Optimization of the machining parameters for EDM wire cutting of Tungsten Carbide

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Abstract. Electrical discharge machining is a thermal erosion process which is based on thermoelectric energy between the work piece and electrode. Its capability of machining in hard and difficult to cut materials has made it most popular. Tungsten carbide is widely used in industry due to its unique properties combination of hardness and wear resistance. But the machining of the tungsten carbide is very difficult. In our research we tried to find optimized procedure to cut the Tungsten carbide by variation of different parameters so that process can be carried out in maximum Material Removal Rate (MRR) with better surface finish. During the experimentation, Brass wire is used for cutting.. The experiment is designed with the help of Taguchi method and further analysis done with the help of ANOVA. In this experiment we find that the minimum mean of surface roughness is 2.214 achieved at Tension- 0.6 N, Feed- 10m/min, Flushing Pressure- 3kg/cm^2, Current- 80A.

Key Words: EDM Drilling, Tungsten carbide, Surface roughness, Machining of hard materials

1 Introduction

Electro Discharge Machining (EDM) is a non-contact electro-thermal machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. Precise machining can be done on electrically conductive and semi-conductive materials using this unconventional machining process. EDM can be used to drill circular and non-circular holes, generate profiles and make complex shaped dies of both macro and micro sizes. Both the macro EDM and the micro EDM have great potential and research work is going on in this field to improve the machining process and equipment [11]

1.1 Principle of EDM

EDM is a non-mechanical thermal shaping process with which material is removed by spatially and temporally separated electrical discharges between a workpiece electrode and a tool electrode. The high frequency discharges cause melting and vaporization of material on the surface of both electrodes. To enhance the material removal EDM operates in a non-conducting fluid, the dielectric fluid (Figure 1).

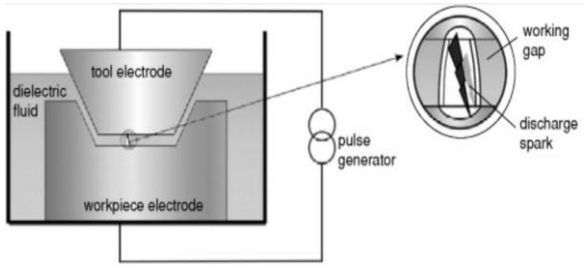

Figure 1 Principle illustration of the EDM process.

During machining, the tool and workpiece electrode are positioned in such a way that a working gap is filled with dielectric fluid remains between them.
EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the workpiece material and the electrode material must be conductors of electricity.

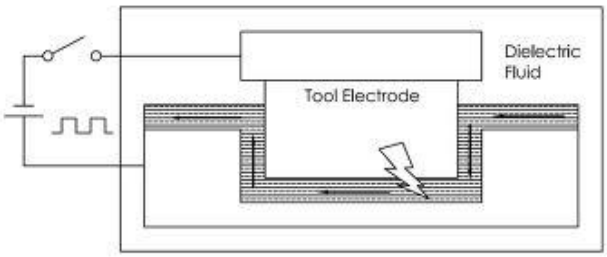

Figure 2. Sparking between the tool and work piece

The 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. The molten metal is not removed completely, but only partially.

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The EDM process can be used in two different ways:
1. A pre-shaped or formed electrode (tool), usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid workpiece.
2. A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path to erode or cut a narrow slot through the workpiece to produce the required shape.

Wire-Cut EDM

The wire-cut EDM is a discharge machine that uses CNC movement to produce the desired contour or shape. It does not require a special shaped electrode; instead it uses a continuous-traveling vertical wire under tension as the electrode. The electrode in wire-cut EDM is about as thick as a small diameter needle whose path is controlled by the machine computer to produce the shape required.

2 Experimental setup

EDM machine Robofil 290, Charmilles Technologies was used as the experimental machine in this study. A Brass wire of diameter of 0.125mm is used for cutting the work piece of Tungsten Carbide. The gap between work piece and electrode was flooded with a moving dielectric fluid.

Table 1 Specifications of EDM Wire Cut M/C Robofil-290 Charmillies

Technical data of EDM wire cut m/c robofil-290 charmillies	
Table size	800 x 500 mm
X, y, z movement	400 x250 x200 mm
Max load capacity	500 kg
Coolant	Distilled water
Wire to be used	Dia. 0.1- 0.25 mm
Accuracy	+/- 0.01mm
Water tank capacity	300 liters
Cutting technology	Steel, copper, aluminium, carbide, graphite
Air pressure	6-7 bar
Electricity	400 volts, 50 Hz
Speed	0-15 meter/min

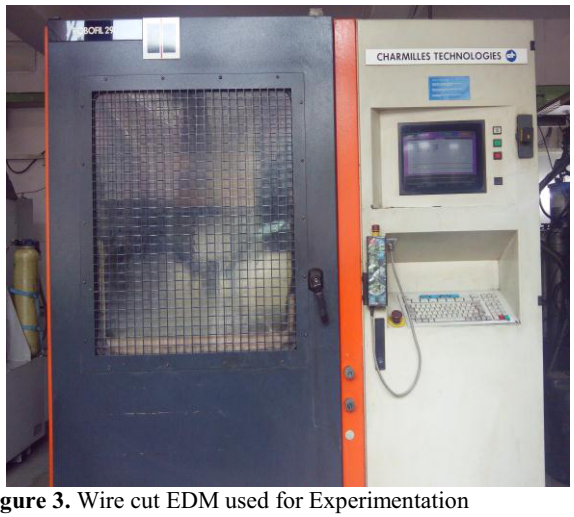

Figure 3. Wire cut EDM used for Experimentation

Properties of Tungsten Carbide

The chemical composition of Tungsten Carbide, which is tested at "Institute of Auto parts and hand tools technology, Ludhiana", is shown below in table 1.

Table 2. Chemical Composition of Tungsten Carbide

W %	**Ni %**	**Co %**	**Fe %**	**Cr %**
87.09	3.89	6.12	1.84	0.29

Experimental Procedure for Wire cut EDM

Taguchi approach was taken as the basis for planning and conducting the experiments so that the appropriate data is collected which may be analyzed to obtain valid and objective conclusions.

Table 3. Range of Significant Process Parameter for EDM Wire cut

Parameter Name	**Unit**	**Lower Limit**	**Upper Limit**
Tension	**N**	**0.6**	**1**
Feed	**m/min**	**8**	**12**
Flushing Pressure	**Kg/cm^2**	**2**	**4**
Current	**A**	**60**	**100**

3 Results and Analysis of Surface Roughness

The Cutting is done on different parameter as per Design of experment. Then surface roughness is checked. In the present work Mitutoyo stylus profilometer surface roughness measurement device is used, with stylus having diamond tip. After having surface roughness following results are found.

Table 4. Observations of SR during Cutting of Tungsten Carbide

S. No	SR1	SR2	Mean SR	S/N	MEAN
1	2.461	2.039	2.25	-7.04365	2.25
2	2.413	2.733	2.573	-8.2088	2.573
3	2.597	2.959	2.778	-8.87465	2.778
4	3.014	2.624	2.819	-9.0019	2.819
5	2.357	2.505	2.431	-7.7157	2.431
6	2.16	2.268	2.214	-6.90356	2.214
7	2.479	2.359	2.419	-7.6727	2.419
8	2.884	2.432	2.658	-8.4911	2.658
9	2.274	2.372	2.323	-7.32098	2.323

Table 5: Results of SR, and S/N ratios of SR

Level	Tension	Feed	Flushing Pressure	Current
1	-7.207	-8.389	-8.252	-7.570
2	-8.229	-7.478	-7.703	-8.260
3	-8.309	-7.878	-7.789	-7.914
Delta	1.102	0.911	0.549	0.690
Rank	1	2	4	3

Table 4 & 5 represents the investigated results obtained during cutting of Tungsten Carbide by utilizing EDM. The results i.e. SR and S/N ratio were obtained.

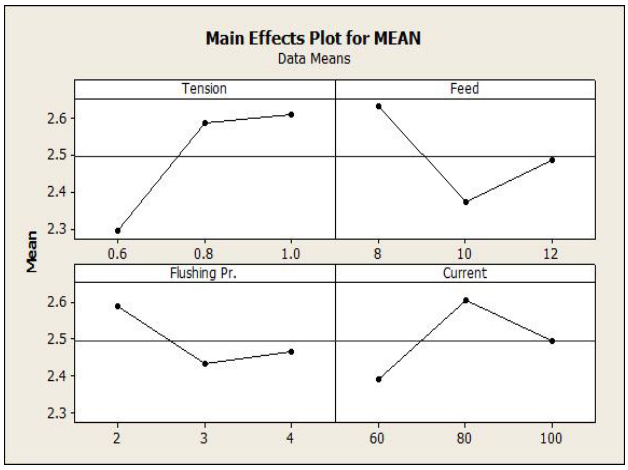

Figure 4 effect of EDM Parameters on Mean SR

Figure 4 shows effect of various EDM parameters on the surface roughness plotted utilizing the machining results obtained. From the figure, it is observed that the mean value of SR is increase by increasing the Tension. Increase the feed decreases the SR upto a certain limit after that SR starts increasing. SR decreases with increase in flushing pressure and remains constant after a certain value.

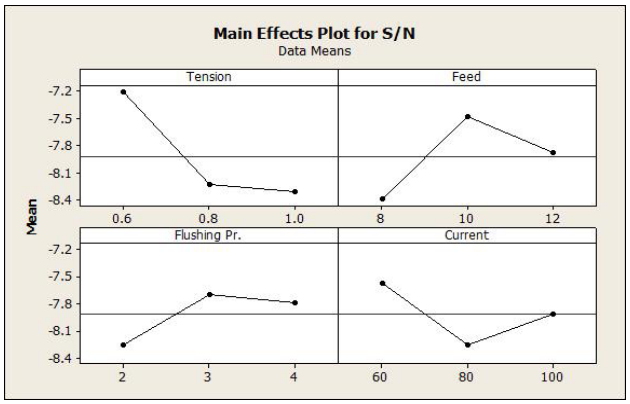

Figure 5 effect of EDM Parameters on Mean of S/N ratio of SR

Figure 5 shows effect of various EDM parameters on the mean S/N ratio of surface roughness rate plotted utilizing the machining results obtained. From the figure, it is observed that the mean value of S/N ratio of SR is decrease by increasing the Tension from 0.6 to 1. The means of S/N for SR increases with increasing the flushing pressure value from 2 to 3 and then decreases very slightly from 3 to 4. The reverse of this happens with the current.

Taguchi Analysis: SR versus Tension, Feed, Flushing Pressure and Current

Response Table for Signal to Noise Ratio smaller is better and SR

Table 6 Ranking of EDM Parameters by Response of S/N ratio of SR

Level	Tension	Feed	Flushing Pressure	Current
1	2.294	2.632	2.59	2.391
2	2.586	2.37	2.434	2.604
3	2.608	2.486	2.464	2.494
Delta	0.314	0.262	0.156	0.213
Rank	1	2	4	3

Table 7. Ranking of EDM Parameters by Response of mean of SR

S. No	**Tension**	**Feed**	**Flushing Pressure**	**Current**	**SR1**	**SR2**	**Mean SR**
1	.6	12	4	100	2.461	2.039	2.25
2	1	10	2	100	2.413	2.733	2.573
3	.8	12	2	80	2.597	2.959	2.778
4	1	8	4	80	3.014	2.624	2.819
5	1	12	3	60	2.357	2.505	2.431
6	.6	10	3	80	2.16	2.268	2.214
7	.6	8	2	60	2.479	2.359	2.419
8	.8	8	3	100	2.884	2.432	2.658
9	.8	10	4	60	2.274	2.372	2.323

Above tables 6 and 7 shows the ranking of EDM parameters for optimizing the SR. It can be observed that Peak Current has the largest effect on the SR of Tungsten Carbide by machining. The pulse on has the smallest effect on the SR.

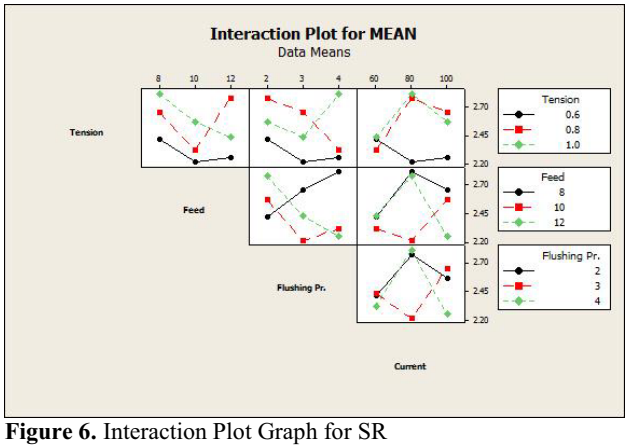

Figure 6. Interaction Plot Graph for SR

- 1st graph is between Tension and Feed. The minimum value of SR is at Tension=0.6 and Feed= 10.
- 2nd graph is between Tension and Flushing Pressure. The minimum value of SR is at Tension=0.6 and Flushing Pressure = 3.
- 3rd graph is between Tension and Current. The minimum value of SR is at Tension=0.6 and Current= 80.
- 4th graph is between Feed and Flushing Pressure. The minimum value of SR is at Feed=10 and Flushing Pressure=3
- 5th graph is between Feed and Current. The minimum value of SR is at Feed=10 and Current= 80.
- 6th graph is between Flushing Pressure and Current. The minimum value of SR is at Flushing Pressure =3 and Current= 80.

Table 8. Confirmation Experiment Result for SR

Performance Measures/ Response	Optimal Set of Parameter	Experimental Value
SR	Tension- 0.6N Feed- 10m/ min Flushing Pressure- 3kg/cm^2 Current- 80A	2.214

From confirmation test we can concluded that our experimental value of surface roughness is less than the predicted value which means surface roughness achieved Tension- 0.6 N, Feed- 10m/min, Flushing Pressure- 3kg/cm^2, Current- 80A is optimum.

Conclusions of Surface Roughness for EDM wire cut

1. It is noted that the minimum mean of surface roughness is 2.214 achieved at Tension- 0.6 N, Feed- 10m/min, Flushing Pressure- 3kg/cm^2, Current- 80A.
2. SR is increase by increasing the peak current. Because Increase the peak current increase the discharge energy.

Scope of Future

In this present work MRR and SR of machined product was studied during the machining of Tungsten carbide using EDM can futher be carried out to study the machining characterstic known as Hardness of machined surface, Properties of HAF etc.

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