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Experimental Studies for Material Removal Rate on AISI D2 Steel using Electrical Discharge Machining

Praveen Kumar Singh[1], Dinesh Kumar Rao[2] and Anshika Gupta[3]
[1]Faculty of Mechanical Engineering, UTU Dehradun. Uttarakhand
[2]Department of Mechanical Engineering, AITS, Haldwani, Uttarakhand.
[3]Department of Industrial and Production Engineering, GBPUAT, Pantnagar, Uttarakhand

ABSTRACT: The electric discharge machining (EDM) is one of the most up-to-date non-traditional machining processes, based on thermo-electric energy between the work piece and an electrode (tool). In this machining method, the material is removed electro thermally by a series of consecutive separate discharges between two electrically conductive materials (electrode and work piece). The performance of the machining process depends on the material, design and manufacturing method of the electrodes. Generally, the machine maker uses the average work piece and electrode materials to establish the EDM parameter settings. The current study paying attention on the effect of Copper and Brass tools on material removal rate (MRR) for AISI (American Iron Steel Institute) D2 tool steel by using Die- Sinker EDM. The current was varied from 4 to 10 amp, the electrical voltage and flushing pressure were constant, the MRR for copper electrode was in the range of 4.8923 -21.9580 mm^3/min whereas the range of MRR for brass electrode was 8.0013-9.7903 mm^3/min. The MRR for copper electrode was continuously decreasing with voltage whereas MRR for brass follow a definite development. The MRR for both the electrodes increases with current. It has been observed that copper electrode is the best for machining AISI D2 tool steel by using Die- Sinker EDM for large material removal rate.

Keywords: AISI, EDM, MRR, D2.

I. INTRODUCTION

Electric Discharge Machining (EDM) is a non-traditional machining process in the logic that they do not employ traditional tools and they do not touch with each other for metal removal and instead directly by means of electric spark erosion. The problems of high Complexity in shape, size and higher demand for as removal rate increases, the cost effectiveness of operations also increase, stimulating ever greater uses of nontraditional process [1]. The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts. It is 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. So it is one of the well-liked non-traditional machining processes being used today. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, as well as automotive areas. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Tool and Work material to be machined by EDM has to be electrically conductive [2].

II. WORKING PRINCIPAL OF EDM

In this course of action the metal is eroding from the work piece due to thermoelectric effects case by fast frequent spark discharge taking place between the electrode and work piece. Figure 1 shows the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap approx 0.025 mm is maintained between the tool and work piece by a servo system shown in Fig.1. The tool and work piece are submerged in a dielectric solution. Kerosene/EDM oil/de-ionized water is very ordinary type of liquid dielectric although gaseous dielectrics are also used in certain cases [3]. The electric setup of the Electric discharge machining is shown in Fig. 1. The tool is made cathode and work piece is anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark. The positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons which create a channel of plasma. Such localized tremendous rise in temperature leads to material removal. The material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially from the work piece [4].

III. TOOL MATERIAL

In this experiment we uses two different materials tool namely as copper and brass.

A. COPPER electrode

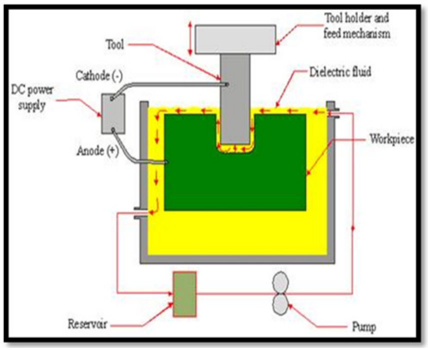

Fig. 1. Working principle of EDM [10].

With improvement of the transistorized, pulse-type power supplies, electrolytic (or pure) Copper became the metallic electrode material of choice. This is because the combination of Copper and certain power supply settings enables low wear burning. The Copper is compatible with the polishing circuits of certain advanced power supplies. Due to its structural integrity, Copper can produce very fine surface finish. This same structural integrity also makes Copper electrodes highly resistant to Direct Current (DC) arcing in poor flushing situations. The Copper is frequently used to make female electrodes on a Wire EDM for subsequent use in reverse burning punches and cores in the Sinker EDM. The addition of 1-3% Tellurium to Copper improves its machinability to a level similar to Brass, eliminating the "gummy" properties normally exhibited by Copper when it is machined **[9]**.

B. BRASS electrode

Brass ensures stable sparking conditions and is normally used for specialized applications such as drilling of small holes where the high electrode wear is acceptable. In addition to the servo-controlled feed, the tool electrode may have an additional rotary or orbiting motion. Electrode rotation helps to solve the flushing difficulty encountered when machining small holes with EDM. The increase in cutting speed, the quality of the hole produced is superior to that obtained using a stationary electrode. Electrode orbiting produces cavities having the shape of the electrode. The size of the electrode and the radius of the orbit (2.54 mm maximum) determine the size of the cavities. Electrode orbiting improves flushing by creating a pumping effect of the dielectric liquid through the gap [7].

IV. LITERATURE REVIEW

It was investigated that the wet and near-dry electrical discharge machining is used to achieve the high material removal rate (MRR) on oil hardened non shrinking steel. In near-dry EDM liquid and air mixture delivered through a tabular electrode instead of liquid dielectric used in Wet EDM. The L-9 orthogonal array was applied to investigate the effect of discharge current, pulse on time, gap voltage and pulse off time on material removal rate in wet and near-dry EDM. Pulse on time and discharge current are identified as a key factors for improving the MRR in wet and near-dry EDM. The comparative performance of wet and near-dry EDM has been made. During experiments it was found that the Wet EDM exhibits the advantage of good machining stability at high discharge energy which results in better MRR [1].

It was investigated the surface modification by using EDM with powder metallurgy (PM) tool electrodes as well as powders suspended in the dielectric fluid. The experimental results were presented on the surface alloying of AISI H13 hot work tool steel during a die sink operation by applying partially sintered WC/Co electrodes operated in a hydrocarbon oil dielectric. The L8 fractional factorial Taguchi experiment was used to identify the effect of key in service factors on output measures. With respect to micro hardness, the percentage contribution ratios (PCR) for peak current, electrode polarity and pulse on time was very low [5].

The researchers carried out the work on comparative analysis of milling of copper and graphite electrodes for EDM and identifying machine capabilities. In this work a tool (cost calculator) is developed to be used on the shop floor for a plastic injection mould manufacturing company for the comparative analysis of Copper and Graphite electrode of EDM. They recommend that the use of the cost calculator reduce the cost and time for producing electrodes and provides the flexibility to change the values fed in the calculator may be customize for ready use by any other tool shop[8].

The performance of the manufacturing process depending on the Electrode material, Work piece material, and manufacturing method of the electrodes as reported by Nikhil et al. [9]. A suitable selection of electrode can reduce the cost of machining. Copper and graphite electrode are used for optimizing Performance parameters and reducing cost of manufacturing. finally it is found that a graphite electrode give better performance in certain characteristics but the cost become high for machining so keeping in mind cost and other some characteristics a graphite electrode is more suitable than Copper electrode in case of both (Material Removal Rate)MRR and (Tool Wear Rate)TWR [9].

V. EXPERIMENTAL SET-UP

For this experimentation the entire work can be done by Electric Discharge Machine, model ELECTRONICA C-3822 (die-sinking type) with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments. A constant voltage (40V), flushing pressure (20 kg/cm^2) and Ton, T_{off} setting was 30 and 9 respectively. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94°C) was used as dielectric fluid. Experiments were conducted with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode.

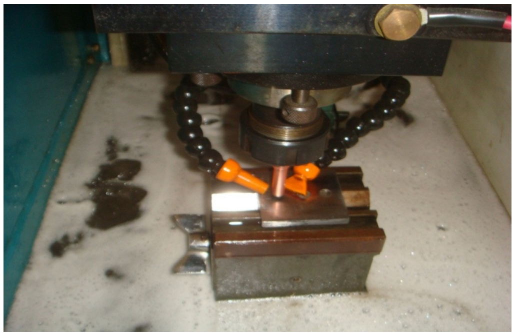

Fig. 2. Positions of Tool and Work piece.

In this experiment using AISI D2 tool steel material this D2 tool steel material is high Carbon, high Chromium tool steel alloyed with Molybdenum and Vanadium. The work piece material composition is given in table below.

Table 1: Composition of AISI D2 material.

Element	C	Mn	Si	Cr	Ni	Co	V	Fe
Composition Weight (%)	1.5	0.3	0.3	12	0.3	1.0	0.8	Remaining

Material removal rate(MRR)

The Material removal rate is expressed as the weight of material removed from work piece over a period of machining time in minutes.

$$MRR = \frac{Wb - Wa}{t * \rho}$$

Where

W_b = Weight of the work piece before machining
W_a = Weight of the work piece after machining
t = Machining time
ρ = Density of the work material (7.7 x 1000 kg/m^3)

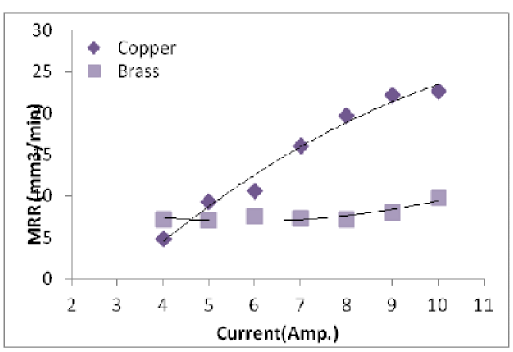

Fig. 3. Outcome of current on MRR for Copper and Brass electrode.

Fig. 3 shows the effect of current on MRR for Copper and Brass electrode. The MRR from work material is increases with increase in applied current for both the electrodes. This is due to the increase in current; the flow of electron increases which results in higher MRR as shown in Fig.3 The curve depicts that MRR for Copper increases from 4.8139 to 22.6580, whereas MRR for Brass increases from 7.2213 to 9.8203.This shows vast increase in MRR for Copper electrode in comparison to Brass electrode.

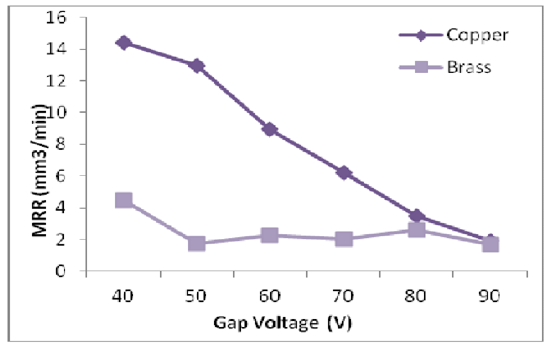

Fig. 4. Outcome of Gap Voltage on MRR for Copper and Brass electrode.

Figure 4 shows the effect of gap voltage on MRR for Copper and Brass electrodes. The MRR for D2 tool steel decreases with increase in the gap voltage for both Copper and Brass electrodes. It has been found that the MRR for Copper decreased from 14.3939mm^3/min to 1.6840 mm^3/min, whereas MRR of Brass decreased from 4.4740mm^3/min to 1.6840 mm^3/min. This shows massive decrease in MRR of Copper electrodes in comparison to Brass electrodes.

VI. CONCLUSION

The choice of the input parameters of the EDM process depends largely on the material combination of electrode and work piece. So the EDM manufactures only supply these parameters for a limited amount of material combinations. Parametric study on D2 tool steel was carried out for MRR by using EDM with Copper and Brass electrodes. It was found that the MRR was maximum for Copper electrode.

So following are the results,

1-In case of increasing the value of current Copper gives better MRR than Brass.

2- In case of increasing the value of gap voltage for both Brass and Copper, MRR will decrease.

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