profile at their bottom with 3 totally different radii of curvature specifically, 6, 8 or10 mm. Electrodes of convex bottom profile perform better than flat or concave profiled electrodes in terms of lesser recast-layer, better surface finish for plain surface machining and closer geometry and MRR for hole drilling. Smaller radius of the profile performs higher in terms of surface end and formability, attributable to the rationale that it's smaller contact surface. Smaller radius profile forever perform higher no matter its contour (convex or concave). Flat profile electrodes perform higher than the concave profile electrodes. EWR is that the least within the case of depressed profile electrodes, preceded by convexo-convex profile conductors and also the flat profile electrode has the best EWR. It is through an experiment incontestable that the results of abrasion of the flat profile electrode may be overcome by commutation it with the convexo-convex profile electrode; additionally that the performance of depressed profile electrodes simulates the machined surface generated by the worn flat profile electrode, over a amount of your time.[3]

F. Klockeet al. In presents study total five totally different forms of graphite were chosen with considerably different physical characteristics regarding their specific electrical phenomenon, thermal physical phenomenon and grain size. The performance of every grade was evaluated in terms of material removal rate and tool wear for roughing. A performed d-optimal style of experiments unconcealed that the discharge current is that the main influence on the material removal rate and also the discharge length is main influence on the tool wear. Typical classification of graphite materials elaborated analysis showed that there's no direct link between the performance and also the grain size relating to MRR and tool wear. Beside the most goals of this investigation another phenomena was ascertained resulting in a rise of electrode mass rather than the assumed tool wear. The rise of electrode mass was explained by a big deposit of labor piece material at the perimeters of the tool conductor exploitation sure parameters.[4]

P Kuppan et al. This paper reports on associate experimental investigation of little deep hole drilling of metal 718 exploitation the EDM method. The parameters like peak current, pulse on-time, duty cycle and electrode speed were chosen to review the machining characteristics. The results unconcealed that MRR is additional influenced by peak current, duty factor and electrode rotation, whereas DASR is powerfully influenced by peak current and pulse on time.For metal 718, the impact of pulse on-time is insignificant on MRR however powerfully influences the DASR. thence to realize higher surface end low worth of pulse on-time to be elite.[5]

III. EXPERIMENTAL DETAILS

- Work piece material: Inconel 718
- Electrode material: Graphite

In this experiment are using the Graphite tool different bottom profiles like flat, convex and concave are shown in following figure 3.In this figure A, B, C are convex shape profiles with radius of 6 mm, 8 mm and10 mm respectively, figure D is flat shape profile and figure E, F, G concave shape profiles with radius of 6 mm, 8 mm and10 mm respectively.

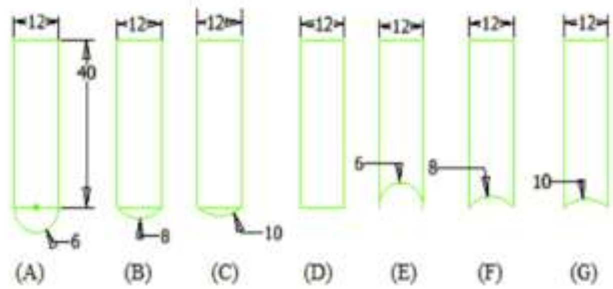

Figure 3 Bottom profile of electrode

- Machining Parameter

Input parameter	Unit	Level 1	Level 2	Level 3
Peak Current(I)	A	13	17	28
Pulse on time(T_{on})	µs	180	210	295
Pulse off time(T_{off})	µs	9	10	14

From the above table according to design of experiments with L9 orthogonal array total no of experiments to be performed are 9.

IV. RESULT AND DISCUSSION

- Material Removal Rate (MRR):

$$MRR = \frac{(W_{tb}-W_{ta})}{D * t}$$

- THE ANALYSIS OF VARIANCE (ANOVA):

The analysis of variance is the statistical treatment most commonly applied to the results oftheexperimenttodeterminethepercentcontributionofeachfactors.Studyof ANOVA table for a given analysis helps to determine which of the factors need control and which do not. Once the optimum condition is determined, it is usually good practice to run a confirmation experiment. In case of fractional factorial only some of the tests of full factorial are conducted. The technique does not directly analyze the data, but rather determines the variability(variance)of the data. Analysis provides the variance of controllable and noise factors. By understanding the source and magnitude of variance, robust operating conditions can be predicted. The analysis is made with the help of a software package MINITAB 18. The main effect plots are showninFig.4 and Fig 5. These show the variation of individual response with the three parameters i.e. Peak current, Pulse on time and Pulse off time separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Horizontal line indicates the mean value of the response. Themaineffectsplotsareusedtodeterminetheoptimaldesignconditionsto obtain the optimum surface finish.

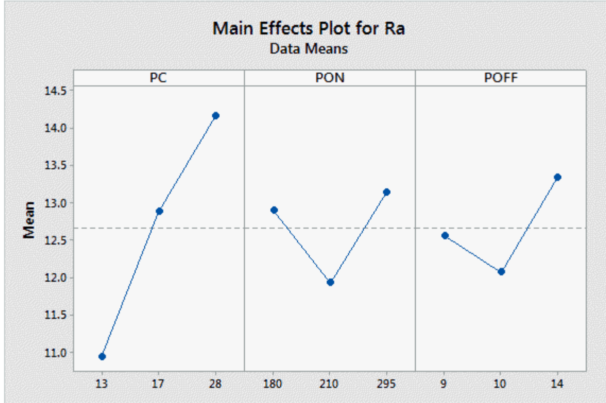

Figure 4Main effect plot for Surface Roughness

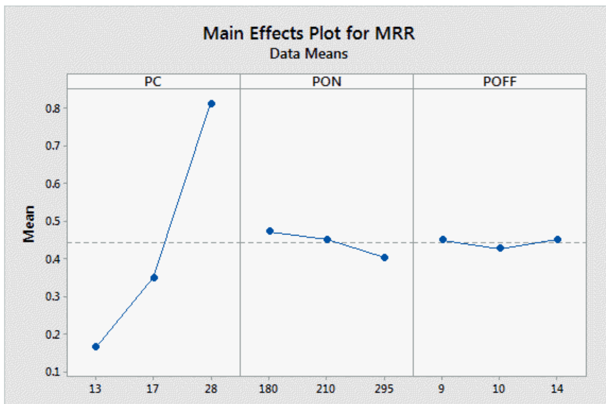

Figure 5 Main effect plot for Material removal rate

- GREY RELATIONAL ANALYSIS:

In grey relational analysis, experimental datai. e. Measured features of quality characteristics of the product are first normalized ranging from zero to one. This process is known as grey relational generation. Next, based on normalized experimental data, grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Then overall grey relational grade is determined by averaging the grey relational coefficient corresponding to selected responses. The overall performance characteristic of the multiple response process depends on the calculated grey relational grade. This approach converts a multiple- response- process optimization problem into a single response optimization situation, with the objective function is overallgreyrelationalgrade.Theoptimalparametriccombinationisthenevaluatedby maximizing the overall grey relational grade.

In grey relational generation, the normalized data corresponding to Lower-the-Better (LB) criterion can be expressed as:

$$X_i(k) = \frac{\text{max yi(k) - yi(k)}}{\max yi(k) - \min yi(k)}$$

For Higher-the-Better (HB) criterion, the normalized data can be expressed as:

$$X_i(k) = \frac{\text{yi(k) - min yi(k)}}{\max yi(k) - \min yi(k)}$$

The purpose of Grey relational grade is to reveal the degrees of relation between the sequences say, [x0 (k) and xi (k), i = 1, 2, 3…, n]. The Grey relational coefficient can be calculated using the pre-processed sequences. The Grey relational coefficient $\boldsymbol{\xi}(\boldsymbol{k})$is defined as follows

$$\xi_i(k) = \frac{\min\Delta + \theta\max\Delta}{\Delta i(k) + \theta\max\Delta}\ ; 0 \le \boldsymbol{\xi}(\boldsymbol{k}) \le \mathbf{1}$$

It shows that optimized parameter for both MRR and Surface Roughness. Parameter is peak current 27 A, pulse on time 180 micro second and pulse off time 14 micro second.

By help of above result experiment carried out with various electrode bottom profile.Experimental result shows that minimum time of hole drilling convex profile with radius of 6mm.It also shows that in case of all concave profile machining time more than flat profile. it reason is that in concave profile there is no proper flushing method and its geometric complexbility because of it consume more time..

V. CONCLUSION

Experimental study was carried out to demonstrate that electrode of convex and concave bottom profile. Study was meant to find optimal parameter of machining Inconel 718 and optimal electrode bottom profile for hole drilling. The conclusion of experimental work could be summarized as follows:

- For getting high MRR peak current must be high.
- Pulse off time is insignificant for better MRR
- Pulse on time up to certain range impact on MRR
- For hole drilling convex bottom profile is better than flat profile electrode.

Flat profile electrodes perform better than concave profile electrode.

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