An Experimental Investigation of Electrode Wear Rate (EWR) using Composite Electrodes on EDM of SS-304

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Abstract: In this paper an attempt has been made to optimize the material of tool electrode in electrical discharge machining of stainless steel-304. In this project die- sink type EDM is used for experimental work. The controllable parameters used are discharge current, spark on time and spark off time and the resulting responses are work piece erosion rate and tool erosion rate. The experiments were conducted using copper tungsten, beryllium copper and copper chromium zirconium alloy as tool electrodes. Electrode Wear Rate will be considered as performance factor for this experimental procedure.

***Keywords*–** EDM, Copper Tungsten, Beryllium Copper, Copper Chromium zirconium, SS-304

I. INTRODUCTION

Electrical discharge machining (EDM) is the non-contact machining techniques have been continuously evolving in a mere tool and die making process to a micro-scale application machining. In recent years, EDM researchers have explored a number of ways to improve the sparking efficiency including some unique experimental concepts that depart from the EDM traditional sparking phenomenon to improve material removal rate It was also found that the wear ratio increases with an increase in current [2]. The working principle of EDM process is based on the thermoelectric energy. This energy is created between a workpiece and an electrode submerged in a dielectric fluid with the passage of electric current. It can be obtained by the formation of different types of spark generators and production parameter optimization. Desired machining process performance is difficult to obtain because of the variation in the product and many number of variables [3-6].

In EDM process the Electrode and Work Piece does not make any direct contact, there will be no chatter, vibration and mechanical stresses during Electrical Discharge Machining of work piece [7]. With the application of rapid and repetitive spark discharge, removal of electrically conductive material takes place [8]. Now is research is going on to develop some suitable tool material for EDM in order to maximize MRR and to reduce EWR for better performance. The gap between electrode and work piece is maintained in such a way that the impressed voltage is great enough to ionize the dielectric The objective of this research is to study the performance of different electrode materials on Stainless Steel-304 workpiece with EDM process. [9]

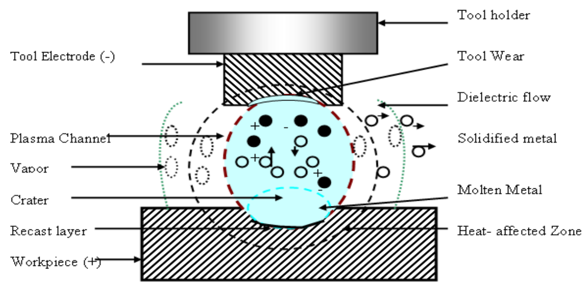


Fig.1 Working Principle of EDM Process

II. EXPERIMENTAL PROCEDURE

Pulse current is generally selected in such a way to increase Material Removal Rate and to decrease electrode wear rate. The experiments were carried out for 2 mm depth of cut. In this experiments 3 pulse current settings of 5A, 10A and 15A is used with the application copper tungsten, beryllium copper and copper chromium zirconium electrode.

a) Design of Experiments

Three parameters namely current, pulse on time and pulse off time is selected for the experimental work. There are three level in this experiment as shown in **Table.1**

Table 1. Machining parameters.

	Parameters	Unit	Level 1	Level 2	Level 3
A	Pulse Current	A	5	10	15

B	T_{on}	µs	450	450	450
C	T_{of}	µs	11	11	11

b) Work Piece Material

The work material used in this experiment is stainless steel 304. Square work piece is 50 mm x 50 mm in dimensions and 3 mm in thickness.

c) Electrode Material

In this copper tungsten, beryllium copper and copper chromium zirconium are selected as electrode material. **Fig.2** explains about the work piece and electrode material.

Fig.2 Work Piece and Electrode Material

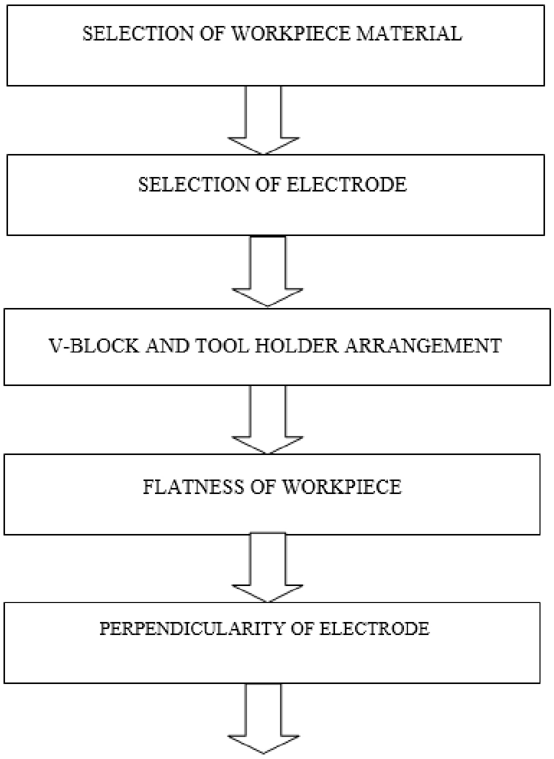
d) Machine Tool

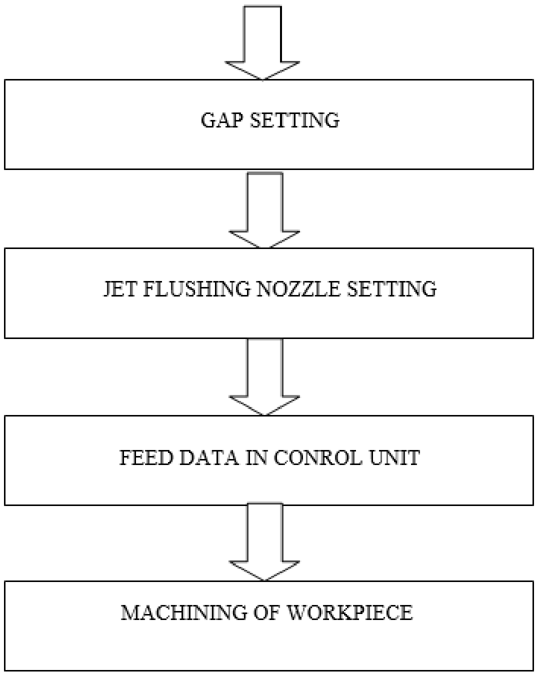
The experiments were performed on ELECTROLUX EDM Machine (Model No.: D7130) shown in **Fig.3**.

Fig.3 Electrolux EDM Machine

e) Steps of Experiment

In order to run the experiment successfully we have to plan the experimental work as given in the following flow chart.





1. Selection of workpiece material

The Square work piece is 50 mm x 50 mm in dimensions and 3 mm in thickness. Electrical Discharge Machining will be done on this work piece. **Fig. 4** explain about the work piece of this experiment. In this experiment the electrode wear rate of SS-304 will be determined.

Fig.4 Workpiece of SS - 202

2. Selection of Electrode

In this experiment copper tungsten, beryllium copper and copper chromium zirconium are selected as electrode material. **Fig.5** shows the tool electrode for electrical discharge machining.

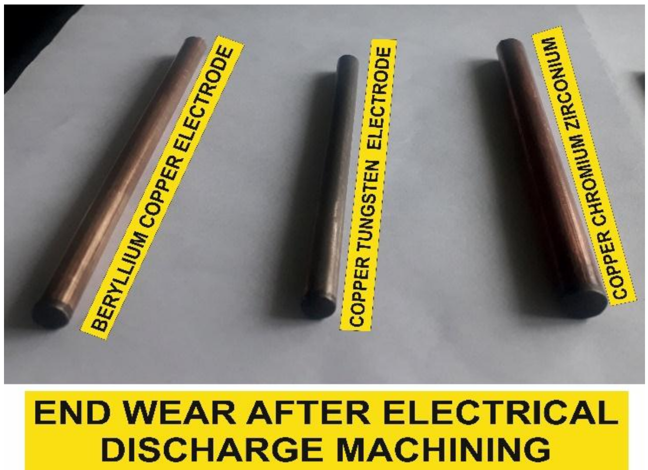


Fig.5 Electrode Materials

3. V-block and Tool holder arrangement

Tool holder and V-Block is arranged in such a manner that machining process should be in desired direction. **Fig. 6** explains about the V-block and Tool holder arrangement.

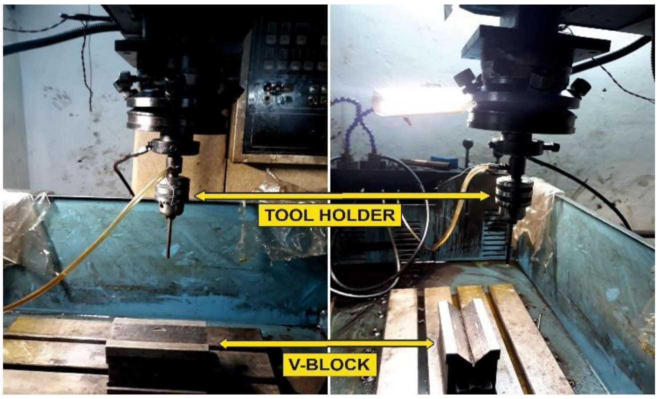


Fig.6 V-Block and Tool Holder arrangement

4. Flatness of Work Piece

Circular workpiece of SS-304 is put on V-block in a flat position so that the desired hole will be in a proper direction. This will also maintain the circularity of the hole. **Fig.7** shows the workpiece position on V-block.

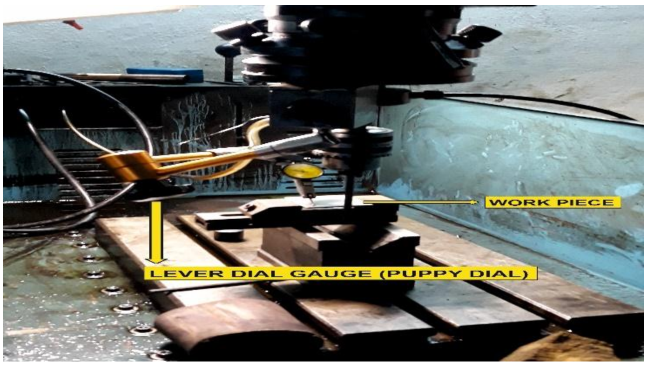


Fig.7 Flatness of Work Piece

5. Perpendicularity of electrode

Perpendicularity of electrode should be maintain before performing the machining operation on EDM machine. **Fig.8** explains about the Perpendicularity of the electrode.

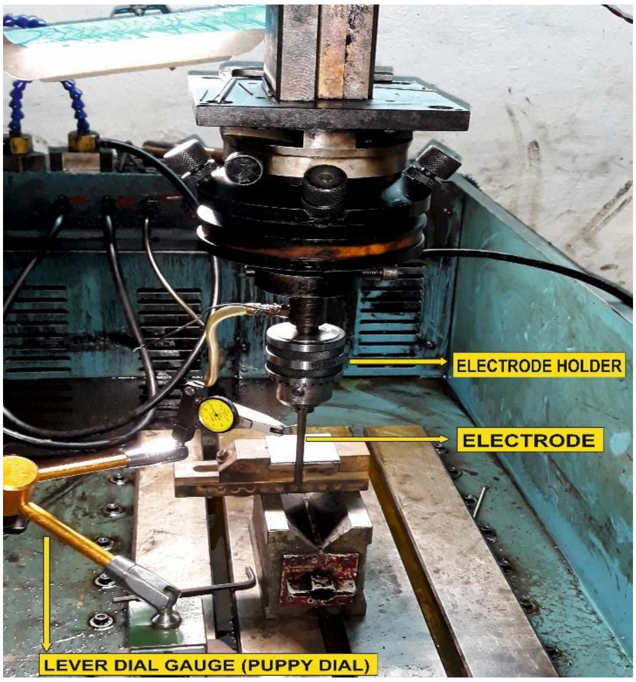


Fig.8 Perpendicularity of electrode

6. Gap Setting

Gap between Tool electrode and Workpiece must be maintain before machining operation. This Gap is generally 0.025 mm. **Fig.9** shows the Gap setting of Tool electrode and Workpiece.

Fig.9 Gap Setting

7. Jet Flushing Nozzle Setting

Position of Jet flushing nozzle should be maintain in such a way that eroded particles from workpiece removed properly. This helps to avoid carbon submission on Tool electrode and Workpiece. **Fig.10** shows Jet flushing nozzle setting.

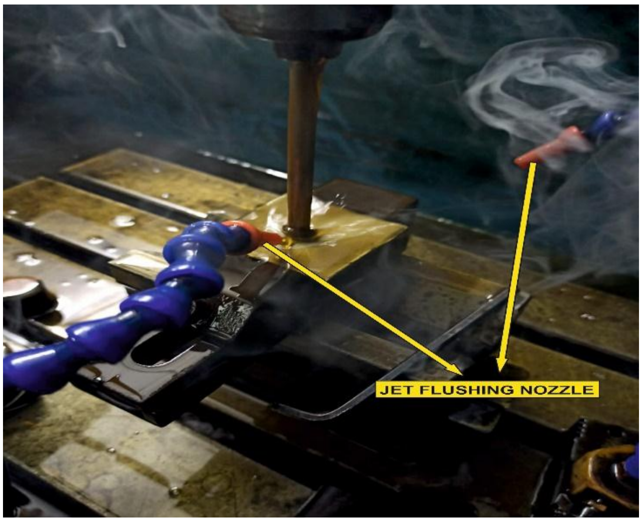


Fig.10 Jet Flushing Nozzle Setting

8. Feed Data in Control Unit

When experiment is about to perform we have to put the values in control unit of machine. First we will set the value of pulse current and depth of cut in control unit. **Fig.11** explains about the control unit of machine.

Fig.11 Control Unit

9. Machining of Work Piece

Now the experiment will performed on machine. **Fig.12** shows the electrical discharge machining of workpiece.

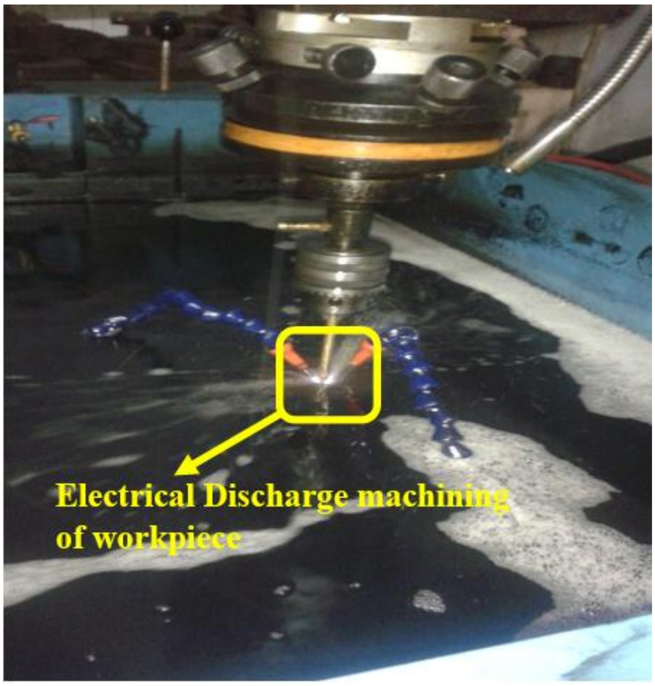


Fig.12 Machining of Work Piece

III. DATA COLLECTION

The pulse current is normally selected on the basis of the maximum removal rate possible within the allowable mean current, electrode wear and surface integrity. The experiments were carried out for a depth of cut of 2 mm for Beryllium Copper, Copper chromium zirconium, Copper Tungsten electrode materials with three different pulse current settings of 5A, 10A and 15A. Electrode Wear Rate (EWR) is expressed as the ratio of difference of mass of the electrode before and after machining to the machining time.

$$\text{EWR} = \frac{W_{eb} - W_{ea}}{T}$$

Where, EWR = Electrode Wear Rate (g/min)

Web = Mass of Electrode before machining (gram)

Wea = Mass of Electrode after machining (gram)

T = Machining time (minutes)

a) EWR with Beryllium Copper Electrode at 5A

EWR of workpiece SS-304 with respect to 5A Pulse current is shown in the **Table.3**

Table.3 Data collection of EWR at 5A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	29.662	29.651	22.02	0.0110	0.000499546
2	29.651	29.645	22.1	0.0060	0.000271493
3	29.645	29.639	22.07	0.0060	0.000271862
4	29.639	29.636	22.13	0.0030	0.000135563
5	29.636	29.634	22.2	0.0020	9.00901E-05

b) EWR with Beryllium Copper Electrode at 10A

EWR of workpiece SS-304 with respect to 10A Pulse current is shown in the **Table.4**

Table.4 Data collection of EWR at 10A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	29.634	29.628	5.23	0.0060	0.001147228
2	29.628	29.624	5.3	0.0040	0.000754717
3	29.624	29.618	5.35	0.0060	0.001121495
4	29.618	29.611	5.13	0.0070	0.001364522
5	29.611	29.593	5.2	0.0180	0.003461538

c) EWR with Beryllium Copper Electrode at 15A

EWR of workpiece SS-304 with respect to 15A Pulse current is shown in the **Table.5**

Table.5 Data collection of EWR at 15A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	29.593	29.581	3.6	0.0120	0.003333333
2	29.581	29.572	3.53	0.0090	0.002549575
3	29.572	29.565	3.63	0.0070	0.001928375
4	29.565	29.561	3.56	0.0040	0.001123596
5	29.561	29.556	3.61	0.0050	0.001385042

d) EWR with Cu Cr Zr Electrode at 5A

EWR of workpiece SS-304 with respect to 5A Pulse current is shown in the **Table.6**

Table.6 Data collection of EWR at 5A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	49.752	49.736	42.25	0.016	0.0004
2	49.736	49.712	42.32	0.024	0.0006
3	49.712	49.681	42.42	0.031	0.0007
4	49.681	49.653	42.36	0.028	0.0007
5	49.653	49.621	42.28	0.032	0.0008

e) EWR with Cu Cr Zr Electrode at 10A

EWR of workpiece SS-304 with respect to 10A Pulse current is shown in the **Table.7**

Table.7 Data collection of EWR at 10A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	49.621	49.607	9.5	0.014	0.0015
2	49.607	49.584	9.25	0.023	0.0025
3	49.584	49.561	9.75	0.023	0.0024
4	49.561	49.538	9.67	0.023	0.0024
5	49.538	49.523	9.25	0.015	0.0016

f) EWR with Cu Cr Zr Electrode at 15A

EWR of workpiece SS-304 with respect to 15A Pulse current is shown in the **Table.8**

Table.8 Data collection of EWR at 15A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	49.523	49.514	5.03	0.009	0.0018
2	49.514	49.496	5.13	0.018	0.0035
3	49.496	49.491	5.2	0.005	0.0010
4	49.491	49.485	5.17	0.006	0.0012
5	49.485	49.482	5.18	0.003	0.0006

g) EWR with Cu-W Electrode at 5A

EWR of workpiece SS-304 with respect to 5A Pulse current is shown in the **Table.9**

Table.9 Data collection of EWR at 5A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	39.968	39.963	110.5	0.005	0.000045
2	39.963	39.958	110.53	0.005	0.000045
3	39.958	39.956	110.56	0.002	0.000018
4	39.956	39.951	110.63	0.005	0.000045
5	39.951	39.946	110.43	0.005	0.000045

h) EWR with Cu-W Electrode at 10A

EWR of workpiece SS-304 with respect to 10A Pulse current is shown in the **Table.10**

Table.10 Data collection of EWR at 10A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	39.946	39.943	32.83	0.003	0.000091
2	39.943	39.941	32.86	0.002	0.000061
3	39.941	39.938	32.91	0.003	0.000091
4	39.938	39.936	32.8	0.002	0.000061
5	39.936	39.935	32.85	0.001	0.000030

i) EWR with Cu-W Electrode at 15A

EWR of workpiece SS-304 with respect to 15A Pulse current is shown in the **Table.11**

Table.11 Data collection of EWR at 15A

Exp No.	Mass of electrode before	Mass of electrode after	Time (Minutes)	Difference of Mass	Electrode Wear Rate
1	39.935	39.934	14.23	0.001	0.000070
2	39.934	39.931	14.3	0.003	0.000210
3	39.931	39.929	14.2	0.002	0.000141
4	39.929	39.928	14.26	0.001	0.000070
5	39.928	39.925	14.25	0.003	0.000211

IV. RESULT AND DISCUSSION

Variation of electrode wear rate for Beryllium Copper electrode with respect to Pulse current 5A, 10A and 15A are shown respectively in the following graph.

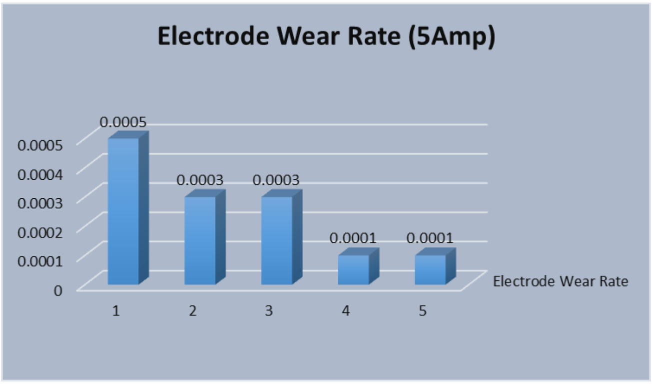


Fig.13 Electrode wear rate at 5A

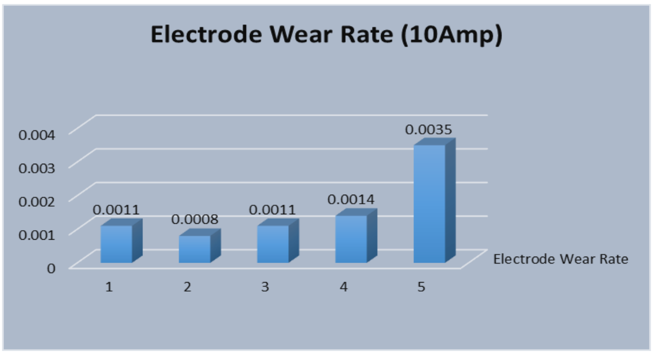


Fig.14 Electrode wear rate at 10A

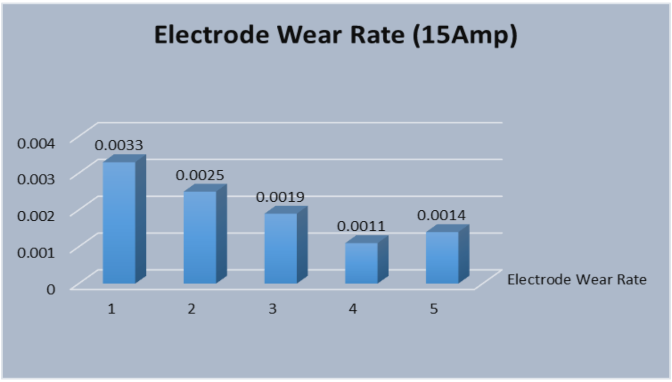


Fig.15 Electrode wear rate at 15A

Variation of electrode wear rate for Copper chromium zirconium electrode with respect to Pulse current 5A, 10A and 15A are shown respectively in the following graph.

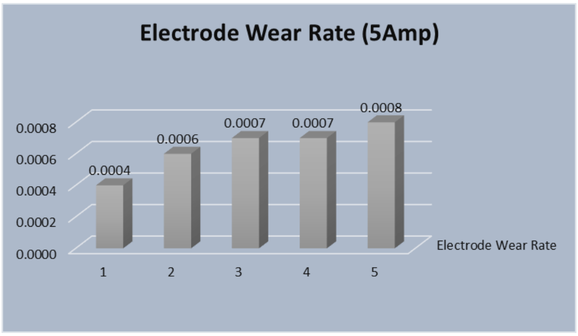


Fig.16 Electrode wear rate at 5A

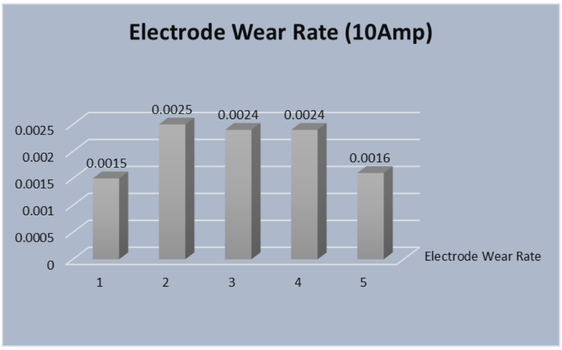


Fig.17 Electrode wear rate at 10A

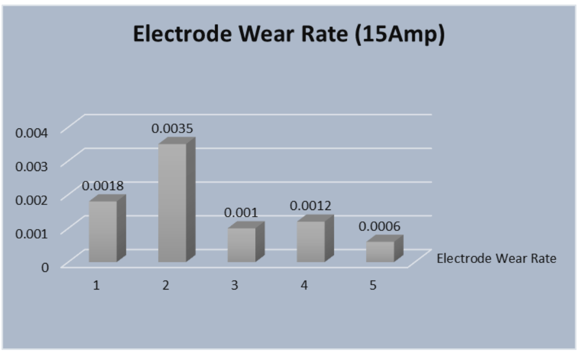


Fig.18 Electrode wear rate at 15A

Variation of electrode wear rate for Copper Tungsten electrode with respect to Pulse current 5A, 10A and 15A are shown respectively in the following graph.

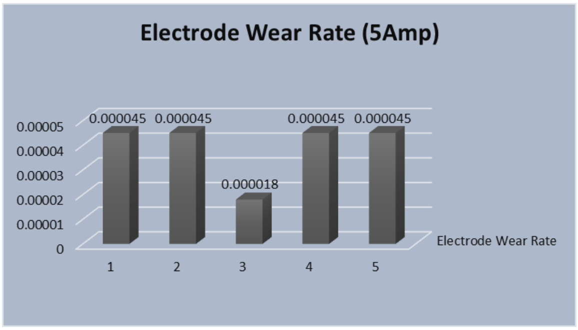


Fig.19 Electrode wear rate at 5A

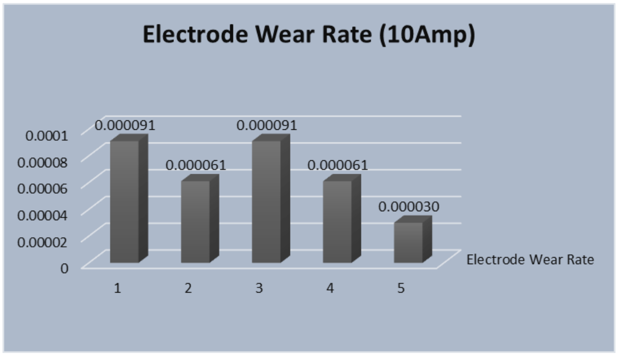


Fig.20 Electrode wear rate at 10A

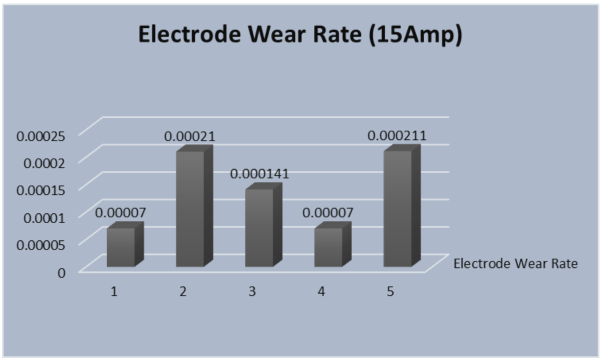


Fig.21 Electrode wear rate at 15A

As the high density of electron impingement occurs at workpiece and electrode material during electrical discharge machining causes electrode wear. The electrode wear vs pulse current for SS- 304 material is shown in **Fig.22**

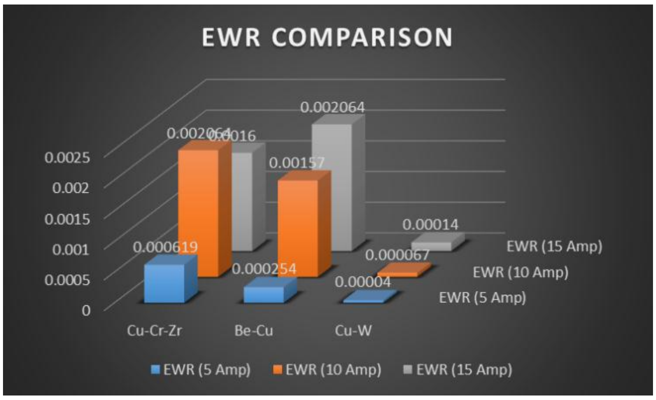


Fig.22 Electrode Wear Rate Vs Pulse Current

Copper Chromium Zirconium has the highest EW of 0.001428 g/min. Copper tungsten shows least amount of electrode wear. As the melting point of Copper is low electrode wear increases as the pulse current increases. Copper tungsten has less electrode wear because of its high melting point.

Copper tungsten also has the property to resist spark which is responsible for less electrode wear as compare to other two electrode.

V. CONCLUSIONS

1. Copper Chromium Zirconium has the highest EW of 0.001428 g/min as against 0.001296 g/min for Beryllium copper and 0.000082 g/min for copper tungsten. **Fig.23** Represent the electrode wear rate for stainless steel – 304 using different electrode.

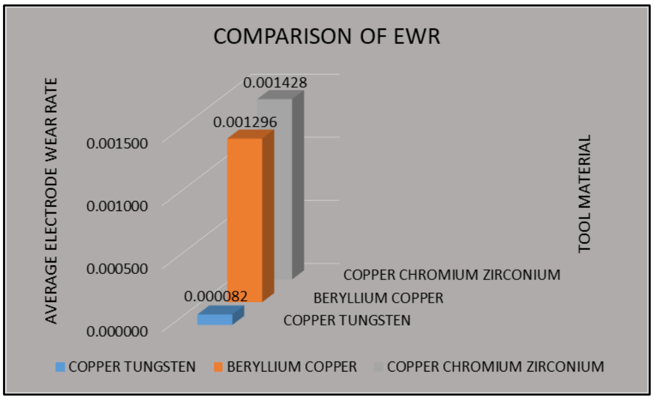


Fig.23 Average Electrode Wear Rate for SS – 304

2. In copper tungsten electrode, least amount of electrode wear occurs and there is no corner wear in the electrode. **Fig.24** explains about the corner electrode wear in different tool electrode.

Fig.24 4 Electrode Wear in different tool electrode

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