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"INFLUENCE OF EDM PARAMETERS ON MRR, TWR AND SURFACE INTEGRITY OF AISI 4340"

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***Abstract*— EDM is material removing process for conductive work piece by applying a high frequency pulsed, electrical current to it through a solid electrode. EDM is used to machine conductive metals of any hardness or those which are difficult to cut with conventional methods. It is a type of non-conventional machining process that produces high quality products without any contact between the work piece and the tool, which are difficult to achieve by other conventional machining processes. This study on EDM with AISI 4340 as work piece and tungsten-copper as electrode is performed to establish the influence of EDM process parameters on material removal rate, tool wear rate and surface integrity. The experimental results concluded that the MRR and TWR are directly influenced by the process parameters. MRR and TWR are mainly influenced by the peak current. Ton is the second most influencing parameter for both MRR and TWR. Voltage is least influencing parameter. The surface integrity is influenced by the crater size and intensity of spark energy. Cracks are observed at higher intensity of spark energy due to induced heat.**

***Keyword* —** EDM, MRR, TWR, Surface Integrity, AISI 4340.

I. INTRODUCTION

EDM or electric discharge machining is achieved when a discharge of sparks take place between two points of the anode and cathode, the intense heat is generated near the zone melts and evaporates the materials in the sparking zone. The material removal takes place due to localized heating and then vaporization of material during machining when the distance between the tool electrode and the work piece electrode is maintained as electrostatic field of sufficient strength is established, causing cold emission of electrons from tool electrode. These liberated electrons accelerate towards the anode. After gaining sufficient velocity, the electrons collide with the molecules of dielectric fluid breaking them into electrons and positive ions. The electrons so produced also accelerate and may ultimately dislodge to other electrons from the dielectric fluid molecules. Ultimately a series of narrow columns of ionized dielectric fluid molecules is established, connecting two electrodes causing an avalanche of electrons since the conductivity of the ionized column is very large and it normally appears as a spark.

Almost all the work performed on EDM is for enhancing the productivity and for improving the quality of surface produced. Studies have been undergone to improve the material removal efficiency and reduce tool wear.

Syed Asghar Husain Rizvi et al [1] in their research studied the surface integrity of AISI 4340 and concluded that the MRR, and SR increases at higher values of pulse current but excessive pulse-on duration results in expansion of the electric plasma channel, and thus results in reduction of both MRR and the SR. They also concluded that cracks on the machined surface will increase with current but will reduce the cracks when pulse on time is reduced. Annamalai et al [2] in their research on MRR and surface roughness while machining AISI 4340 on EDM concluded that with increase in peak current, the MRR increases significantly. In another study performed by Satpal Singh et al [3], tungsten powder mixed in dielectric was used to machine EN 24 steel. The study concluded that MRR tends to increase with increase in the powder concentration. The investigation conducted by Muhamed Mehmedović et al [4], studied the effect of white layer which results in decrease of machined surface roughness compared to its expected value. Uniform thickness along the machined surface increases the micro hardness as compared to the raw material.

J. Krawczyk et al [5] in their investigation concluded that white layer can be readily formed on the surface of heat treated forged steel rolls. To avoid the consequences of the white layer formation it is necessary to uniformly distribute the precipitates of secondary cementite in the material structure. Harpreet Singh et al [6] from their concluded that use of powder in electrolyte provide mirror like surface finish and increase in material removal rate. Ultrasonic vibration makes the equipment simple and increases the material ejection from work piece. Subramanian Gopalakannan [7] observed that the output parameters such as MRR, electrode wear and surface roughness of EDM increase with increase in pulse current. High material removal rate was achieved with copper electrode whereas copper-tungsten yielded lower electrode wear, smooth surface finish and good dimensional accuracy. K.S. Banker et al [8] concluded that floating particles impede the ignition process by creating a higher discharge probability and lowering the breakdown strength of the insulating dielectric fluid. This results in increased MRR, decreased TWR and sparking efficiency is improved.

Pravin R. Kubade [9] concluded that both material removal rate and electrode wear rate are mainly affected by peak current. Mr. Anand et al [10] concluded that the value of material removal rate increases when intensity and duty cycle were increased, while an increase in pulse time decreases the MRR. Therefore, in order to obtain high values of material removal rate for OHNS tool steel one should use high values for intensity and duty cycle.

II. Experimental Design and Setup

The present study was conducted on AISI 4340 of size of 10 mm diameter and 8 mm thickness with Tungsten-Copper rod of 2 mm diameter as electrode. The performance measures to be tested were material removal rate, tool wear rate and surface integrity using current, pulse on duration and gap voltage as machining parameters. The machine tool used was S-70 ZNC EDM machine.

Table 1: The levels of EDM parameters

Parameters	Unit	Levels		
Peak Current (I_p)	A	1	5	9
Pulse on Time (*Ton*)	µsec	15	20	30
Gap Voltage (V_g)	V	75	100	125

Scanning electron microscopy (SEM) is conducted to analyze the surface integrity of the machined surface. For analyzing the material removal rate and tool wear rate, the initial and final weight of the work piece and tool was measured and machining time for each experiment was noted.

III. Results and Discussions

A. Material Removal Rate

The volume of material removed from the work piece while machining is calculated and in relation to the machining duration, the material removal rate was found. Current is found to be the most significant factor and has major effect on MRR with 80.91% contribution. Pulse on duration is the second most significant factor for MRR with a contribution of 8.27%. Voltage has least effect on MRR with 5.74% contribution.

From the main effect plot shown in figure 1 it is clear that as we increase the current, the MRR tends to increase. Current is observed to be the most significant factor for MRR. The MRR also increases with increase in pulse on time, but later it decreases. This is because when discharge energy is higher at higher levels of pulse on time, the time for clearing the debris from the spark gap is less and hence the MRR tends to get reduced. Thus we get lower spark at higher level of pulse on time. In the case of voltage, the MRR tends to decrease with increase in its value. This is because increased gap voltage results in higher discharge energy per spark because of large ionization of dielectric between working gap. However, a too high voltage result in high discharge energy per spark which causes unfavorable break down of dielectric and large amount of debris between the working gap which decreases the material removal rate.

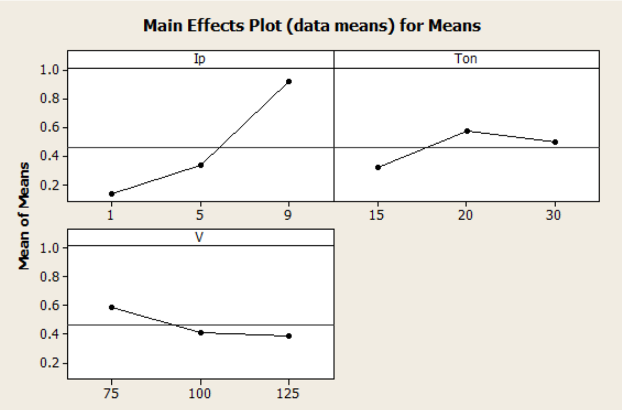

Figure 1: Main Effect Plot For Means For MRR

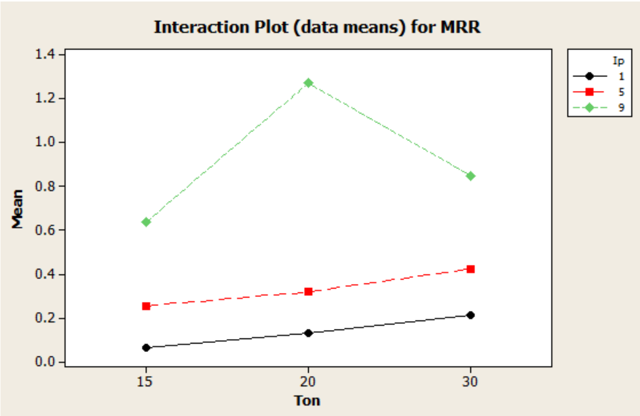

Figure 2: Relation between MRR and EDM parameters

Figure 2 illustrates the interaction plot between MRR and EDM parameters. The plot elucidate that at low level of peak current, the MRR increases at a very slow pace with increase in pulse on time. At 9A peak current, the MRR initially increases with increase in pulse on time, but with further increase in pulse on time, the MRR starts to degrade because the time for clearing the debris from the spark gap is less.

B. Tool Wear Rate

The current is the most significant factor and has major effect on TWR with 80.91% contribution. Pulse on duration is the second most significant factor for TWR with a contribution of 8.27%. Voltage has least effect on TWR with 5.74% contribution.

Figure 3 shows the main effect of plot for tool wear rate. It is observed that with increase in current, TWR will increase. It is clear from the plot that initially TWR increases at a slower rate with current but with further increase in current the TWR increases at a faster rate. This is because of the increased pulse duration. The minimum TWR is generated at 1 A. Peak current is the most dominating parameter for TWR with a contribution of 80.91%. In case of pulse on time, TWR initially increases with it and then it tends to decrease. The pulse-on-time has very low influence on TWR with a contribution of 8.27%. With increase in voltage the TWR decreases. This is due to unfavorable breakdown of dielectric. Voltage is the least affecting parameter for TWR and has only a contribution of 5.74%.

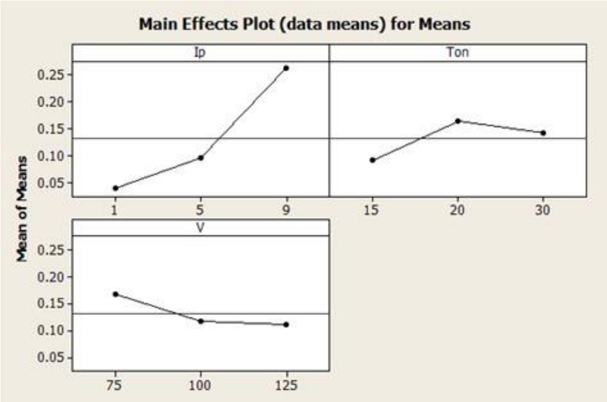

Figure 3: Main effect plot for TWR

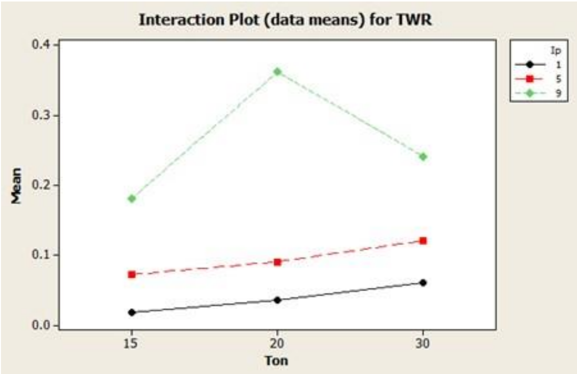

Figure 4: Main effect plot for TWR

The above plot shows the interaction plot of TWR for pulse on time a different levels peak current. The plot elucidate that at low level of peak current, the TWR increases slowly and linearly with increase in pulse on time. At 9A peak current, the TWR initially increases with increase in pulse on time, but with further increase in pulse on time, the TWR starts to degrade because the time for clearing the debris from the spark gap is less.

C. Surface Integrity

The EDM parameter has a great influence on the surface of the machined surface. It is observed that the size of crater obtained is small at initial level of parameters which results in small MRR. Low heat gradients are developed due to low intensity of spark energy and hence the surface is not rough. Figure 5 shows the surface of sample 1 machined at low level of parameters.

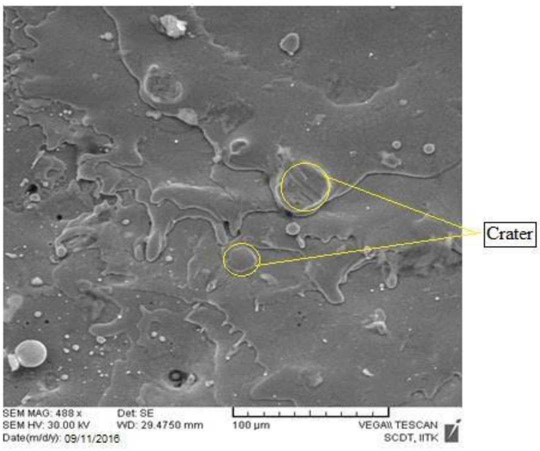

Figure 5: Surface Image of Sample 1

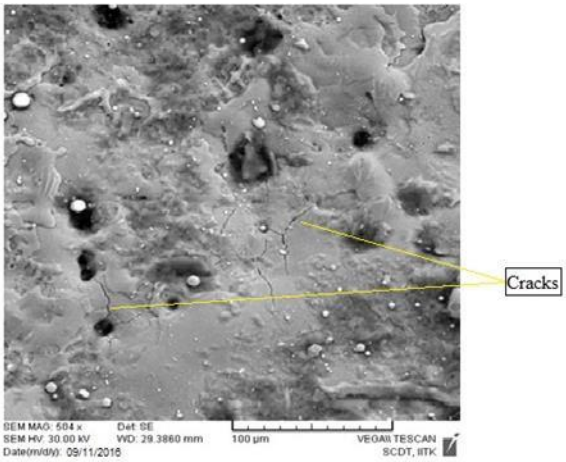

Figure 6: Surface Image of Sample 5

On increasing the level of parameters, the intensity of spark increases and hence the surface starts to degrade. The figure 6 of sample 5 shows the induced cracks on the surface of the work piece due to high intensity of spark energy. The cracks are dispersed on the surface and are mainly due to high current and voltage which ruins the surface finish.

With further increase in the level of parameters, the surface finish gets poorer and more cracks are dispersed on the surface of the work piece. An adverse effect of parameters is observed which is leading to abrupt degrading of surface.

Conclusions

The experiments conducted on AISI 4340 using tungsten-copper as electrode have determined the relation between EDM parameters with MRR, TWR and surface integrity. The following conclusions were made:

1. Peak current was the most dominating parameter for MRR. Pulse on time was the second most influencing factor for MRR but its impact is very less as compared to peak current.
2. Voltage was found to be the least influencing factor for MRR. Too high voltage result in high discharge energy per spark which causes unfavorable break down of dielectric and large amount of debris between the working gap which decreases the material removal rate.
3. When discharge energy is higher at higher levels of pulse on time, the time for clearing the debris from the spark gap is less and hence the MRR tends to get reduced.
4. Smaller crater is obtained at lower levels of EDM parameters due to low intensity of spark which results better surface finish.
5. As we increase the levels of parameters, the crater size increases due to increased intensity of spark. Cracks are also observed on the surface due to internal stresses caused by sudden cooling of surface.
6. The cracks are dispersed on the surface and are mainly due to high current and voltage which ruins the surface finish.

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