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Study of the Effect of Machining Parameters on the Machining Characteristics of Tungsten Carbide in Electrical Discharge Machine

Subhakanta Nayak *, Puspa Ranjan Swain

*Asst. Professor, Mechanical Department, College of Engineering Bhubaneswar, India

subha.nayak2007@gmail.com

Abstract

Electrical discharge machining (EDM) is a widely used process in the mould / die and aerospace industries. It is a process for shaping hard metals and forming deep and complex-shaped holes by arc erosion in all kinds of electro-conductive materials. The objective of this research is to study the influence of operating parameters of EDM of tungsten carbide on the machining characteristics. The effectiveness of EDM process with tungsten carbide is evaluated in terms of material removal rate, the relative wear ratio and the surface finish quality of the workpiece produced. It is observed that copper tungsten is most suitable for use as the tool electrode in EDM of tungsten carbide.

Keywords: Electrical discharge machining, material removal rate, wear rate, surface roughness.

Introduction

Diesel engines are typically characterized by low fuel consumption and very low CO₂ emissions. In the beginning they were used in power tractors and heavy trucks, but now they increasingly used in smaller trucks and passenger cars due to their low fuel consumption. However, from a pollution aspect, the Electrical Discharge Machining (EDM) is a non-traditional manufacturing process based on removing material from a part by means of a series of repeated electrical discharges (created by electric pulse generators at short intervals) between a tool, called electrode, and the part being machined in the presence of a dielectric fluid [2]. Electrical Discharge Machining (EDM) is a process that is used to remove metal through the action of an electric discharge of short duration and high current density between the tool and the work piece. It has been proven to be especially valuable in the machining of super-tough, electrically conductive materials such as the new space-age alloys. These metals would have been difficult to machine by conventional methods, but EDM has made it relatively simple to machine intricate shapes that would be impossible to produce with conventional cutting tools. This machining process is continually finding further applications in metal machining industry. It is being used extensively in plastic industry to produce cavities of almost any shape in metal moulds. In EDM, a potential difference is applied between the tool and

work-piece. Both the tool and the work material are to be conductors of electricity. The tool and the work material are immersed in a dielectric medium. Generally kerosene or de-ionized water is used as the dielectric medium. A gap is maintained between the tool and the work-piece. Depending upon the applied potential difference and the gap between the tool and work-piece, an electric field would be established. Generally the tool is connected to the negative terminal of the generator and the work-piece is connected to positive terminal. As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces. If the work function or the bonding energy of the electrons is less, electrons would be emitted from the tool (assuming it to be connected to the negative terminal). Such emission of electrons are called or termed as cold emission. The "cold emitted" electrons are then accelerated towards the job through the dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionization of the dielectric molecule depending upon the work function or ionization energy of the dielectric molecule and the energy of the electron. Thus, as the electrons get accelerated, more positive ions and electrons would get generated due to collisions. This cyclic process would increase the

concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap. The concentration would be so high that the matter existing in that channel could be characterized as “plasma”. The electrical resistance of such plasma channel would be very less. Thus all of a sudden, a large number of electrons will flow from the tool to the job and ions from the job to the tool. This is called avalanche motion of electrons. Such movement of electrons and ions can be visually seen as a spark. Thus the electrical energy is dissipated as the thermal energy of the spark.

The high speed electrons then impinge on the job and ions on the tool. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux. Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000°C. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting.

C.H. Che Haron et al. [3] has taken copper electrodes of different diameters and done machining in EDM of AISI 1045 tool steel at two current settings and concluded that the material removal rate and the electrode wear rate were not only dependent on the diameter of the electrode but also had close relation with the supply of current. Same result has been found by S.H Lee [1] by machining tungsten carbide with Cu, CuW and Graphite electrodes.

I. Puertas et al. [5] has concluded the same result in machining WC-Co in EDM. Lau et al. [6] carried out an experiment work to investigate the feasibility of EDM as a means of machining carbon fiber composite materials. The machining was conducted at various currents, pulse durations and with different tool materials and polarities. It was clearly concluded that there exists an optimum material removal rate with peak current and pulse on time. It was again proved that copper electrodes perform better than graphite electrodes in terms of tool wear and surface finish. M. Kiyak (4) has examined the machining parameters on surface roughness in EDM of tool steel and has concluded that surface roughness increases with increase of pulse current and pulse time and increases material removal rate.

The aim of the project is to study the effect of the machining parameters in EDM of tungsten carbide on the machining characteristics. The characteristic of EDM refer essentially to output machining parameters such as material removal rate

(MRR), relative wear rate (RWR) and surface roughness (Ra). The machining parameters are the input parameters of the EDM machine i.e. electrode material and current.

Experimental Setup

During this study, a series of experiments were conducted on ECOWIN MIC-432C electrical discharge machine to examine the effects of input parameters such as electrode material and current on the machining rate and workpiece surface roughness. In the tests, the machining characteristics i.e. material removal rate, relative wear ratio and surface roughness were measured using different techniques and equipments.

Machine tool

The ECOWIN 432C machine is a die-sinking machine manufactured by Ecowin Corporation, Taiwan. It is energized by a 60 A pulse generator. Paraffin was used as dielectric fluid during the experiments. All the machining work has been done in this machine taking separate copper electrode and tungsten carbide as work-piece for individual experiments. The surface roughness of the workpiece was measured by using a portable style type profilometer, Talysurf (Taylor Hobson, Surtronic 25+).

Workpiece Material

The workpiece material used in this study was tungsten carbide material, having the following properties shown in Table 1.

Table 1. Properties of workpiece material

1. Density (g/cm ³)	15.1
2. Melting Point (°C)	2597
3. Hardness	HRA87.0
4. Tensile Strength (kg/mm ²)	179
5. Compressive Strength (kg/mm ²)	410
6. Toughness (kg/mm ²)	50

Electrode Material

The electrode material used in this research was graphite, copper and copper tungsten and their properties are listed below.

Table2. Electrode material properties

Material	Graphite	Copper	Copper Tungsten
Composition		99.9% copper	75% tungsten, 25% copper
Density (gm/cm ³)	1.811	8.904	15.2
Melting Point(°C)	3350	1083	3500
Electrical Resistivity	1400	9	5.5
Hardness	HB 10	HB100	HB200

Experimental Procedure

During this study a series of experiments on tungsten carbide were carried out using different machining parameters settings with copper, graphite and copper tungsten electrodes. The machining performance was obtained by calculating the material removal rate, relative wear ratio and surface finish.

The effect of electrode material was studied in the successive experiments conducted. In this experiment, electrode material was selected based on the material removal rate, relative wear rate and surface roughness under different current settings.

Results and discussion

In this study, the machining parameters studied were the types of electrode materials and current whereas the machining characteristic factors evaluated were material removal rate (mm³/min), relative wear ratio (%) and machined workpiece surface roughness, Ra (μm).

Material removal rate represents the average volume of material removed from the workpiece per unit time and the relative wear ratio is calculated as the volume of material eroded from the tool electrode per unit time divided by the volume of material eroded from the workpiece in the same time. The surface roughness is Ra, which is the arithmetic mean deviation of the surface height from the mean line through the profile while the mean line is defined so as to have equal areas of the profile above and below it.

Effect of type of electrode material

The effect of type of electrode materials on EDM characteristics are shown in figures 1-3, respectively, for varying currents and copper (Cu), graphite (Gr) and copper tungsten (CuW) as the tool electrode materials with negative polarity and tungsten carbide as the workpiece material.

Figure 1 shows the effect of current on the workpiece material removal rate for copper, graphite and copper tungsten material. The graph shows that with the increase in current the material removal rate also increases. It is almost directly proportional for all the three electrode materials. The graphite electrode gives the highest material removal rate followed by copper tungsten and then copper.

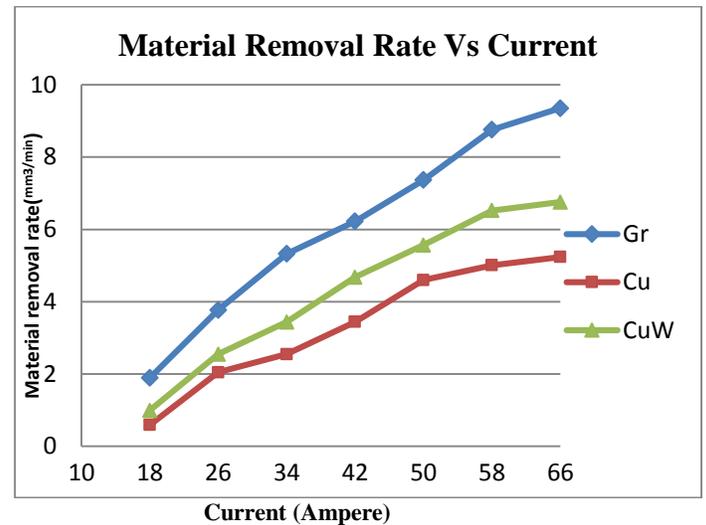
**Figure1.Effect of electrode material on material removal rate**

Figure 2 shows the effect of current on the relative wear ratio for copper, graphite and copper tungsten material. The graph shows that when machining with copper tungsten electrode, the relative wear ratio is maintained at a level below 22% for the whole range of current settings. Electrode wear ratio is the least for CuW as compared with Cu and Gr electrode material. The relative wear ratio produced using copper tool increases from 42% at 18 A to about 116% at 34A and after that it remain almost constant up to 66 A. The relative wear ratio produced while machining using graphite electrode lies in between 64% to 100%. It can be seen from the graph that the relative wear ratio for all the three electrodes are almost constant after a current setting of 34A. Here we can see that the graph of copper is very different from that of copper tungsten and graphite. This is because generally copper electrode is used as positive electrode polarity, but here it is used as negative polarity just for comparison purpose.

Figure 3 shows the effect of current on the workpiece surface roughness for copper, graphite and copper tungsten material. It shows that the surface finish of the workpiece is the best when machined

with copper electrode material and poorest when machined with graphite electrode material.

Electrode material required must be electrically conductive and maintain a good tool-to-workpiece wear ratio. The material best suited must have a very high melting point and a very low resistance to electricity. Copper, Copper tungsten and graphite material are very widely used. Electrode wear is dependent on the electrode materials and the energy of discharge. The higher the melting point the lower the electrode wear (melting point of CuW = 3500°C, Gr = 3300°C and Cu = 1083°C). It was found that the electrode wear rate is inversely proportional to the melting point of the electrodes. Copper tungsten has the highest melting temperature hence lowest tool wear which has been observed in figure 2.

The figures 1-3 shows that the choice of electrode tool material from the point of view of high machining rate should be graphite while from the point of view of high surface finish is copper. The material removal rate of graphite is highest but the surface finish quality produced is rough and therefore it is good for use in roughing operations only. Because of the low melting temperature of copper electrode, its wear rate is highest and thus its material removal rate is lowest but the surface finish is the best among all the three electrodes used in this study.

Among the three electrodes used in this study it was found that copper tungsten is the best choice of electrode material in EDM of tungsten carbide, giving a low relative wear ratio, high dimensional accuracy and a reasonable good material removal rate.

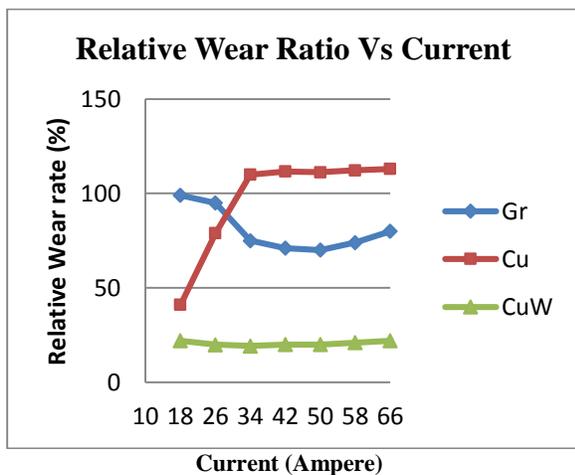


Figure 2. Effect of electrode material on relative wear ratio

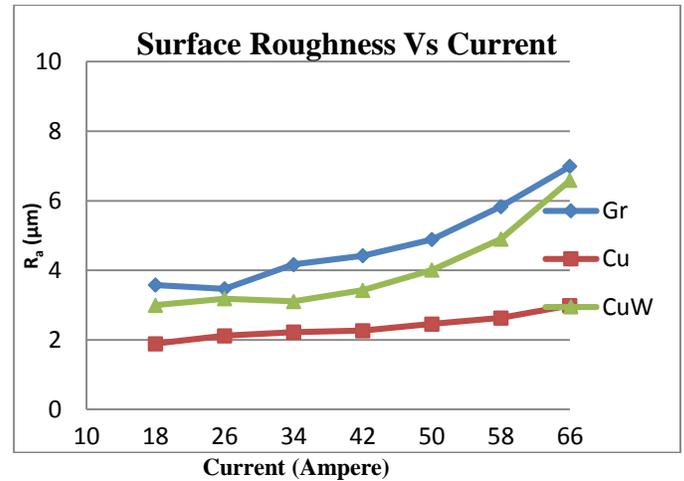


Figure 3. Effect of electrode material on workpiece surface roughness

Conclusion

An experimental study has been conducted to investigate the effect of the machining parameters on the machining characteristics in EDM of tungsten carbide. The machining parameters were electrode material and current and the machining characteristics were material removal rate, relative wear ratio and surface roughness. The conclusion drawn is that for all electrode materials, the material removal rate increases with increasing current. Copper gives the least material removal rate and graphite gives the best material removal rate. At a low range of current, the relative wear ratio decreases with the current for graphite electrodes but increases with current for copper electrodes. At high current setting copper electrodes have the highest relative wear ratio. Copper tungsten has lowest wear ratio at all current settings. Copper has the best surface finish and graphite has the poorest surface finish.

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Reference

1. S.H. Lee, X.P.Li, Study of the effect of machining parameters on the machining characteristics in EDM of tungsten Carbide, *J. Mater. Process. Technol*, 115(2001) 344-358
2. Soo Hiong Lee, Xiaoping Li, study of the surface Integrity of the machined work piece in the EDM of tungsten Carbide, *J. Mater.Process.Technol*,139(2003) 315-321

3. *C.H. Che Haron, B. Md. Deros, A. Ginting, M. Fauziah, Investigation on the influence of machining parameters when machining tool steel using EDM, J. Mater. Process. Technol, 116(2001) 84-87*
4. *M. Kiyak , O. Cakır, Examination of machining parameters on surface roughness in EDM of tool steel, J. Mater. Process. Techno, 191 (2007) 141–144*
5. *I. Puertas, C.J. Luis, L. Álvarez, Analysis of the influence of EDM parameters on surface quality, MRR and EW of WC–Co, J.Mater.Process. Technol, 153–154 (2004) 1026–1032*
6. *W. S Lau, M. Wang, W.B. Lee, Electrical discharge machining of carbon fiber composite materials, Int J Mach Tools Manuf 1990; 30(2); 297-308*