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Investigative Study on Metal Removal Rate and Tool Wear Rate in Electric Discharge Machining of H11 Using Different Electrode Material

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Abstract : *H11, known as hot die steel, has wide applications in hot working forging dies, highly stressed plastic moulds, helicopter rotor blades and mandrels. This paper is an attempt to find the effects of pulse-on time (T_{on}) on material removal rate (MRR) and tool wear rate (TWR) during electric discharge machining of H11 using three different tool materials. The experiments have been conducted on die-sinking EDM by varying T_{on} in four steps while keeping the values of other parameters constant. Copper, Copper Tungsten and Graphite have been used as the tool materials. On the basis of experimental results, the effects of T_{on} on MRR and TWR have been reported for each tool material separately. Finally a comparison of all three tool materials has been presented.*

Keywords: *EDM, MRR, TWR, T_{on}, H11*

1. INTRODUCTION

AISI H11, a 5% Chromium based special tool steel, is used in fabrication of special tools, aircraft landing gears and helicopter rotor blades [1-3]. Having less carbon content in comparison to other tool steels, it belongs to hot work chromium steel (H10-H19) category. Owing to its high excellent shear strength, high thermal resistance and high temperature ability, H11 find its application in die casting moulds and inserts. It has high tool life expectancy and can be used for manufacturing of hot work dies such as forging dies, extrusion dies etc. [4]

Machining of H11 on conventional machines is difficult due to its mechanical and metallurgical properties. Non-conventional machines such as EDM are found to be a better choice to machine H11 with great accuracy and surface finish. EDM is characterized by the absence of plastic deformation and chip formation. In this process, material is removed by a series of continuous electrical discharges which take place between tool electrode and the work piece separated by a dielectric medium. A temperature of around 8000 to 12000^0C is generated by the discharge energy at the point of the spark that is sufficient to vaporize the work piece and tool material. The vaporized material is flushed away by dielectric fluid when the spark is off. Since the spark is generated between tool and work piece, the tool material has its own importance in respect of machining performance. High melting point and good thermal conductivity are normally the desired characteristics of tool material. Many authors have shown how machining performance may vary by changing the tool material. The most important performance output measures in EDM process are the Metal removal rate (MRR), Tool wear rate (TWR) and Surface Roughness (SR) [5]. Efforts are made for obtaining high MRR and low TWR. In the past, many methods were studied to improve MRR and TWR in EDM process by taking different input parameters. Payal et al. [6] studied the surface integrity of H11 and H13 material by taking three different electrodes i.e. copper, graphite and aluminum. They concluded that out of the three electrode copper electrode offered maximum surface finish. Singh et al. [7] presented an experimental investigation for EDM on H11 tool steel .It was found that negative polarity and suspension of powder particles in the dielectric fluid reduces the surface roughness. Kapila and Kumar [8] investigated H11 material by taking conventional copper and powder metallurgy electrode i.e. CuW. The results revealed that conventional copper electrode provided best MRR in positive polarity. Singh and Kumar [9] investigated and compared the effect of powder metallurgy electrode and cryogenically treated electrode on H11 tool steel .It was found that copper tungsten electrode with negative polarity showed a better MRR. Mathew et al. [10] studied the MRR by taking conventional copper and powder metallurgy copper tungsten electrode as tool material. It was observed that conventional copper electrode at reverse polarity gives best MRR in comparison with powder metallurgy tool electrode. Gill and Kumar [11] studied the wear effect by taking H11 as work piece and aluminum as electrode. They treated the aluminum electrode by cryogenic and non-cryogenic process. The results revealed that cryogenic treated Al electrode showed better results.

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In this work, an experimental investigation has been carried out for electric discharge machining of H11 tool steel with an objective to compare the performance of three different electrode materials copper (Cu), copper-tungsten (CuW) and graphite (Gr) on MRR and TWR. The effect of pulse-on-time has been studied on MRR and TWR by taking different electrode materials.

2. EXPERIMENTATION

The Experiments were conducted on Electronica ZNC die sinking EDM as shown in figure 1. AISI H11 tool steel has been taken as work material. The size of the work piece has been taken as 40mmx36mmx18mm for the present experiments. Three different tool electrodes namely Cu, CuW (Cu20%W80%) and Gr have been used during experimentation. The various electrodes used are shown in figure 2. The properties of different tool material have been shown in table 4.The mechanical properties and chemical composition of H11 have been shown in table 1 and table 2 respectively. Pulse-on-time has been varied in four steps. The values of the rest of the parameter were fixed during experimentation. Table 3 represents the details of the parameter taken during experimentation. The MRR and TWR are calculated by the following equation:

$$\text{MRR or TWR } (mm^3/\min) = \frac{\text{Reduction in weight of work piece or electrode (g)}}{\text{Density of work piece or electrode } (g/mm^3) \text{ x machining time (min)}}$$

The initial and final weights of electrode and work piece are measured by electronic weighing balance of make Shimadzu ATX224 having a resolution of 10mg.

TABLE 1: Mechanical properties of H11

Property	Unit	Value
Density	g/cm^3	7.81
Melting Point	°C	1427
Elastic modulus	GPa	207
Thermal expansion	(10-6/°C)	11.9
Thermal conductivity	(W/m-K)	42.2
Hardness	HRC	57

TABLE 2: Chemical composition (wt %) of H11 material

Elements	Composition (wt %)
C	0.648
Si	0.603
Mn	0.262
P	0.0078
S	0.0145
Cr	5.17
Mo	1.23
V	0.756

TABLE 3: Experimental Conditions

Pulse on Time	10µs,20µs,30µs,40µs
Sparking Voltage	60V
Current	8A
Dielectric used	Spark Erosion oil (SEO-250)
Polarity	Straight
Servo system	Electro Hydraulic
Electrode polarity	Negative
SEN	6
ASEN	4

TABLE 4: Electrode material properties

Material	Graphite	Copper	Copper tungsten
Composition		99.9% copper	20% Cu + 80% W
Density(g/cm^3)	1.811	8.904	15.2
Melting point(^{o}C)	3350	1083	3500
Electrical resistivity(Ωmm^2/m)	10	9	5.5

Fig. 1. EDM Machine

Fig. 2. Electrodes Gr,CuW,Cu

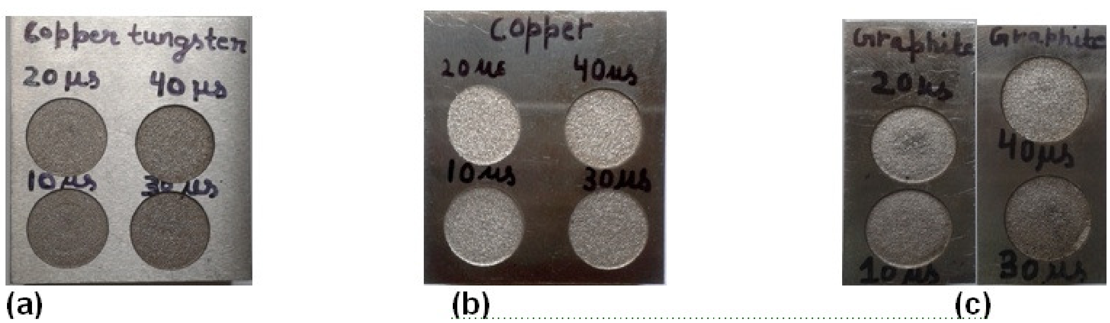

Fig. 3. Copper- tungsten (a) and copper (b) graphite (c)

3. RESULTS AND DISCUSSION

On the basis of the experimental results, the effect of pulse-on-time on MRR and TWR with different tool electrode material has been given in subsequent section.

3.1 EFFECT OF PULSE ON TIME ON MATERIAL REMOVAL RATE (MRR)

The values of metal removal rate (for different tool materials) with different values of pulse-on-time have been reported in table 5. Figure 4 shows the graph between pulse-on-time and MRR that has been drawn on the basis of values as given in table 5.Figure 4 shows that MRR increases with increase in pulse-on-time. This is due to fact that as pulse-on-time is more the more energy is discharge during spark which results in removal of more material from the work piece. The longer the period of spark the broader and deeper would be the size of the craters formed at the surface .On the basis of experimental results it is observed that Gr tool offers the best MRR followed by Cu and CuW respectively.

TABLE 5: MRR with Cu, CuW, Gr electrodes at different pulse- on- time

Pulse on Time (µs)	MRR by Cu (mm^3/min)	MRR by CuW (mm^3/min)	MRR by Gr (mm^3/min)
10	3.2031	2.8123	3.8056
20	3.9032	3.6131	4.5928
30	4.4972	4.3261	4.7669
40	5.6431	5.1242	5.8669

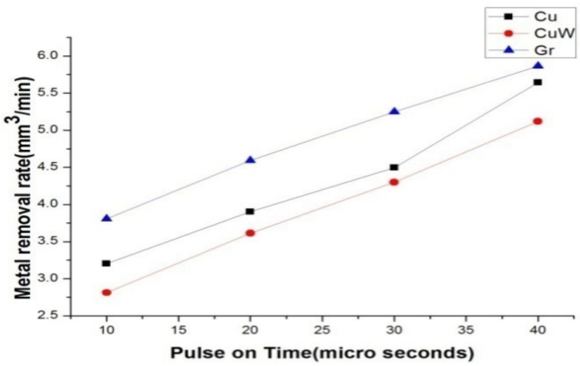

Fig. 4. Pulse on Time vs MRR

3.2 EFFECT OF PULSE ON TIME ON TOOL WEAR RATE (TWR)

The value of TWR (for different material) with different value of pulse-on-time has been reported in table 6 and corresponding graph has been shown in Figure 5. Figure 5 shows that TWR decreases with increase in pulse-on-time. This is due to the fact that more pulse duration means more amount of heat transfer from plasma channel to the tool electrode which ultimately leads to heat dissipation through the surface of tool electrode. It is observed that CuW offers lowest TWR followed by Cu and Gr. The thermal conductivity and melting point of the tool electrode are the key factors on which TWR depends.

TABLE 6: TWR with Cu, CuW, Gr electrodes at different pulse- on- time

Pulse on Time (μs)	TWR by Cu (mm^3/min)	TWR by CuW (mm^3/min)	TWR by Gr (mm^3/min)
10	1.012	0.612	2.7363
20	0.91	0.4212	1.7412
30	0.712	0.3123	0.9950
40	0.412	0.0957	0.5572

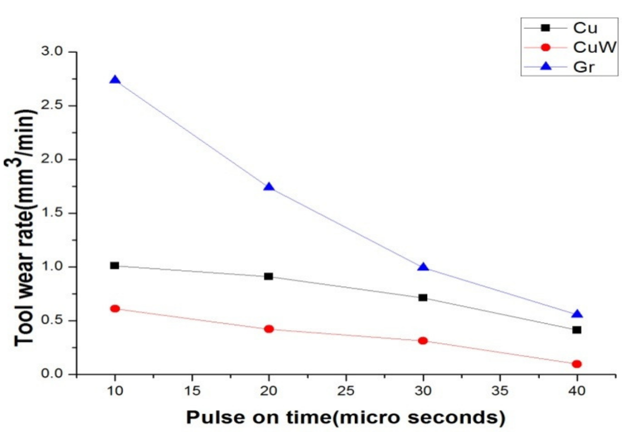

Fig. 5. Pulse on time vs TWR

4. CONCLUSIONS

On the basis of experimental results for electrical discharge machining of H11 tool steel by three different tool electrode materials (Cu, CuW and Gr), it is concluded that Gr offers the highest MRR and CuW offers lowest TWR. On the contrary, Gr offers the lowest MRR and CuW offers highest TWR.

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