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ELECTRODE WEAR IN EDM-PART 2

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ABSTRACT

Electric Discharge machining (EDM) is a non-traditional production method that has widely used in the production of dies throughout the world in recent years and has achieved remarkable success in the manufacturing of conductive materials for the modern industry. The most important performance measure in EDM is the tool wear among other measures material removal rate and surface roughness. In most of the EDM Process, cost of the tool is more than 70 % of the total operation cost, which generate the necessity of minimization of tool wear and it should be taken into very careful consideration while planning and designing EDM operation. The objective of this paper is to study the optimization of machining process parameters to prevent Electrode wear /minimize electrode (tool) wear in Electro-discharge Machining. In EDM, the tool wear problem is very critical since the tool shape degeneration directly affects the final shape of the die cavity. In this paper, the effect of different machining variables on the electrode wear in EDM like flushing rate, type of flushing, T_{on},duty cycle. Current, gap & voltage were studied. The experiments were conducted on EN 31 & round copper tools with kerosene as dielectric under center flushing with varying different parameters. The experiment has shown that machining parameters & flushing conditions had large effect on tool wear (electrode wear).

Keywords: *Electric discharge machining (EDM), Electrode wear- Ton, Duty cycle, Flushing*

1. Introduction

EDM is a manufacturing method, which could be used to machine hard materials in complex shapes with high precision., EDM has drawn a great deal of researchers' attention because of its broad industrial applications [1]. In EDM process material is removed by a succession of electrical discharges occurring between an electrode and work-piece that are both submerged in a dielectric bath, such as kerosene or distilled water [2]. EDM is extensively used in machining hard, high strength and temperature-resistant materials like high strength steel, tungsten carbide, hardened steel and alloys which are widely used in aerospace, automotive and die industries. In this process material is removed by controlled erosion through a series of electric spark discharges across the gap between electrode (tool) and the work-piece as shown in Fig. 1. In a complete EDM process, machining stages that include rough cut, middle cut and finish cut are carried out sequentially. The thermal energy of the sparks leads to intense heat conditions on the work-piece causing melting and vaporization of work-piece material [3]. Due to high temperature of sparks, not only work-piece material is melted and vaporized, but electrode material is also melted and vaporized, which is known as electrode wear (EW).

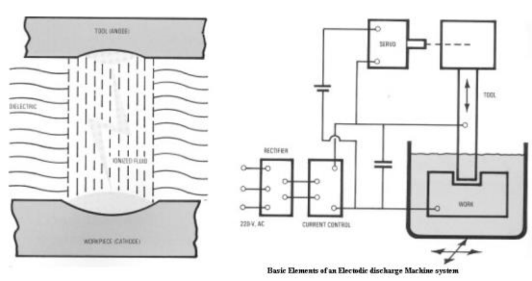

Fig. 1 Systematic Line Diagram of EDM Process

The EW process is quite similar to the material removal mechanism as electrode in EDM [4], which causes the variation in accuracy due to the dimensional loss of electrode. So it is desirable to obtain maximum material removal rate (MRR) with Minimum Electrode Wear. Hence the MRR, WR, EW and Job surface finish R_a are the machining performance criteria's often applied to evaluate the machining effects in each stage. Many process parameters that can be varied in the different machining stages of EDM process greatly affect the machining performances. Subsequently, it becomes important to select properly the process parameter set for different machining stages in order to promote efficiency [5]. Usually the desired process

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parameters are determined based on experience or hand-data-book values. However, it is undoubtedly a challenge to ensure that the selected process parameters result in optimal or near optimal machining performance for that particular EDM and environment.

1.1 Electrical discharge machining process

Electro-discharge machining (EDM) is widely used for machining of hardened tool materials. EDM is a non traditional manufacturing process based on the removing material from the work-piece by means of series of repeated electric discharge between the electrode (tool) and the work-piece in the dielectric liquid. By servo controlled feed of tool electrode, the discharge conditions can be stabilized and the complementary shape of the electrode is impressed upon the work-piece. An electrical spark erosion effect takes place in the EDM process to remove the material of work-piece. Metal removal is on a thermal basis and therefore machinability with EDM is governed by thermal rather than mechanical properties. Various parameters are kept optimum during the process to obtain optimum results.

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1.2 Electrode material (Tool)

Common electrode materials used in EDM Process are graphite, brass, copper and copper-tungsten alloys [6]. As electrode wear is always there in the process because of high temperature sparks, efforts have been done to minimize EW. A metal matrix composite have also developed adding different amount of copper to get an optimum combination of wear resistance, electrical and thermal conductivity [7].

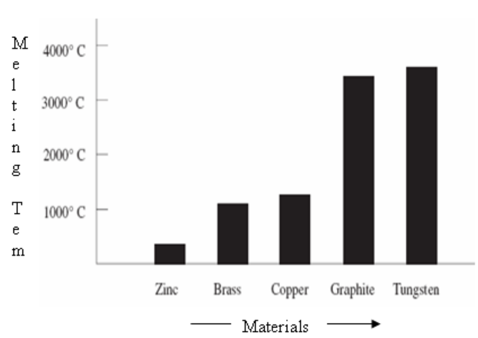

Fig. 2 Melting Temperature of Materials

Copper combination shows more material removal with less EW. Manufacturing of electrodes of special composition of materials have given significant results but they are expensive and not always cost effective. Kunieda suggested that by using a multi-spark electrode discharging system, the MRR can be substantially increased with reduced EW [8]. But again, a special electrode involves additional cost.

1.3 Tool wear

Even after 66 years of EDM, still tool wear is not eliminated completely but it has been reduced to very small level. The tool wear is a very critical problem in EDM because the tool shape degeneration directly affects the final shape of the die cavity. Due to these reasons, the electrode wear should be taken into very careful consideration in planning and designing of EDM operations because the contribution of the tool cost to the total operation cost is more than 70% in most of the EDM Processes.

A power supply delivers high-frequency electric pulses to the tool and the work-piece in EDM. A stream of dielectric liquid is flushed through the Electrode and work-piece. The insulating property of the dielectric fluid is momentarily broken down as an electric pulse is delivered from the power supply, which causes a small spark (discharge) to jump the shortest distances between the tool and work-piece. This results in formation of a small pool of molten metal on the work-piece and the tool at the point of discharge. A gas bubble forms around the discharge and the molten pool. As the electric pulse ceases and the discharge disappears, the gas bubble collapses. The surge of cool dielectric causes the molten metal to be ejected from the work-piece and the tool, leaving small craters. This action is repeated hundreds of thousands of times each second during EDM processing. This removes material from the work-piece in a shape complementary to that of the tool. And it also removes some of the material from the tool electrode that is known as EW. It also affects the accuracy. So a special consideration should be given while designing an electrode (tool) for EDM considering EW. Considering the geometric tool wear characteristics during designing of Electrode (Tool) & EDM process would reduce the error to minimum level, resulting in good quality and cost reduction.

Electrode (tool) wear is generally expressed by means of tool wear rate (TWR) or relative wear and also some times by wear rate. TWR can be calculated by ratio of volumetric material removal from the tool to machining time and can be expressed as

$$TWR = V_E / t_m \quad (1)$$

Where,
V_E is volumetric material removed from tool (mm^3) and
t_m is machining time (min**).**
Work piece removal rate is generally expressed by MRR and can be calculated by ratio of volumetric material removal from the work piece to machining time. It is

expressed as,

$$MRR = V_W / t_m \quad (2)$$

Where,
V_W is volumetric material removed from the work-piece (mm^3) and t_m is machining time (min**).**
Wear Ratio is expressed as TWR/MRR

$$WR = TWR/MRR \quad (3)$$

Although there are some other ways for measuring MRR and EW, normally we can calculate them by weight difference of sample and electrode just before and after being subjected to the EDM process. Many investigations have been conducted on EW in EDM process. An experimental analysis is performed to determine EW ratio in EDM with high carbon steel [9] and during the machining process it was observed that a black layer of carbon was formed on the surface of the electrode, which prevented the electrode from being eroded. It indicates that the EW ratio was strongly associated with carbon film. Luis et al. [10] designed and developed models for MRR and EW using the design of experiment (DOE) method and multiple regression analysis considering generator intensity (I), Pulse time, duty cycle, and dielectric parameters as input parameters and the MRR and EW as responses. It is shown that EW is directly proportional to pulse time.

2. Experimental Setup

The electric discharge machine used in this investigation which was the Electra R 50 Model die sinking machine. Kerosene dielectric was used in the experiment. Fig. 3 and 4 show a machining setup.

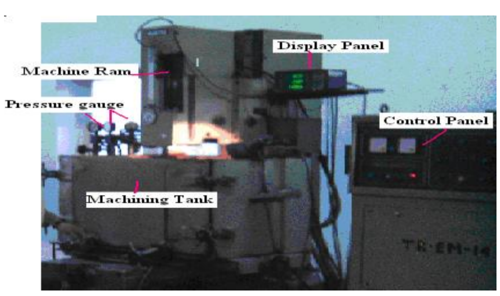

Fig.3 Experimental Setup

2.1 Preparation of work piece

EN-31 steel was used. Work-piece of diameter 22mm & length 30mmwere cut from a bar. Both the surfaces of the specimen were made parallel & ground and harden to HRC 48 using salt bath hardening method. Fig. 5 shows the specimens.

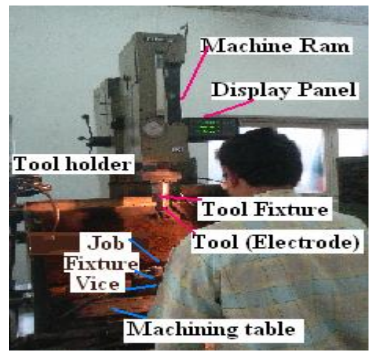

Fig. 4 Machine Setup

2.2 Preparation electrode

Tool was prepared by cutting round copper road of 22mm diameter and 30 mm length. the tool were turn to 20mm diameter & end surfaces are made parallel and ground as shown in Fig. 6.

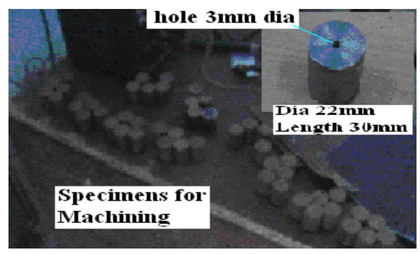

Fig. 5 Different Specimens ready for Machining

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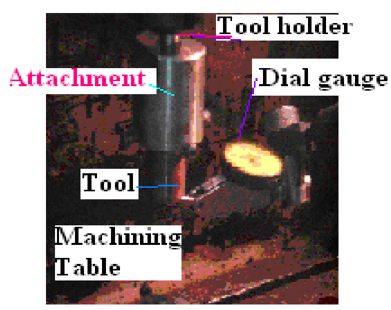

Fig. 6 Setting of Electrode

2.3 Machining parameters

Currents (i_e) of 4,6,8,10,12A , Voltage (V) 30,35,40,45,50V, spark gap 0.3,0.4,0.5, 0.6,0.7mm, Pulse on time (ton) 50,100,150,200,500µs, Duty cycle 6,7,8,9,10 , flushing pressure 0.2,0.4,0.6,0.8,1.0 bar with centre flushing (injection flushing) and side flushing were used. The effect of flushing, current, voltage, spark gap, pulse on time, and pulse off time on electrode wear were investigated by using one variable at- a- time approach. Every experiment was repeated thrice and average of the three values of measurements was used to calculate tool wear keeping machining time for 12 minutes.

2.4 Determination of tool wear

Weight loss of the tool was calculated by weighing the initial and final (after machining) weights of the tool by using digital scale with .001g accuracy china made. The machining time (t_m), measured by a stopwatch, equation 1 is used to calculate tool wear. A digital vernier caliper with accuracy 0.01mm is used to measure the length of the tool before and after the machining loss in the length of the tool was calculated by taking the difference between initial and final length measurements.

Fig. 7 Different Specimens Ready after Machining for Measurement

3. Experimental Results and Discussion

3.1 Centre flushing

Effect of current is shown in the Fig. 8**.** The tool wear is increasing as the current increases. At low current TWR is increasing at low rate with crease in the current but at high current TWR increases at high rate.

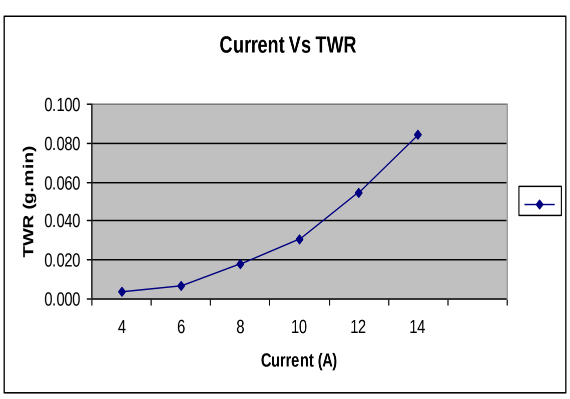

Fig. 8 Effect of Current on TWR

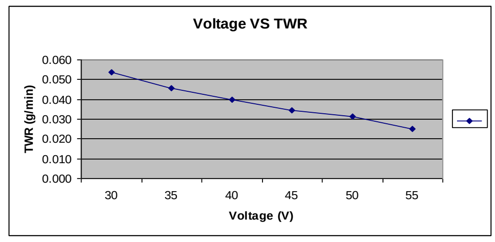

Fig. 9 Effect of Voltage on TWR

Effect of voltage is shown in the Fig. 9**.** The tool wear rate decreases with increase in the voltage. Effect of spark gap is shown in the Fig. 10 with increase in the spark gap tool wear is decrease in the initial stage at comparatively low rate and then starts increasing after reaching a point from the Fig. 8 it is clear that upto 0.5 mm spark gap tool wear rate is decreasing and above 0.5mm spark gap tool wear is increased significantly with increase in the spark gap.

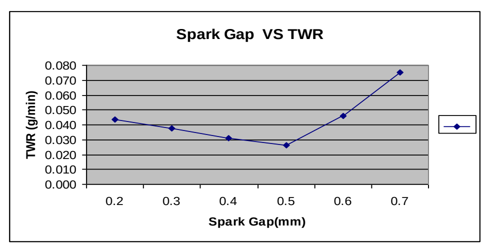

Fig. 10 Effect of Spark Gap on TWR

Effect on Ton is shown in the Fig. 11**,** tool wear rate decreases with increase in the Ton. It clearly shows that at lower t_{on} the rate of decrease in tool wears is higher as compared to the higher t_{on}.

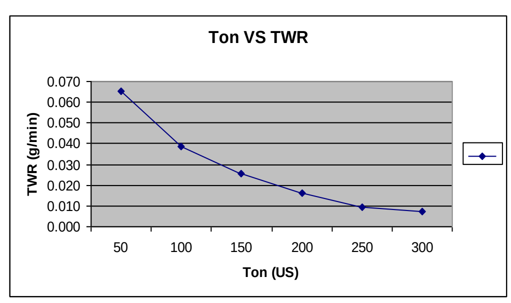

Fig. 11 Effect of Ton on TWR

Effect of duty cycle is shown in the Fig. 12**,** tool wear rate increases and decreases at very low rate with increase in the duty cycle.

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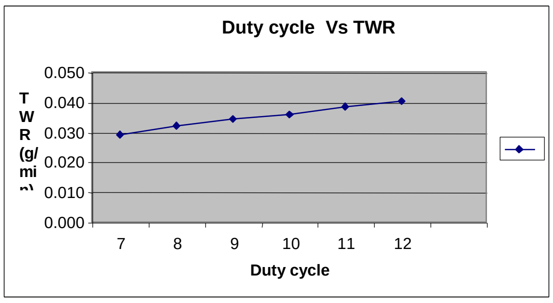

Fig. 12 Effect of Duty cycle on TWR

Flushing pressure is shown in the Fig. 13. The tool wear is reduced with the increase of flushing pressure at the initial stage but after reaching to a point it starts increasing significantly with increase in flushing pressure.

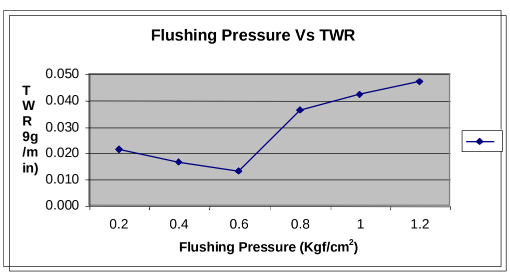

Fig. 13 Effect of Flushing Pressure on TWR

3.2 Side flushing

Effect of current is shown in the Fig. 14, tool wear is increasing as the current increases. At low current TWR is increasing at high low with increase in the current but at high current TWR increases at very low rate with increase in current.

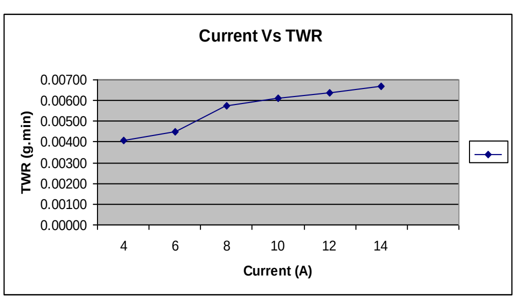

Fig. 14 Effect of Current on TWR

Effect of voltage is shown in the Fig. 15**,** tool wear rate increases with increase in the voltage. Figure clearly shows that at lower voltage the rates of increase in tool wear is lesser than the rate of tool wear at higher voltage.

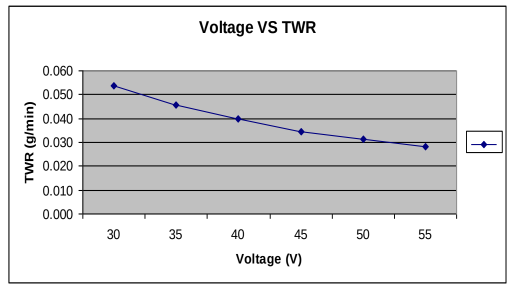

Fig. 15 Effect of Voltage on TWR

Effect of spark gap is shown in the Fig. 16 with increase in the spark gap tool wear is decrease in the initial stage and the starts increasing after reaching a point from the Fig. it is clear that up to 0.5 mm spark gap tool wear rate is decreasing and above 0.5mm spark gap tool wear is increased significantly as increase in spark gap.

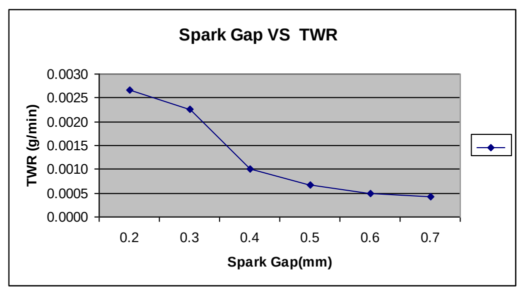

Fig. 16 Effect of Spark Gap on TWR

Effect on Ton is shown in the Fig. 17**,** tool wear rate increases with increase in the Ton. Fig. 17 clearly shows that at higher ton the rate of increase in tool wear is higher as compared to the lower ton.

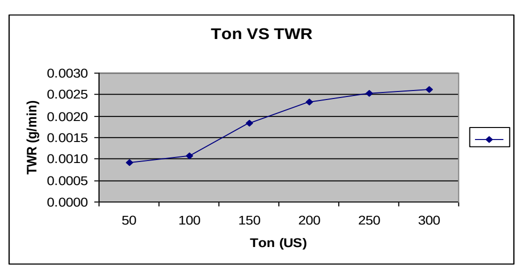

Fig. 17 Effect of Ton on TWR

Effect of duty cycle is shown in the Fig. 18**,** tool wear rate decreases with increase in the duty cycle. Fig. 16 clearly shows that tool wear is decreases with increase of duty cycle.

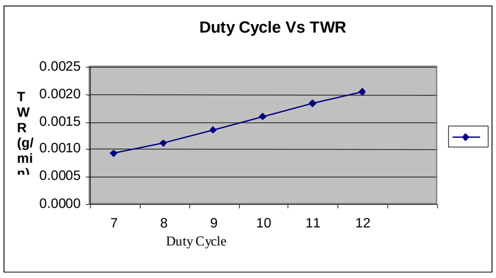

Fig. 18 Effect of Duty Cycle on TWR

Flushing pressure is shown in the Fig. 19 the tool wear is reduced with the increase of flushing pressure. Fig.17 shows that at very low flushing pressure tool wear is decreased significantly with increase in flushing pressure, but after reaching to an optimum flushing pressure tool wear rate decreases at low rate with the increase of flushing pressure.

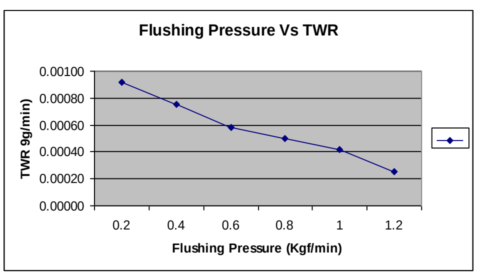

Fig. 19 Effect of Flushing Pressure on TWR

4. Conclusion

The effects of various parameters like current, voltage, spark gap, T_{on}, duty cycle, flushing rate, and flushing methods on Electrode wear are studied dielectric flushing method, pulse duration, tool geometry and powder particles in dielectric on the performance measures like MRR, EWR, R_a and relative wear are considered. The following conclusions can be drawn

i. The Electrode wear increases with the increase of current and gap voltage.
ii. In the centre flushing tool wear rate is higher than the side flushing but if we observe in all the aspects considering MRR & surface roughness. It is recommended to use centre flushing because in side flushing MRR is also very low.
iii. Tool wear rate is higher at high flushing pressure.
iv. Tool wear rate is higher at high current off and also high at high Duty cycle.
v. It is also observed that at high voltage Tool wear rate is low.

From all the observations it is found that the optimum machining parameters for minimum electrode wear of copper electrode working on EN31 kept as follow to get optimum output**.** Table 1 shows the optimum machining parameter.

Table 1: Optimum Machining Parameter

Current	Voltage	Spark gap	Ton	Toff	Flushing pressure
Amperes	Volts	mm	µSec	µSec	Kgf/cm^2
6-8	40-45	100-150	100	0.4-0.6	0.6

References

1. *Zarepour H, Tehrani A F, Karimi D and Amini S (2007), "Statistical Analysis on Electrode Wear in EDM of Tool Steel DIN 1.2714 used in Forging Dies", Journal of Material Processing Technology, Vol. 187-188, pp 711-714.*

2. *Shu K M and Tu G C (2003), "Study of Electric Discharge Grinding using Metal Matrix Composite Electrode", International Journal of Machine Tool Manufacturing, Vol. 43, pp 845-854.*

3. *Yan B H, Tsai H C and Huang F Y (2005), "The Effect of EDM of Dielectric of a Urea Solution in Water on Modified Surface of Titanium", International Journal of Machine Tool Manufacturing, Vol. 45(2), pp 194-200.*

4. *Ho K H and Newman S T (2003), "State of Art Electric Discharge Machining (EDM)", International Journal Machine Tool Manufacturing, Vol. 43(13), pp 1287-130.*

5. *McGeough J A (1988), "Advanced Methods of Machining", Chapman and Hall, New York.*

6. *Kalpakjian S and Schmid S R (2001), "Manufacturing Engineering and Technology", 4th Edn. Prentice Hall, Upper saddle River*

7. *Khanra A K, Sarker B R, Bhattacharya B, Parthak L C and Godkhindi M M (2007), "Performance of ZRB2-Cu Composite as an EDM Electrode", Journal of Material Processing Technology, Vol. 1831, pp 122-126.*

8. *Kunieda M and Muto H (2000), "Development of Multi-Spark EDM". ANN CIPR, Vol. 49(1), pp 119-122.*

9. *Marafona J (2007), "Black Layer Characterization and Electrical Discharge Machining", Journal of Material Processing Technology, Vol. 184, pp 27-31.*

10. *Luis C J, Puertas I and villa G (2005), "Material Removal Rate and Electrode Wear Study on EDM of Silicon Carbide", Journal of Material Processing Technology, Vol. 164-165, pp 889-896.*

