International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Investigating Machinability Aspects of Cu-W MMC in Wire Electrical Discharge Machining (WEDM)

S. B. Ubale[1], Dr. S. D. Deshmukh[2]

[1] *Research Scholar, Department of Mechanical Engineering, MGM's Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India. ubalesb@yahoo.co.in.*
[2] *Principal, MGM's Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India. sddeshmukh47@rediffmail.com.*

Abstract - Copper tungsten (Cu-W) metal matrix composite (MMC) is a very useful material for electrical discharge machining (EDM) electrodes. It has high strength, good wear resistance and exceptional arc erosion resistance. It is often fabricated using powder metallurgy route and is too hard to be machined with conventional techniques. In this paper, an attempt has been made to investigate machinability aspects of Cu-W with 30 wt.% copper and 70 wt. % tungsten in WEDM. The effects of Pulse on Time (Ton), Pulse off Time (Toff), Peak Current (IP), Wire Tension (WT) and Spark Gap Set Voltage (SV) have been investigated experimentally on Material Removal Rate (MRR) and Surface Roughness (Ra).
Keywords - WEDM, MMC, Copper-Tungsten (Cu-W), Machinability.

I. INTRODUCTION

The wire electrical discharge machining is widely used for machining conductive materials of any hardness. It is extensively used in tool and dies industry because of its ability to machine complicated shapes with desired accuracy. The material removal mechanism in WEDM is because of erosion of material by discrete sparks occurring between traveling wire electrode and workpiece through dielectric medium. Each spark produces a temperature around 8000^{0}C to 12000^{0}C. Because of thousands of sparks generated per seconds, tiny craters are produced in the material and material is removed by melting and vaporization [1-6].
EDM electrodes are commonly made from copper, graphite, brass and silver. Copper has high thermal and electrical conductivity but has lower wear resistance. Among these, the copper-tungsten electrodes are widely used as they provide better surface finish and longer life than graphite electrodes. Copper-tungsten electrodes are extensively used in manufacturing sector due to good wear resistance, thermal conductivity and spark erosion resistance. Therefore, an attempt has been made to investigate the machinability aspects of Cu-W MMC in WEDM.

II. MATERIALS AND METHOD

2.1. Workpiece Material

In this work, Cu-W MMC with 30 wt. % of Cu and 70 wt. % of W fabricated using sintering process is directly procured. The hardness of material is 91-92 HRB.

Figure 1: Pictorial View of Cu-W MMC.

2.2. Wire Electrode

The wire electrodes widely used in WEDM are copper and brass. The zinc coated brass wire has high tensile strength and gives better surface finish as compared to copper wire. Hence, in this work, brass wire manufactured by Kriicut of 0.25 mm diameter has been employed.

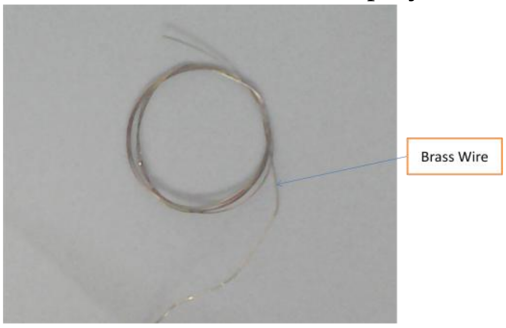

Figure 2: Pictorial View of Brass Wire.

2.3. Dielectric

De-ionized water is widely used as dielectric fluid in WEDM. Therefore, de-ionized water is used as dielectric fluid.

2.4. WEDM Parameters and Setting

Figure 3: Pictorial View of WEDM Experimental Setup.

From literature survey and machine tool manual, pulse on time, pulse off time, peak current, wire tension and spark gap set voltage have been identified as input parameters affecting the performance characteristics of WEDM. Minimum and maximum limits and step size of each parameter have been noted from machine tool manual and confirmed from machine tool. The machine tool manual provides the ranges of parameter setting for limited materials such as tool steels and carbides. Therefore, the parameter setting for Cu-W MMC has been done by conducting trials.

2.5. Experimental Work

In the present work, one factor at time approach (OFT) has been employed for the experimentation. Each trial is conducted by varying each parameter at five different levels while keeping all other parameters constant. In each trial, 6 mm by 6 mm workpiece has been cut as depicted in figure 4.

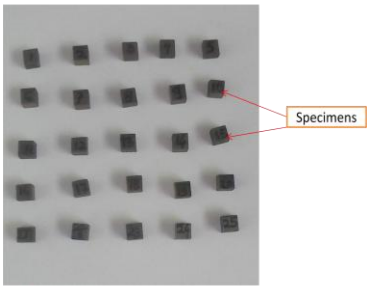

Figure 4: Pictorial View of Specimens.

2.6 Measurement Systems

The weight of workpiece is measured with precise weighing machine having the least count of 0.01 gram (g). The weight of workpiece is measured before and after each trial. Total machining time required for each trial is noted using stop watch and the material removal rate is calculated by weight difference method given by equation (1).

$$MRR = \frac{Weight\ Before\ Machining - Weight\ After\ Machining}{Machining\ Time \times\ Density\ of\ Workpiece} \quad (1)$$

The surface roughness of machined surface is measured with TAYLOR HOBSON surface roughness tester. Surface roughness has been measured with stroke length of 0.25 mm and evaluation length of 0.50 mm. Two readings on each machined surface, one parallel to wire and one perpendicular to wire direction comprising of total four readings are taken. The average of these four readings has been taken for analysis purpose.

III. RESULTS AND DISCUSSION

3.1 Effect of Pulse on Time on Performance Measures

The pulse on time (Ton) has been varied from 103 µs to 115 µs in step of 3 µs. The values of all other parameters are kept constant and their values are given as Toff = 63 µs; IP = 210 A; WT = 6(900 g); SV = 20 V. The experimentally observed data for the MRR and Ra for different values of pulse on time is given in Table 1. Figure 5 shows the scatter plot of pulse on time versus MRR, Ra.

Table 1: Performance Measures for Pulse on Time.

Sr. No.	Pulse on Time (µs)	MRR (mm^3/min)	Ra(µm)
1	103	0.0063	0.775
2	106	0.0157	0.950
3	109	0.0263	1.750

4	112	0.0367	1.800
5	115	0.0465	1.900

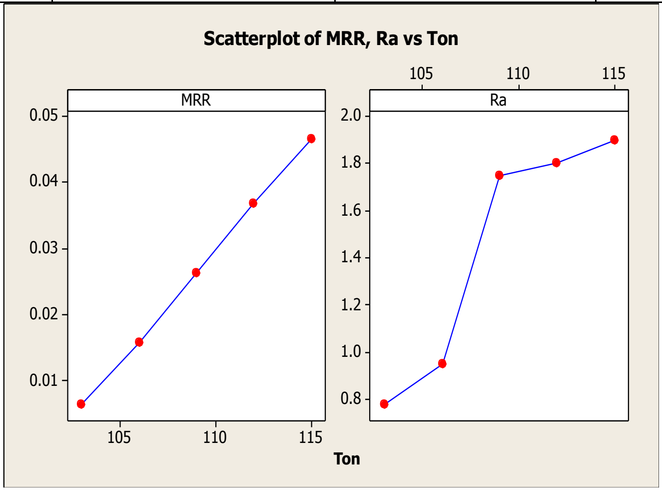

Figure 5: Scatter Plot of MRR, Ra vs Ton.

The MRR increases with the increase in the pulse on time in a straight line fashion. As seen from figure 5, surface roughness has increasing trend with increase in Ton. Material removal rate and surface roughness increase with increase in Ton due to the fact that discharge energy increases with increase in Ton. When Ton is increased beyond 115 µs, the wire breakage was reported and hence upper limit of Ton has been fixed at 115 µs. The lowest level of Ton has been set on the basis of high machining time required.

3.2 Effect of Pulse off Time on Performance Measures

The pulse off time has been varied from 51 µs to 63 µs with an increment of 3 µs. The values of the other parameters are kept constant and their values are given as Ton = 110 µs; IP = 210 A; WT = 5(780 g); SV = 20 V. The observed data for the performance measures has been illustrated in Table 2. Figure 6 depicts the scatter plot of pulse off time versus MRR, Ra. It can be seen that material removal rate decreases linearly with increase in the pulse off time. This is due to the fact that with

Table 2: Performance Measures for Pulse off Time.

Sr. No.	Pulse off Time (µs)	MRR (mm^3/min)	Ra (µm)
1	51	0.0372	1.600
2	54	0.0338	1.450
3	57	0.0311	1.575
4	60	0.0289	1.500
5	63	0.0263	1.850

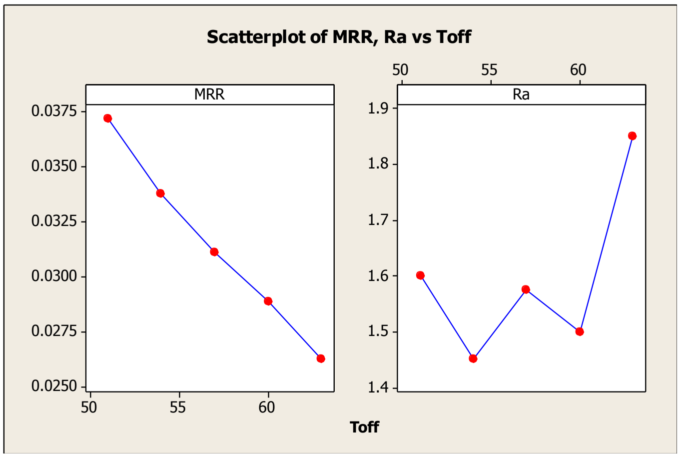

Figure 6: Scatter Plot of MRR, Ra vs Toff.

increase in Toff, the non- cutting time increases and therefore, material removal rate decreases. Hence for reducing machining time, Toff should be set at lowest possible level. When Toff has been reduced below 51 µs, wire breakage was reported and hence lowest level of Toff has been fixed at 51 µs. From the figure 6, surface roughness fallows no specific trend with Toff. Practically, surface roughness should decrease with increase in Toff. It can be seen that with increase in Toff, Ra decreases initially and again increases at higher level of Toff. The increases in Ra drastically at higher level of Toff may be because of noise factors.

3.3 Effect of Peak Current on Performance Measures.

The peak current is varied from 180 A to 220 A in the increments of 10 ampere. The values of the other parameters are kept constant and their values are given as Ton = 110 µs; Toff = 57 µs; WT = 5(780 g); SV = 20 V. The experimentally observed data for the performance measures for different values of peak current is given in Table 3. Figure 7 shows the scatter plots of peak current versus response characteristics. The material removal rate first increases then decreases and again increases with increase in peak current. The surface roughness value decreases slightly first with increase in peak current then increases linearly and thereafter again decreases with increase in IP.

Table 3: Performance Measures for Peak Current.

Sr. No.	Peak Current (A)	MRR (mm^3/min)	Ra(µm)
1	180	0.0293	1.600
2	190	0.0324	1.525
3	200	0.0311	1.650
4	210	0.0283	1.975
5	220	0.0304	1.600

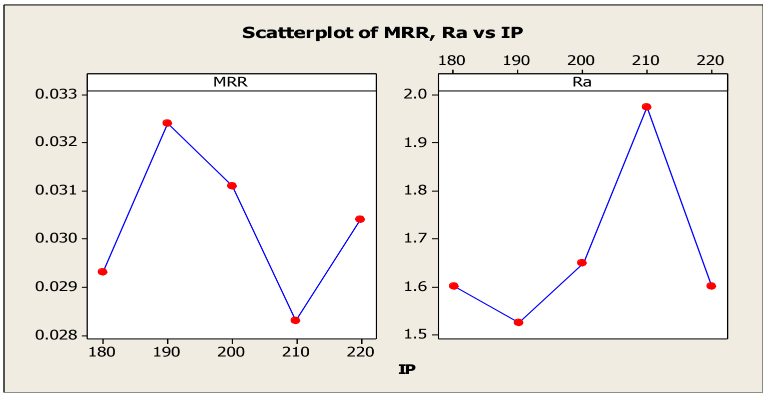

Figure 7: Scatter Plot of MRR, Ra vs IP.

3.4 Effect of Wire Tension on Performance Measures

The wire tension is varied from 2(420 g) to 6 (900 g) in the steps of 1(120 g). The values of the other parameters are kept constant and their values are given as Ton = 110 µs; Toff = 57 µs; IP = 200 A and SV = 20 V. The experimentally observed data for the performance measures for different values of wire tension is given in Table 4. Figure 8 shows the scatter plot of wire tension versus response characteristics. The material removal rate initially increases and there after decreases linearly with increase in WT. When wire tension has been set at 2 units, the intermediate cutting was observed. This may be due to excessive vibrations of wire. With increase in WT, surface roughness decreases initially, remains constant for intermediate wire tension and then increases again.

Table 4: Performance Measures for Wire Tension.

Sr. No.	Wire Tension (g)	MRR (mm^3/min)	Ra (µm)
1	2(420)	0.0321	1.675
2	3(540)	0.0342	1.500
3	4(660)	0.0334	1.500
4	5(780)	0.0311	1.650
5	6(900)	0.0300	1.725

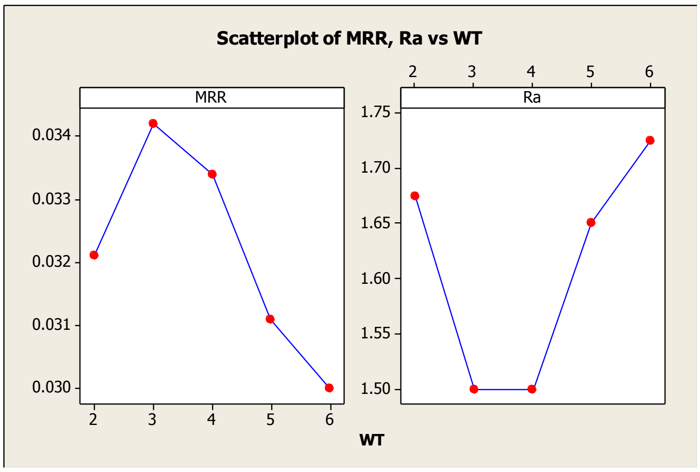

Figure 8: Scatter Plot of MRR, Ra vs WT.

3.5 Effect of Spark Gap Set Voltage on Performance Measures

The spark gap set voltage is varied from 14 volt to 22 volt in the increment of 2 volt. The values of the other parameters are kept constant and their values are given as Ton = 110 μs; Toff = 57 μs; IP = 200 A and WT = 5 (780 g). The experimentally observed data for the performance measures for different values of SV is given in Table 5. Figure 9 illustrates the scatter plot of spark gap set voltage versus response characteristics.

Table 5: Performance Measures for Spark Set Gap Voltage.

Sr. No.	Spark Set Gap Voltage (V)	MRR (mm^3/min)	Ra (μm)
1	14	0.0300	1.700
2	16	0.0311	1.500
3	18	0.0340	1.500
4	20	0.0323	1.575
5	22	0.0307	1.625

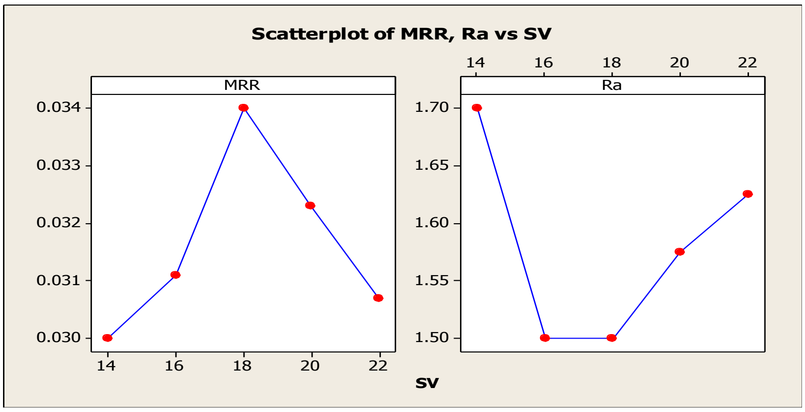

Figure 9: Scatter Plot of MRR, Ra vs SF.

The material removal rate firstly increases and then decreases linearly with increase in SV. Surface roughness firstly decreases, then almost remains constant and then increases with increase in SV.

CONCLUSIONS

In this paper, Cu-W MMC has been machined with brass wire in the presence of de-ionized water on wire electrical discharge machine and effects of important process parameters on material removal rate and surface roughness have been investigated experimentally. On the basis of analysis of experimental observed data, fallowing conclusions can be drawn:

1. Material removal rate and surface roughness increase with increase in pulse on time.
2. Material removal rate varies inversely with pulse off time whereas surface roughness shows no clear pattern with pulse off time.
3. No specific trends were observed for material removal rate and surface roughness with peak current.
4. Maximum material removal rate and minimum surface roughness were observed at 18 volt spark gap set voltage.

ACKNOWLEDGMENTS

The authors would like to thank IGTR Aurangabad, for providing the facilities to conduct the experiments.

REFERENCES

[1] J. T. Huang, Y. S. Liao, W. J. Hsue, "Determination of Finish-Cutting Operation Number and Machining-Parameters Setting in Wire Electrical Discharge Machining", Journal of Materials Processing Technology 87, pp. 69–81, 1999.

[2] S. S. Mahapatra, Amar Patnaik, "Optimization of Wire Electrical Discharge Machining (WEDM) Process Parameters using Taguchi Method", International Journal of Advanced Manufacturing Technology, 2006.

[3] A. Ikram, N. Ahmad Mufti, M. Qaiser Saleem, A. Raza Khan, "Parametric Optimization for Surface Roughness, Kerf and MRR in Wire Electrical Discharge Machining (WEDM) using Taguchi Design of Experiment", Journal of Mechanical Science and Technology 27, pp. 2133 –2141, 2013.

[4] K. Lingadurai, B. Nagasivamuni, M. Muthu Kamatchi, J. Palavesam, "Selection of Wire Electrical Discharge Machining Process Parameters on Stainless Steel AISI Grade-304 using Design of Experiments Approach", Journal of the Institution of Engineers (India) 93, pp. 163–170, 2012.

[5] S. Y. Martowibowo, A. Wahyudi, "Taguchi Method Implementation in Taper Motion Wire EDM Process Optimization", Journal of The Institution of Engineers (India) 93, pp.357–364, 2012.

[6] F. Nourbakhsh, K. P. Rajurkar, A. P. Malshe, J. Cao, "Wire Electro-Discharge Machining of Titanium Alloy", Procedia CIRP 5, pp. 13–18, 2013.

