Experimental Investigation of Surface Integrity of Cobalt Bonded Tungsten Carbide (Wc-Co) Using EDM Process Material

Vikram Singh, Suresh Kataria, Sunil Kadiyan, Anup Lega, Seeone Sharma

Abstract
Electric Discharge Machining (EDM) process is the one in which material is removed by thermo-electric action. EDM is an important machining process among non-conventional machining processes. The present research describes the experimental investigation of cobalt bonded tungsten carbide (WC-Co) surface integrity by EDM process using Cu-SiC composite electrode. EDM parameter such as peak current, voltage, pulse duration and interval time taken as input parameters and material removal rate (MRR) and surface roughness (SR) is taken as response parameters. It is found that these parameters have a significant influence on machining characteristic such as metal removal rate (MRR) and surface roughness (SR). MRR increases with peak current. SR decreases with increase of peak current.

Keywords
EDM, Cobalt Bonded Tungsten Carbide (WC-Co), Material Removal Rate, Surface Roughness (SR).

I. Introduction
In recent years, materials having the properties of high hardness, high strength, wear resistant and temperature resistant are demanding. Therefore material scientists and researchers are developing materials such as composites, super alloys, tool steels, cemented carbides etc. The applications of these materials are increasing widely in almost every field ranging from automobiles to aerospace. Tungsten carbide and cobalt (WC-Co) composite is of special attention in producing cutting tools, dies and other special tools and components due to its very high hardness and excellent resistance to shock and wear. It is possible to machine this material with some conventional methods; however, high accuracy required in machining complex shapes cannot be achieved [1]. Therefore there is a need of the non conventional machining methods. Among the non conventional machining methods, Electric discharge machining (EDM) is one of the techniques used to machine hard, high strength, and temperature resistance materials. In this process, material is removed by means of rapid and repetitive spark discharges across the gap between electrode and workpiece [2]. EDM is used to machine electrically conductive material regardless of its hardness and strength. Therefore EDM parameters (peak current, machining voltage, pulse duration and interval time) are of utmost importance and have significant effect on the machining characteristics such as electrode wear rate (EWR), material removal rate (MRR), surface roughness (SR) etc. The basis of EDM dates back to 1770, when English chemist Joseph Priestly discovered the erosive effect of electrical discharges or sparks [3]. However, it was only in 1943 at the Moscow University where Lazarenko and Lazarenko [4] exploited the destructive properties of electrical discharges for constructive use. At that time EDM was mainly used to remove broken taps and drills from hydraulic valves. The effective use of EDM is achieved only in the 1980s with the advent of Computer Numerical Control (CNC). At present, EDM is a widespread technique used in manufacturing industry for machining all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials precisely and accurately. One of the earliest researches on EDM of cemented tungsten carbide was done by Pandit and Rajurkar [5]. They reported that due to the complex composition and microstructure of the cemented carbide, it is difficult to correlate the effect of operating parameters on the surface integrity. Pandey and Jilani [6] studied the effects of pulse parameters and the carbide composition on the MRR, electrode wear and crater shape and size. Lee et al. studied the effect of machining parameters on MRR, Relative wear ratio (RWR) and SR [7]. Tungsten carbide was used as the workpiece material and graphite, copper and copper-tungsten as electrode material. They concluded that MRR increases with increase in peak current for all the electrode materials, whereas graphite produces higher MRR followed by copper tungsten and then copper. Copper tungsten exhibits the lowest RWR for all ranges of peak current. Copper electrode gives best surface finish followed by copper tungsten and then graphite. Moreover they concluded that SR increases with increase in peak current. The negative tool polarity gives higher MRR, lower RWR and better SR. With the increase of open circuit voltage MRR decreases whereas RWR and SR decreases. Lee and Li [8] investigated the machined workpiece surface integrity, including the microstructures, surface topography, micro-cracks, composition and hardness at various machining conditions. They found no difference between the hardness of the EDMed surface and the original hardness of the workpiece for all EDM conditions. Moreover, scanning electron microscopy (SEM) shows clearly observable damaged layer on the workpiece surface, distinguished by the amount of WC grains and micro-cracks. It is also observed that damage caused by EDM on the EDMed surface is limited to a certain depth only. However, it is also observed that with the increase in peak current and pulse duration, the depth of the damaged layer and the average length, width and number of micro-cracks also increases. At low values of peak current and pulse duration, the damaged layer and micro-cracks disappears. Lajis et al. [9] investigated the effect of peak current, voltage, pulse duration and interval time on MRR, EWR and SR during EDM of Tungsten Carbide with graphite as electrode. Taguchi methodology has been implemented to analyze the effect of machining parameters on the machining characteristics. They concluded that the peak current has a significant effect on EWR and SR, whereas MRR is mainly influenced by pulse duration. Tomadi et al. [10] analyzed the influence of EDM parameters on surface quality (SQ), MRR and EW of tungsten carbide. Low values of peak current, pulse off time and voltage are used to obtain a good surface finish in the case of tungsten carbide. High values for peak current and voltage produces high MRR. Moreover they concluded that Low EW is obtained at the high values of the pulse off time and low values of peak current. Janmanee and Muttamara [11] studied the performance of different electrode
materials on tungsten carbide workpiece with EDM process. They used graphite (Poco EDM-3), copper-graphite (Poco EDM-C3) and copper-tungsten (solid) electrode. They concluded that the electrodenegative polarity performs very well. Poco EDM-3 gives higher MRR as compared to other electrodes. Copper-tungsten gives the best SR at a peak current intensity up to 20 amperes.

II. Experimental Setup
Cobalt bonded tungsten carbide (WC-CO) was workpiece material used in this investigation. Cu-SiC composite is used as electrode material. Chemical composition (wt %) of workpiece and tool electrode is shown in Table 1. Experiments were performed using an Electronica Electrical Discharge Machine (EDM) as shown in fig. 1. Kerosene was used as the dielectric fluid in this experiment.

<table>
<thead>
<tr>
<th>Element Material</th>
<th>W%</th>
<th>Cu %</th>
<th>Al %</th>
<th>Ni %</th>
<th>Mn %</th>
<th>Zn %</th>
<th>Si %</th>
<th>Fe %</th>
<th>Cr %</th>
<th>Co %</th>
<th>C %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten Carbide</td>
<td>63.36</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.41</td>
<td>0.14</td>
<td>4.50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Copper-SiC</td>
<td>-</td>
<td>90</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
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The MRR and was evaluated for each cutting condition by measuring the average amount of material removed and the required cutting time. Next, the SR of the cobalt-bonded tungsten carbide (WC-CO) was measured by a Surface Roughness Tester, series-Talysurf. Essential parameters of the experiment are given in Table 2.

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<th>Work-piece Material</th>
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III. Results and Discussion
The following discussion focuses on the effects of process parameters to the observed values (MRR and SR)

A. Material Removal Rate (MRR)
MRR is increasing with increase of peak current. Peak current ($I_p$) is directly proportional to the MRR, i.e., by increasing $I_p$ from 5 to 35 A, MRR increases significantly. This is expected because an increase in pulse current produces strong spark, which produces the higher temperature, causing more material to melt and erode from the work. Besides, it is seen that with the increase on $T_{on}$ and $T_{off}$, MRR decreases first after which it starts to increases up to a maximum value. Fig. 2 shows the effect of peak current on MRR by keeping other parameters fixed.

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Table 2: Parameters of the Experiment

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MRR increases with increase of pulse-on, because higher energy for long time will be tranferred to workpiece and MRR increases speedily as shown in fig. 3.

MRR decreases with increase of pulse interval. Fig. 4 shows that MRR decreases with increase of pulse interval.

![Fig. 2: Effect of Peak Current ($I_p$) on MRR](image)

![Fig. 3: Effect of Pulse-on ($T_{on}$) on MRR](image)

![Fig. 4: Effect of Pulse-off on MRR](image)
B. Surface Roughness (SR)

SEM photograph in fig. 5 and 6 shows machined work piece surface machined by EDM (with kerosene oil) exhibit non-uniform craters and severe undulations. The craters are bigger in size and their shape is uneven and peculiar. Further, the craters are very distinct and deep with a high density of global appendages.

![Fig. 5: Effect of Peak Current (5 A) on Discharge Crater](image)

Surface roughness decreases with increase of peak current ($I_p$). Larger craters were produced by a larger power supply voltage, possibly producing a larger discharging energy. The variation of crater diameter, depth and volume with respect to peak current is consistent with the general findings in EDM literature that higher currents generate larger crater and therefore produces rough surfaces.

![Fig. 6: Effect of Peak Current (35 A) on Discharge Crater](image)

IV. Conclusion

This research revealed the feasibility of machining cobalt bonded Tungsten Carbide like high strength cerments by EDM with a Cu-SiC composite electrode. Based on the results presented herein, we can conclude that, the peak current of EDM mainly affects the MRR and SR. The pulse duration largely affects the MRR. With the increase of Peak current MRR increases. SR decreases with increases of peak current.

References


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