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A Study on Optimization of Process Parameters in Machining of Bronze using Wire-EDM

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ABSTRACT

Wire cut electrical discharge machining (WEDM) is a hybrid manufacturing technology which enables machining of all engineering materials. This research article deals with investigation on Optimization of the Process Parameters of the wire cut EDM of Bronze material of dimension (80*80*40) in mm. Material removal rate, Surface roughness and Kerf width were studied against the process parameters such as Pulse on time(TON), Pulse off time (TOFF) and Current(IP). The machining parameters for wire EDM were optimized for achieving the combined objectives. As there are three input parameters 27 experiments is carried out and full factorial is used. Optimized parameters were found using (ANOVA) and the error percentage can be validated and parameter contribution for the Material Removal Rate (MRR) and Surface roughness were found.

Keywords: Wire EDM (Electrical Discharge Machining), Bronze, ANOVA (Analysis of Variance)

I. INTRODUCTION

Mechanical Industries aims at quality and time with respect to efficiency of the product, demand, competence and global acceptance as well. It also conveys the necessity in using complicated parts and precise components which are having good dimensional tolerances with special shapes. The demand and need for temperature resistant, hard, tough, wear, corrosion and abrasive resistant materials are increasing day by day. These increasing trends needs have enforced on the usage of advanced and well-equipped technologies to convert the raw materials into finished products with low cost and time required for the operations such as tooling.

The traditional machining processes, in spite of recent advancements, fails to machine difficult to machine components in high strength, high temperature, hard and die steels as well. Considering these scenarios into account, a number of an conventional machining processes have been discovered and developed. Unconventional machining methods such as Ultrasonic machining, electrochemical machining, electrical discharging machine (EDM) can be applied in machining of components which are difficult to machine. The non-traditional machining methods exhibit few unique advantages over conventional techniques which are not restricted by any mechanical properties such as toughness, brittleness and hardness. It ensures good surface finish on any intricate components by excellent control over physical parameters. Since the conventional methods are not suitable for machining hard materials, non-traditional machines are used which are feasible, economical too. There are some characteristics listed below which provides the limitations of conventional techniques.

Removal of the metal in the form of chips is a difficult procedure.

1. Chips are usually unwanted in the process of metal removal.
2. Chips removal and the disposal of the chips are tedious, involves the wastage of energy and money.
3. Since the presence of larger cutting forces, it is difficult to hold the work piece properly. Proper holding of the work piece also avoids distortion.
4. Due to the excess amount of heat is generated at the interface of tool and work piece; there will be some undesirable effects which diminishes the properties.

Developing these non-traditional methods encourages the machining of complex shaped dies and moulds in hard and high temperature resistant alloys for example titanium alloys, carbides, heat resistant steels etc. These non-traditional machined components have greater applications in the fields of nuclear engineering and aerospace industries

New advanced/ technological processes are divided into different categories.

(a) Type of energy (Shaping of materials)–thermal, Mechanical, Electro thermal and Electro chemical;

(b)The process involves some basic mechanisms such as ionic dissolution, erosion and vaporization;

(c) Energy sources required in removal of material–high current density, hydrostatic pressure, ionized material, high voltage.

(d)Transferring of energies in a particular medium – electrolyte, Electron, hot gases and high velocity particles.

II. METHODS AND MATERIAL

Material preparation

The work piece material used for the experimental analysis is bronze with dimensions of 80mm*80mm*40mm. The work piece is initially surface cleaned before conducting the experiments. The molybdenum wire with diameter 0.18mm is used as electrode. The machining accuracy is 0.01mm. DK 7732 CONCORD wire EDM Machine is used for the experimentation.

Figure 1.Bronze Material used for experimentation

Preliminary experimentation:

Three parameters were chosen, namely Pulse On, Pulse Off and Current. These parameters were varied simultaneously so as to obtain the minima and maxima of the chosen set of parameters. The response variable considered in this regard was material removal rate and wire strength. As the material removal rate was increased, probability of snipping of wire increased. The maximum MRR was achieved keeping in mind the wire life.

Sl No.	Parameter	Pulse on (μs)	Pulse Off(μs)	Current(A)
Material Removal Rate	Maximum	35	10	5
	Minimum	25	8	3

Equipment used for Experimentation

DK 7732 CONCORD Wire EDM Machine is used for the experimentation; molybdenum wire is used for the experimentation. Once the wire is wound on the wire drum, that particular amount of Wire will be used for all the experiments and it can be replaced once the material is changed. Work material will be clamped tightly on the work table so as to avoid any relative motion between work piece and the wire. Dielectric flow is constant during the experiment.

Experimental Design (Input parameters)

Sl. no	Process parameters	Unit	Level1	Level2	Level3
1	Pulse ontime(T on)	µs	25	30	35
2	Pulse offtime(T off)	µs	8	9	10
3	Current(Ip)	A	3	4	5

The experimental design was according to Full factorial. Table shows the process parameters with their level consider for this experimentation.

1. The Bronze material is clamped tightly so that there is no movement of work piece material during machining.
2. The Molybdenum wire is wound on the wire drum which is brought near the material during machining.
3. The table movement should be adjusted so that the wire comes in contact with the work piece.
4. The values of input parameters are fed to computer which is in connected to the Wire Cut EDM machine.
5. The electric discharge is produced and dielectric fluid is sprayed on the bronze material.
6. The machining of the bronze material takes place and output parameters can be calculated.

Figure.2 Wire Electrical Discharge Machine

Figure3 Surface Roughness tester

The measurement of Surface Roughness was done using Taylore Hobbson Surtronic device. The reason for using this device is that they are tough, fast and reliable testers. The device used is user friendly. Surtronic series stand and primer the integrated roughness measurement station can be obtained. Roughness measurements can be easily done and on multiple parts and results can be stored internally or in a standard USB device.

Durable roughness testers are used for shop floor, industrial and inspection room applications.

III. METHODOLOGY

Analysis of Variance (ANOVA)

ANOVA is a standard statistical technique which is used to interpret the experimental results. The percentage contribution of various process parameters to the selected performance characteristic can also be estimated by ANOVA technique. Thus, information about how significant the effect of each controlled parameter is on the quality characteristic of interest can be obtained. ANOVA for raw data has been done to identify the important parameters and to quantify their effect on the performance characteristic. The ANOVA based on the raw data helps to identify the factors which affect average response rather than reducing variation.

ANOVA is used in testing and significance of all the main factors and interactions and mean square values and experimental errors at specific confidence level. Study of ANOVA table helps to determine the factors which needs controls and which factors do not need control. The confirmation experiment is done to determine the optimum conditions. The analysis of partial experiment consists of analysis of Confidence which can be shown in the results.

IV. RESULTS AND DISCUSSION

Inputandoutput parametervalues

Expt.No.	PulseON	PulseOFF	Current	Wb	Wa	Wb-Wa	Time	MRR	Ra	KwT	KwB	kwT-KwB
1	25	8	3	2.420	2.385	0.035	28.14	0.0012438	3.70	10.03	10.02	0.01
2	25	8	4	2.385	2.344	0.041	22.01	0.0018628	4.40	10.03	10.01	0.02
3	25	8	5	2.344	2.303	0.041	18.19	0.0022540	4.30	10.03	10.02	0.01
4	25	9	3	2.303	2.262	0.041	28.03	0.0014627	3.40	10.02	10.01	0.01
5	25	9	4	2.262	2.222	0.040	22.40	0.0017857	4.10	10.01	9.99	0.02
6	25	9	5	2.222	2.180	0.042	18.34	0.0022901	4.00	10.00	9.99	0.01
7	25	10	3	2.180	2.137	0.043	30.08	0.0014295	3.40	10.01	10.00	0.01
8	25	10	4	2.137	2.095	0.042	23.05	0.0018221	4.00	10.04	10.02	0.02
9	25	10	5	2.095	2.049	0.046	20.55	0.0022384	4.30	10.05	10.03	0.02
10	30	8	3	2.049	2.014	0.035	26.09	0.0013415	3.60	10.04	10.00	0.04
11	30	8	4	2.014	1.972	0.042	19.37	0.0021683	3.60	9.97	9.94	0.03
12	30	8	5	1.972	1.931	0.041	16.42	0.0024970	4.50	10.02	10.01	0.01
13	30	9	3	1.931	1.891	0.040	26.30	0.0015209	4.70	10.00	9.99	0.01
14	30	9	4	1.891	1.850	0.041	21.13	0.0019404	4.50	10.00	9.99	0.01
15	30	9	5	1.850	1.810	0.040	18.52	0.0021598	4.20	10.03	10.02	0.01
16	30	10	3	1.810	1.768	0.042	30.05	0.0013977	4.30	10.05	10.03	0.02
17	30	10	4	1.768	1.725	0.043	24.09	0.0017850	4.90	10.03	10.02	0.01
18	30	10	5	1.725	1.679	0.046	20.41	0.0022538	3.90	10.03	10.02	0.01
19	35	8	3	1.679	1.638	0.041	25.50	0.0016078	4.90	10.04	10.03	0.01
20	35	8	4	1.638	1.598	0.040	19.46	0.0020555	4.70	10.03	10.01	0.02
21	35	8	5	1.598	1.561	0.037	17.01	0.0021752	4.30	10.04	10.02	0.02
22	35	9	3	1.561	1.521	0.040	28.02	0.0014276	4.00	10.00	9.98	0.02
23	35	9	4	1.521	1.482	0.039	22.25	0.0017528	4.50	10.02	10.00	0.02
24	35	9	5	1.482	1.444	0.038	19.07	0.0019927	4.50	10.03	10.01	0.02
25	35	10	3	1.444	1.402	0.042	31.01	0.0013544	4.20	10.00	9.98	0.02
26	35	10	4	1.402	1.361	0.041	24.46	0.0016762	4.70	10.01	9.99	0.02
27	35	10	5	1.361	1.321	0.040	21.03	0.0019020	4.60	10.02	10.01	0.01

EFFECT OF PROCESS PARAMETERS ON MRR

1. Effect ofPulseONTimeon MRR

The figure 4. shows the relationship between Pulse on Time and MRR. This may be due to reason that with high pulse on time, more material gets melted at the tool work piece interface, which require proper flushing time but as the value of pulse off time is too short, so there is not enough time for the flushing to clear the debris from the inter-electrode gap between the tool and work piece, so arcing take place which result in decreasing the MRR.

2. Effect of Pulse OFF Time on MRR

There is a decrease in the MRR with an increase in the Pulse Off Time. MRR and Pulse Off Time are inversely related. The MRR decreases with lesser amplitude of Variations from 8to10 as shown in figure 4. This is because number of discharges within the desired period of time becomes smaller due to the time between two pulses which leads to lower cutting speed.

Also, there may be due to reduction in melting rate and spark ignition ratio in the plasma channel which causes lower MRR.

3. Effect of Peak Current on MRR

Figure 4 shows the significant increase in MRR with increase in peak current. This is because of the fact that with increase in the value of peak current, the energy/discharges get enhances which leads to wards increase in the cutting speed and material removal rate.

Regression Equation

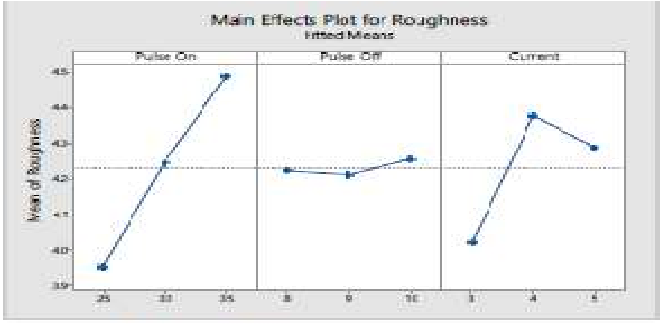
MRR=0.001185-0.000011Pulse on -0.000077

Pulse off+ 0.000419 Current

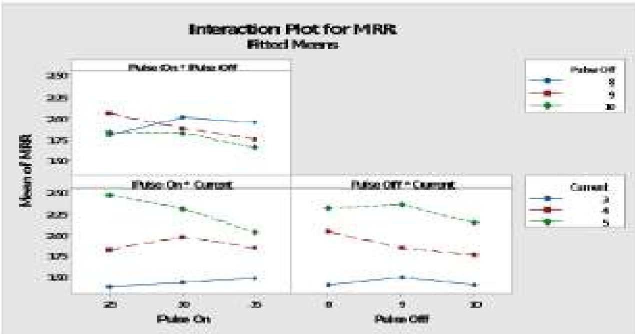
Expt. No.	Pulse ON	Pulse OFF	Current	MRR
1	25	8	3	0.0012438
2	25	8	4	0.0018628
3	25	8	5	0.0022540
4	25	9	3	0.0014627
5	25	9	4	0.0017857
6	25	9	5	0.0022901
7	25	10	3	0.0014295
8	25	10	4	0.0018221
9	25	10	5	0.0022384
10	30	8	3	0.0013415
11	30	8	4	0.0021683
12	30	8	5	0.0024970
13	30	9	3	0.0015209
14	30	9	4	0.0019404
15	30	9	5	0.0021598
16	30	10	3	0.0013977
17	30	10	4	0.0017850
18	30	10	5	0.0022538
19	35	8	3	0.0016078
20	35	8	4	0.0020555
21	35	8	5	0.0021752
22	35	9	3	0.0014276
23	35	9	4	0.0017528
24	35	9	5	0.0019927
25	35	10	3	0.0013544
26	35	10	4	0.0016762
27	35	10	5	0.0019020

Table 4.2 Effects of input parameters on Material removal rate

Figure4 Main Effects plot for Material removal rate



Graph 4.4 Main Effects plot for Surface Roughness



Graph 4.2 Interaction plot for Material removal rate

Surface Roughness

Expt. No.	Pulse ON	Pulse OFF	Peak Current	Ra Value
1	25	8	3	3.70
2	25	8	4	4.40
3	25	8	5	4.30
4	25	9	3	3.40
5	25	9	4	4.10
6	25	9	5	4.00
7	25	10	3	3.40
8	25	10	4	4.00
9	25	10	5	4.30
10	30	8	3	3.60
11	30	8	4	3.60
12	30	8	5	4.50
13	30	9	3	4.70
14	30	9	4	4.50
15	30	9	5	4.20
16	30	10	3	4.30
17	30	10	4	4.90
18	30	10	5	3.90
19	35	8	3	4.90
20	35	8	4	4.70
21	35	8	5	4.30
22	35	9	3	4.00
23	35	9	4	4.50
24	35	9	5	4.50
25	35	10	3	4.20
26	35	10	4	4.70
27	35	10	5	4.60

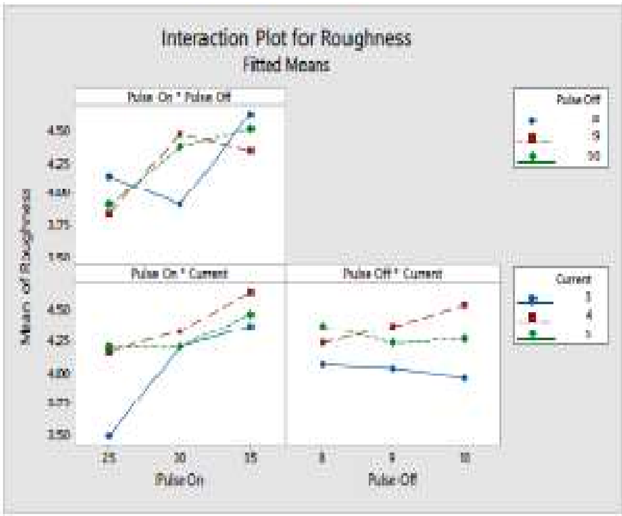
The figure4.4 shows the Main effects plots for Surface Roughness.

1. As the pulse on time increases from 25 to 35, the mean of Surface Roughness increases gradually. The increase in surface roughness was observed with increased pulse on time. This is because of increased pulse on time which produces larger discharge energy between electrode and the work piece. It ceases to melt more amounts of Material which helps to create a larger and deeper crater.

2. As the pulse off time increases from 8 to10, the mean of roughness remains constant from 8 to 9 and increases from 9 to 10. As the increase in pulse off time, there were no changes in the surface rough nesses during machining of bronze material. This is due to the time between the pulse width which is in consequentially increased and which is not much affecting the ratio of pulse energy in the plasma channel between the electrode and work piece surface.

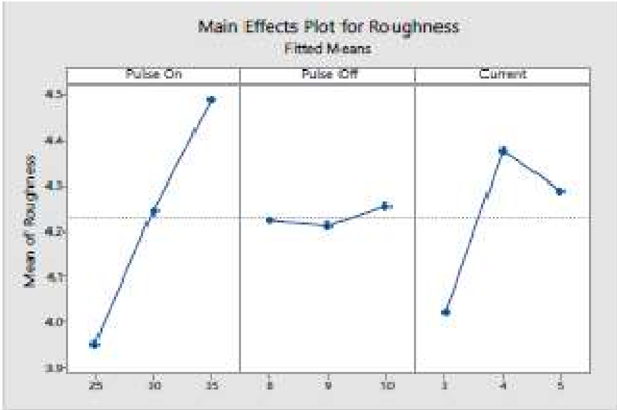
3. As the current increases from 3 to5, the mean of surface roughness increases from 3 to4 but decreases gradually from 4 to5. The mean of surface roughness increases from 3 to4 due to the presence of larger discharge energy as the current is increased and form 4 to 5 the melting of material and large and deeper crater decreases the surface roughness.

Regression Equation =1.95+0.0533 Pulse on +0.0167 Pulse off +0.1333 Current



Graph 4.3 Interaction plot for Surface Roughness

Figure4.4 MainEffectsplotforSurfaceRoughness



Graph 4.4 Main Effects plot for Surface Roughness

Table 4.3 Statistical and Experimental values of MRR and surface roughness

SI	Pulse on	Pulse off	Current	Experimental values Surface roughness	Experimental values MRR	Statistical values Surface roughness	Statistical values MRR
1	25	8	3	3.7	0.001243	3.816	0.001551
2	25	8	4	4.4	0.001862	3.9493	0.00197
3	25	8	5	4.3	0.002253	4.0826	0.002389
4	25	9	3	3.4	0.001462	3.8327	0.001474
5	25	9	4	4.1	0.001785	3.966	0.001893
6	25	9	5	4	0.0029	4.0993	0.002312
7	25	10	3	3.4	0.001425	3.8494	0.001397
8	25	10	4	4	0.001782	3.9827	0.001816
9	25	10	5	4.3	0.002238	4.116	0.002235
10	30	8	3	3.6	0.001341	4.0825	0.001496
11	30	8	4	3.6	0.002168	4.2158	0.001915
12	30	8	5	4.5	0.00249	4.3491	0.002334
13	30	9	3	4.7	0.00152	4.0992	0.001419
14	30	9	4	4.5	0.00194	4.2325	0.001838
15	30	9	5	4.2	0.002159	4.3658	0.002257
16	30	10	3	4.3	0.001397	4.1159	0.001342
17	30	10	4	4.9	0.001784	4.2492	0.001761
18	30	10	5	3.9	0.002253	4.3825	0.00218
19	35	8	3	4.9	0.001607	4.349	0.001441
20	35	8	4	4.7	0.002055	4.4823	0.00186
21	35	8	5	4.3	0.002175	4.6156	0.002279
22	35	9	3	4	0.001475	4.3657	0.001364
23	35	9	4	4.5	0.00176	4.499	0.001783
24	35	9	5	4.5	0.0019926	4.6323	0.002202
25	35	10	3	4.2	0.0013544	4.3824	0.001287
26	35	10	4	4.7	0.0016762	4.5157	0.001706

The statistical and experimental values are shown in the table. The experimental values formetal removal rate and surface roughness are shown in the table. The statistical values are obtained by substituting the values of input parameters in the regression equation.

Regression Equation

MRR=0.001185-0.000011 Pulse on- 0.000077 Pulse off+ 0.000419 Current

Regression Equation

Sur Rou =1.95+0.0533 Pulse on + 0.0167 Pulse off + 0.1333 Current

The graph 4.5 shows the interaction plots for Kerf width

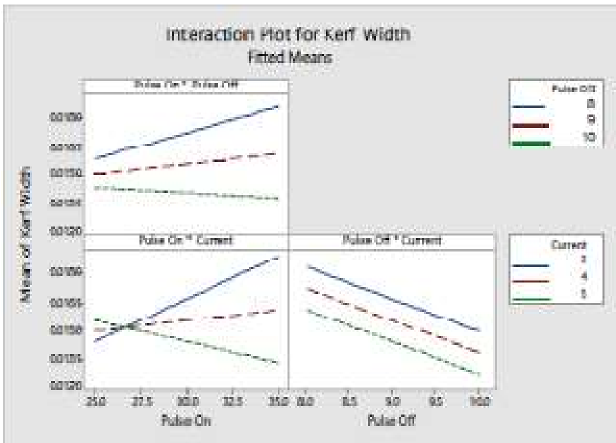
The graph 4.6 shows the main effect plots for Kerf width

1. As the pulse on time increases from 25 to 35, the Kerf width also increases. This because unevenly distribution of sparks and the discharge energy also decreases so the pulse on time increases.

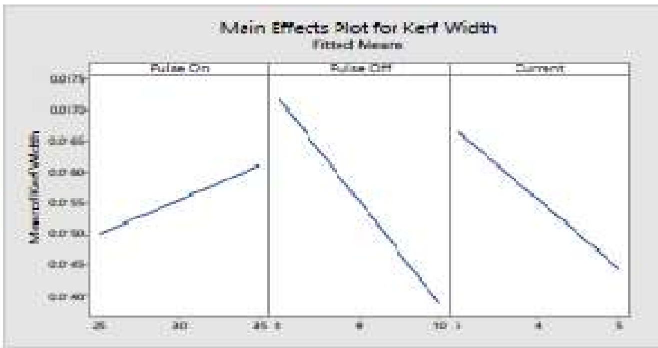
Kerf width

Expt. No.	Pulse ON	Pulse OFF	Current	KwT	KwB	kwT-KwB
1	25	8	3	10.03	10.02	0.01
2	25	8	4	10.03	10.01	0.02
3	25	8	5	10.03	10.02	0.01
4	25	9	3	10.02	10.01	0.01
5	25	9	4	10.01	9.99	0.02
6	25	9	5	10.00	9.99	0.01
7	25	10	3	10.01	10.00	0.01
8	25	10	4	10.04	10.02	0.02
9	25	10	5	10.05	10.03	0.02
10	30	8	3	10.04	10.00	0.04
11	30	8	4	9.97	9.94	0.03
12	30	8	5	10.02	10.01	0.01
13	30	9	3	10.00	9.99	0.01
14	30	9	4	10.00	9.99	0.01
15	30	9	5	10.03	10.02	0.01
16	30	10	3	10.05	10.03	0.02
17	30	10	4	10.03	10.02	0.01
18	30	10	5	10.03	10.02	0.01
19	35	8	3	10.04	10.03	0.01
20	35	8	4	10.03	10.01	0.02
21	35	8	5	10.04	10.02	0.02
22	35	9	3	10.00	9.98	0.02
23	35	9	4	10.02	10.00	0.02
24	35	9	5	10.03	10.01	0.02
25	35	10	3	10.00	9.98	0.02
26	35	10	4	10.01	9.99	0.02
27	35	10	5	10.02	10.01	0.01

Table 4.4 Effects of input parameters on Kerf width



Graph 4.5 Interaction plot for Kerf width



Graph 4.6 Main Effects plot for Kerf width

2.As the pulse off time increases from 8to10, the Kerf width decreases gradually. The reason for decrease in Kerf width is with the decrease of discharge duration, the overcut during discharge also increases as the discharge energy per pulse increases.

3. As the current increases from 3 to 5, the Kerf width decreases gradually. The main reason behind this is that higher the peak current, higher will be the spark energy. This high spark energy produces larger amount of debris. The debris sticks on the work piece trap and may cause unwanted spark. The unwanted sparks result in tool material erosion, which results in less material removal, as the significant amount of spark energy is used in sparking With debris, leading to less Kerf width.

EDS (Energy dispersive X-ray spectrometry)

EDS makes use of the X-rays emitted when a beam of electrons hits the sample. This provides the information regarding the chemical composition present in the sample. In this project chemical composition is checked for Bronze Material. The major principal elements present in the bronze material are copper with 69.37%. The other elements like zinc, lead, carbon and tin are present in the small percentages.

The graph shows the higher peaks of copper which means copper is present in higher percentage which is indicated in the table as 69.37%. The other elements like Zinc(3.54),Tin(1.82), lead (14.4) and carbon (10.88) are present in small percentages which is indicated by small peaks in the graph.

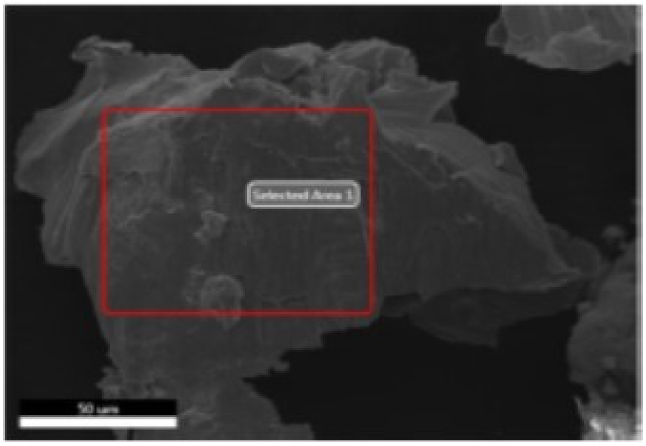


Figure 4.7 Selected area of Bronze material

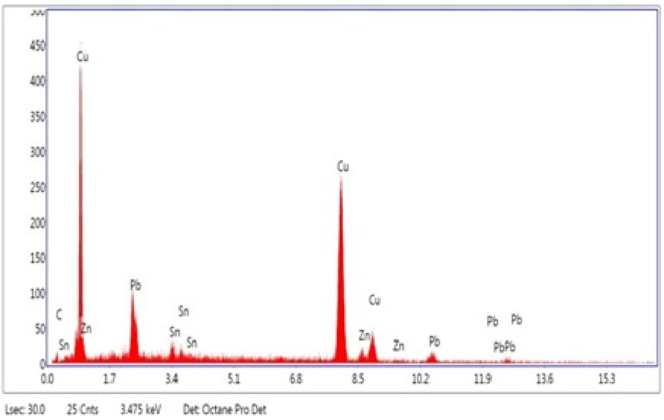


Figure 4.8 Composition of Bronze material

V. CONCLUSION

Experimental investigation on wire electrical discharge machining of Bronze has been done using Molybdenum wire of 0.18mm. The performance parameters included pulse on time(Ton), Pulse off time (Toff), Current(Ip). Experiments were conducted according to L27 Orthogonal Array Design. The optimum parameters value combination was found which would yield minimum Surface Roughness (SR) and Maximum Material Removal Rate(MRR).

The following conclusions are made.

1.The main significant factor which affects the Material removal rate is Current.

2.Pulse ON time and Pulse OFF time has least significant effect on material removal rate.

3.The two significant factors which affects surface roughness is Pulse ON time and Current.

4.The Pulse OFF time has negligible influence on surface roughness.

5. The Material removal rate is found to be maximum at Pulse ON Time-30, Pulse OFF Time10, Current-5.

6. The surface roughness was found be minimum at Pulse ON Time-25, Pulse OFF Time-9, Current-3.

7.EDS (Energy dispersive X-ray spectrometry) analysis was done on the Bronze sample.

8. Kerf width increases with increase in Pulse ON time, Pulse OFF and current decreases with increase in Kerf width values.

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