Effect of Electrode Material and Geometry on EDM Performance for OHNS dies Steel

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***Abstract*—*Modern EDM machinery is capable of machining micro-hole, thin slots, geometrically complex or hard material components, that are precise and difficult to machine, such as heat treated tool steels, composites, super alloys, etc. The studies of an experimental investigation evaluate the effects of EDM machining parameters such as MRR, EWR and Surface Roughness with two different electrode materials. The process parameters such as Input current, Pulse on time and duty cycle keeping flushing pressure constant. The full factorial design of experiment ($L2^{5)}$ is used to study the effects of machining parameters. Investigations indicate that the output parameters of EDM increases with the increase in input current and the best machining rates are achieved with copper with through hole electrodes, better surface roughness compare to brass electrode. A brass electrode with higher input current and maximum pulse on time resulted in more EWR compared to copper electrodes. Also the increase in MRR by copper electrode, it improves the SR during Electric Discharge Machining.*

***Keywords*— EDM, OHNS, Steel, Geometry.**

I. INTRODUCTION

1.1 ELECTRICAL DISCHARGE MACHINE

Electrical discharge machining (EDM) is a manufacturing process by which a tool cut the required shape in to the work piece within a dielectric fluid. Short duration discharge is generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharge channel. The work-piece material removed in the form of crater and tool material removed in the form of debris at the melting temperature. This temperature at the surface of both electrodes is due to the thermal energy generated in a discharge channel has a non-cylindrical shape. However, the assumption that the discharge channel has a cylindrical shape has been done in order to simplify the model construction. EDM began to be a viable technique that helped shape the metal engineering industries.

1.2 OPERATION OF EDM

In this method, tool as an electrode reproduced at higher frequencies removes the material from the work piece surface. The surface of the electrode material is intensively heated in the area of discharge channel. The collapse of discharge channel occurs immediately when the current flow is interrupted. This in turrn evaporates the work piece and the electrode surface. The eroded material subsequently disposes into the dielectric fluid, due to which craters are formed on the surface of the work piece and the electrodes The spark is reported in the range of 8000^0 C to 12000^0 C and it vaporizes the work piece material.[1]

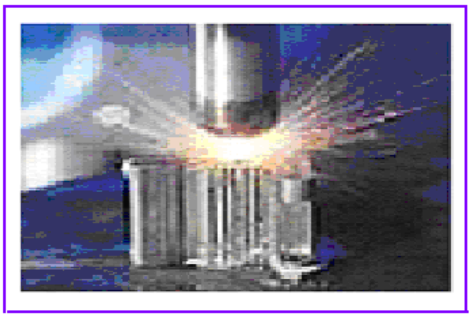

Fig.1: Sparking Mechanism [5]

1.3 APPLICATIONS

The main applications of EDM are metal cutting dies, injection molding, blow molding, automobile and aerospace applications. An essential requirement of the aerospace components those are thin, complex and demands higher dimensional stability. As these components are subjected to sever and hostile environment and operate under cyclic loading conditions, a good surface integrity is essential. EDM is mainly used to machine, difficult materials and high strength temperature resistant alloys.

1.4 OBJECTIVES OF WORK

Objectives of the project for OHNS steel are as follows,- To examine the influence of process parameters such as (Ele. Para) input current, pulse on time and duty cycle with constant flushing pressure.-To check the tool type and geometry, (Mech. Para) comparison with Material Removal Rate (MRR), Electrode Wear Rate (EWR) and Surface Roughness (SR) and the best result of EDM processes. Here the tool types are Copper and Brass electrode where as the tool geometry is either a through hole given in the electrode for flushing of vapor and other impurities or without hole to check the difference of surface finishing, MRR and EWR. And comparison of input variables with each other to find out best result with regression analysis.

II. LITERATURE REVIEW

The quality of a machined surface is becoming more and more important to satisfy the increasing demands of sophisticated component, longevity and reliability. Die steel and OHNS steel has wide range of physical and Mechanical properties which are available in the Indian market depending on their Carbon percentage. As per that EN-8, EN- 10, EN-18 and EN-31etc. increase of number indicates lower the carbon %. OHNS steel is also the same strength as EN-18. Liao et al. had given details about electrical discharge machining (EDM) as a well established non-conventional machining option for manufacturing electrically conductive and geometrically complex or hard material parts.[2] Soni and Chakraverti showed an appreciable amount of elements diffused from the electrode to the work-piece and vice versa. [3] Singh and Ghosh, showed that the electrostatic forces and stress distribution acting on cathode electrode are the major causes of metal removal for shot pulses. In addition, reverse polarity of sparking alters the material removal phenomenon with an appreciable amount of electrode material depositing on the work-piece surface.[3] They also performed on high carbon high chromium die steel to investigate the mechanical effect on ED machined surface, material removal rate and electrode wear rate. Raman et al. noticed an improvement in machining characteristics of GT-20 grade of cemented carbides by electric discharge machining using copper and copper–tungsten electrodes. Morao Dias, rebelo et al. concluded that EDM allows tool steels to be heat treated to full hardness before EDM, avoiding the problem of dimensional variations, which are common after post heat treatment. Jeswani made an analytical study of mechanical characteristics of spark machined surfaces limited to metal removal rate (MRR), electrode wear and surface integrity. Moroa et al. (1998) did surface roughness and micro crack analysis of AISI 1045 steel with both copper and copper chromium composite electrode for positive as well as negative polarity machining.[4] Pawade and Brahmankar had shown the effect of electrode shape, where they used a cylindrical, reverse tee and dovetails Copper electrodes for experiments. The other parameters, electrode rotation and electrode shape have moderate influence on MRR. However, duty cycle has insignificant effect on MRR. The influence of EDM parameters, found from the main effects plots that at 8 Amp, the MRR is lowest. As the pulse current increases to 14 Amp, a sudden increase in the MRR is observed. Further increase in pulse current to 22 Amp produces higher MRR. It means MRR is high when the electrode is stationary. It is observed that pulse current and electrode shape have more significant influence on surface roughness. [5] Marafona et al. worked on Copper and Tungsten electrodes, the parameters such as discharge voltage, input current, duty cycle, During the EDM process, both tool and work piece undergo surface modification. Many researchers have looked at modification of the work piece, but few have examined modification of the tool. Chen et al. showed that migration of elements from workpiece to the tool electrode occurs using both high and low current intensities, [2] Some authors have claimed that most of the electrode wear is due to evaporation and fusion Eubank. However, it was pointed out that the EDM material removal is caused by violent explosion of the super heated electrode as it melts from the melt cavities at the end for the machine pulse. Mohari and Pandey claim that carbon on the tool surface inhibits the wear of the tool electrode. [7]

Petropoulos had given details about Arithmetic average surface roughness that is (Ra) for the most commonly used parameters in surface measurement. He proved that as soon as improve in current it also improves the surface roughness. When pulse energy increases, with a gradually lower rate. The EDM surface area reviled to be in view of topography Empty, Open, steep and Random, in shape, and the observed characteristics become more profound, when intensifying the machining condition.[8]

Lee L.C.and Lim L.C. have reviled to get quality surface finish the spark should have minimum voltage as well as minimum gap between electrode and work piece. When the electrode is close to the work piece the electrostatic force between the anode and cathode will increase. This attractive force will increase deflection making bigger sparks and produces bigger crater causing increase in the surface roughness.[9]

III. EXPERIMENTAL DETAILS

3.1 EXPERIMENTAL SET UP

The electric discharge machine (Make: Electronica, Model Electra plus leader-1-znc*)* with constant servo gap head facility was used for conducting the experiments. This experiment evaluate the detailed experimental study employed to determine the effect of Copper and Brass electrode of various mechanical and electrical process parameters; used OHNS steel material for practical work. The machinability measured in terms of material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR).Electrical parameters used are Input current, pulse on time, duty cycle. Mechanical parameters used are tool type and tool geometry with constant flushing pressure. The experiments were planned using full factorial $L2^5$ Design of Experiment that is 32 run and two replicates. Therefore, total 64 experiments.

Table.3.1: Chemical composition of OHNS steel.

C %	Si %	P %	W %	Mn %	S %	Cr.%
0.37	0.16	0.031	0.015	0.55	0.04	1.37

Work piece material. The OHNS steel was selected as a work material. The sample was received in the form of plate. The final dimensions made out of plate were 48 x 48 x 8mm. Hardness of material was HBW 70 before hardening and HBW 270 after hardening.Electrode material.

Electrode Material

Tool Type and Tool geometry

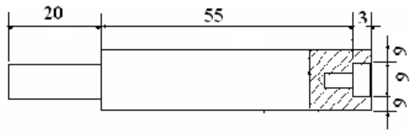

Figure. 3.1(a): Emboss Type electrodes without Flushing hole in Brass & Copper Electrodes.

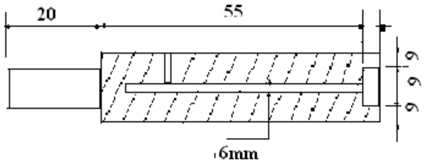

Table.3.2: Electrode Material

Tool material	Copper and Brass
Tool Shape and Size	Cylindrical Emboss Shape
Density	1400 m/unit volume
Hardness	17 BHN for Copper

Table.3.3: Selected parameters

Control Factors	Parameter	Level-I	Level-II
A	Pulse Current Ip(Amps)	5	25
B	Pulse on Time Ton	50	100
C	Duty Cycle %	4	12
D	Electrode Type	Cu	Brass
E	Electrode Geometry	WH	NH

3.2PROCESS PARAMETERS

3.2.1 Material Removal Rate (MRR)

Used three electrical parameters and two mechanical parameters for practical work with minimum and maximum level, which are as follows, 3.2.1 Material Removal Rate (MRR)

Material Removal Rate is the material removed in a given amount of time. It is formulated as below and is expressed in mm^3/min. or grams per minute. Generally, material removal rate is increased with intensity of current and this causes more surface damage in the machine surfaces. The MRR can calculated as,

$MRR = W_{wb} - W_{wa} / t_m$ *(1.1)*

3.2.2 Electrode Wear Rate (EWR Electrode wear rate affects the dimensional accuracy of machined component. It can be calculated by the ratio of weight difference of the sample and electrode before and after the EDM process to the machining time. Tool (electrode) wear rate is expressed as,

$\boldsymbol{EWR = W_{tb} - W_{ta} / t_m}$. **(1.2)**

3.2.3 Surface Roughness (SR)

As we know that surface integrity and MRR are inversely proportional to each other, it is necessary to correlate the machining parameters, which produce machined component with good surface integrity at high MRR.

Before measurement of surface finishing, specimens were cleaned and dried. Surface roughness of each specimen was assessed using the Stylus method. All the measurements were carried out with portable roughness measuring instrument (Mitutoyo make). The cut of length of each work piece was eight mm length and collected average measure of thrice measures.

3.4 MEASUERMENTS AND RESULTS

3.4.1 Analysis of variance for MRR

For this purpose a statistical software Minitab was used. In this experiment, each effect having P-valueless than 0.05 is considered as significant for 95% confidence interval. All the effect with P-value together greater than 0.05 are non significant and therefore is discarded. It is observed from ANOVA that pulse on time tool type and tool geometry is most significant factor for all responses.

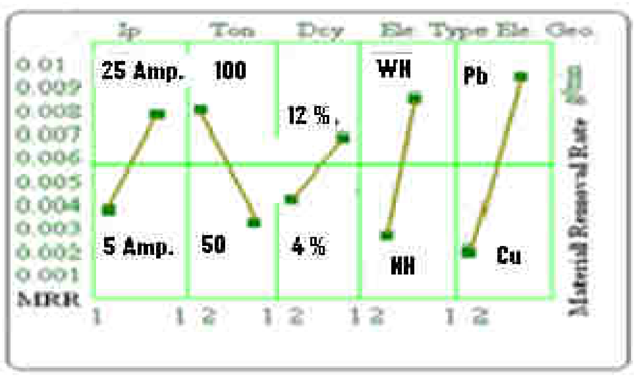

Fig.3.3: Main effects plot for MRR

Figure3.3 shows the corresponding main effects plot. **Effect of current on MRR,** MRR increases with an increase in the input current from 5 to 25 Amperes. Since increasing the input current would increase the discharge energy of a single discharge, the discharge craters generated on machined surface became larger and surface quality becomes rough and resulted in increase of MRR.

The effect of Pulse on time on MRR. Here the increase of pulse on time gives reverse result, as in the low level of 50 τ_{on} pulse off time is more and at higher level 100 τon reduces the pulse off time. Material removal rate becomes low because of long idle time and very short spark time which creates problem for flushing of crater and debris. Also at low level carbon particles stuck on the face of the electrode which causes minimization of MRR.

The effect of Duty Cycle on MRR As per Figure during the process at low level 4 % Duty Cycle MRR decreases while at high level at 12% Duty Cycle it will not make much difference on MRR. The main reason behind this ispulse off time is less at high duty cycle. At high level of duty cycle the developed Carbon is stuck on the face of the electrode which causes direct contact between work piece and electrode; As a result it reduced MRR.

Effect of electrode type. Figure shows different material Copper and Brass are used as a electrode materials. Compared to Copper, Brass has low melting temperature; MRR through Brass electrode is more than copper. But drawback is that brass which vaporized during process causes produced more Carbon, which makes dielectric fluid dirty.

Effect of electrode geometry. As per Figure Copper and Brass both have hole at the center for the flushing of dielectric fluid. This allows the Carbon and other impurities flow easily and causes no sticking of Carbon on electrode surface which improves MRR.

3.4.2 Analysis of variance for EWR

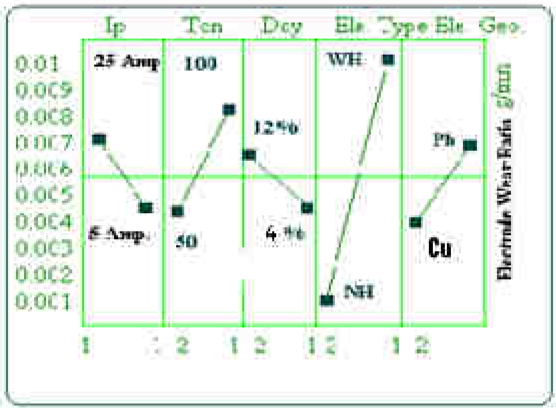

Figure.3.4: Electrode Wear Rate

The effect of input current, As per Figure at 5-Amp.of current, EWR is less than 25-Amp. of Current. Because as the current decreases it decreases its density and same way the spark will also decreases and it minimize EWR. Here the main reason for low level improvement of EWR because at low level OHNS steel will not melt as fast as high level current.

The effect of Pulse on time on EWR, As per Figure during the process as it proves by the graph that at low level 50 τ_{on}, EWR is low and at high level 100 τ_{on}. it increases EWR. As pulse on time increase it decreases pulse off time which significantly increases EWR.

The effect of duty cycle on EWR, As per Figure duty cycle at low level 4 % off time is more compare to high level which gives advantage to flush away all crater and debris, and minimize EWR. At high level it will not get enough time so certain impurities comes in between tool and work piece causes not much difference in EWR.

Effect of Electrode material on EWR, As per Figure Pure Copper electrode is a good conductor of Current and heat, Brass is a composition of Copper and Zink. Causes compare Copper Brass loses its density because Zn has lowmelting temperature and OHNS steel having high melting temperature which improves EWR.

The effect of electrode geometry on EWR, As per Figure during the machining process, Electrode geometry that is Copper and Brass electrode with flushing hole-condition produces maximum electrode wear particularly in Brass electrode, because Brass alloy is Zink which have low melting temperature compare to other material, causes it burnt fast during the process and increases EWR.

3.4.3 Analysis of variance for S.R.

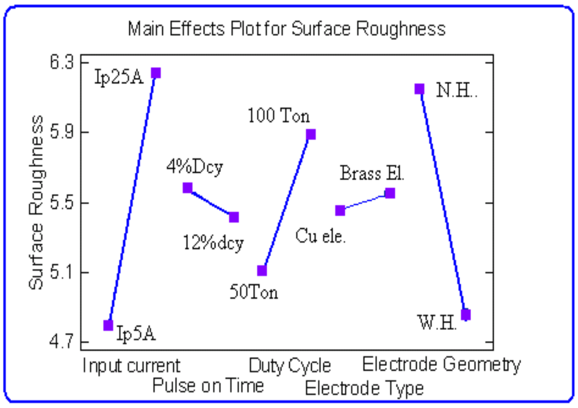

Figure.3.5: M. E. Plot for S.R.

Effect of Input Current on S.R; As per Figure 3.5 at 5Amp.of current work-piece have good surface finishing while at 25-amp. it produces rough surface. Because as the current increases it increases its density which creates higher spark and high level heat which produce comparatively bigger crater, causes rough surface.

Effect of Pulse on time on S.R; As per the Figure Pulse are not much significant for surface roughness, but if we see the graph at lower level it produces rough surface while at high level comparatively good surface finishing. Because at lower level with Brass electrode it improves EWR and vice versa produces rough surface because of used composite material is zinc. On the other hand, with higher pulse rate with copper electrode produces better surface finishing.

Effect of Duty Cycle on S.R; As per Figure Duty cycle at lower level give better surface finishes, and at high levels it increases surface roughness. Because as the cycle time reduces it increases pulse off time where as cycle time is minimum which reduces the pulse off time, causes all impurities cannot flushed properly and it creates repetitive spark on the same plain creates the rough surface.

Effect of electrode type on S.R; As per Figure While using two different materials as a tool, Copper gives better surface then Brass electrode, Because Copper having better density as well as it's a good conductor for electric current and heat which improves surface finishing at 5Amp.current. While Brass has poor density causes same range of Current it will produce little rough surface. Overall there is notmuch different with Copper and Brass electrode during machining.

Effect of Electrode Geometry on S.R; As per Figure there is more variation in SF during the process. With the Cu electrode we found good surface finishing compare to Brass electrode. More variation because Cu is a pure material and have better density then Brass, and also Zn is a alloys for Brass electrode which melt at lower temperature produces rough surface.

IV. CONCLUSIONS

In this work, designs of experiments were carried out to assess the effects of various process parameters on surface integrity of OHNS steel. To evaluate the desired objectives maximum material removal rate, minimum electrode wear rate and SR were observed.

Following conclusions can be deduced from the experimental study.

(1) For the OHNS work material, brass with hole electrodes offer higher MRR compare to Copper electrode.

(2) Electrode wear rate on OHNS is comparatively low when using copper with flushing-hole electrode, which may be preferred for OHNS when required high accuracy

(3) Copper with flushing-hole electrode has comparatively low electrode wear; which shows good results while brass wears the most because of poor density.

(4) Out of four electrodes, Cu with flushing-hole electrodes produced comparatively high surface roughness for the tested work material at high values of currents. Brass electrode offers comparatively low values of surface roughness at high discharge currents giving law surface finish compare to copper.

(5) Copper is comparatively a better electrode material as it gives better surface finish, high MRR and less electrode wear for OHNS work material, while Brass is next to copper in performance, and may be preferred where surface finish is not the requirement.

(6) As per study brass had produced high MRR but it also improved EWR and Surface Roughness, because of poor density compared copper electrode.

(7) At 4% duty cycle MRR reduces and it improves EWR and surface Roughness, due to low pulse off time.

(8) As per Figure10 and 11 the input current at 25 Amp. It improves MRR of work piece and also improves the EWR. But at lower current it improved the surface of work piece and also EWR.

V. FUTURE SCOPES

Further work may be carried out to explore the following:Performance of other geometrical shapes of electrodes may be evaluated.

Effect of powder mixed EDM may be examined.

Effect of ultrasonic vibration may also be examined.

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