Response Parameter Optimization For Micro Edm Under Influence of Cu Nano Powder For Taitanium Matrix Composite (Tmcs)

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ABSTRACT

This research highlight the effect of Cu nanopowder on the electro-discharge machining (EDM) on hard to cut material Titanium matrix composite (TMCs). In the space of optimization, Taguchi L16 standard orthogonal array is used. Analysis of variance (ANOVA) is to check the significance level of the experiments. Speed, Voltage (GAP) and volume concentration of Cu nanopowder are selected as the input variable and material removal rate (MRR) and tool wear rate (TWR) are the response parameters. The end outcome of the result shown that both response parameters are influenced by Cu nanopowder. Under the high volume concentration, MRR of the machining process is increased, but on the other side TWR also increases due to the presence of Cu nanopowder. The result of ANOVA explains the significance of the experiment.

KEYWORDS: *TMCs(Titanium matrix composite), ANOVA, Material removal Rate (MRR), Tool Wear rate(TWR), Cu nanopowder.*

I. INTRODUCTION

In the EDM through erosion process is responsible for metal elimination from work material with the help of a tool.[4,11] Dielectric fluid is used for improving the effectiveness of the erosion process and responsible for the easy and fast removal of debris from the workpiece and also maintain continuity of erosion process.[3,12]

Polarity is depended on the experiments design and normally workpiece is considered as the anode and tool an electrode as cathode for the high erosion rate and high material removal rate (MRR).[5] Thermal erosion and vaporization are taken place due to the pulse between tool and workpiece, this is pulse is generated by the help of generator and stability of the spark is maintained by the help of dielectric fluid.[3]

In recent times, the Development of minor holes especially in superalloy category material and carbon-based composite is a very important and difficult process due to the level of super finish and cost.[1,2] As we know these two materials equipped with a higher level of properties like high corrosion resistance, stability, working temperature mechanical properties, higher strength, lightweight, etc. and due to these properties today manufacturing word attract toward these materials with application in the field of the aeronautical industry, thermal power plant, automobile sector, and life support equipment industry.[6,7]

In super alloy conventional sharp edge tool-based machining suffer by number of problem like geometrical error, high tool wear rate, high-temperature zone and sometimes resistance to cut also and in carbon fiber-based material pull-out of carbon fiber and a poor finish. So supper alloy marked as a "Difficult to machine" by the normal machining process. [3,5,8] Due to the number of machining problems EDM is suitable for machine such material especially for creating micro the level hole which is not possible by conventional drilling process with high quality of finish.[9-10] Current material world is deals with hard to cut material and machining of these material is not easy by simple machine tools so to machine these material EDM is most suitable machine.[13-14] Due to machining of hard to cut material EDM also play a vital role in the area of optical, medical, dental, surgical, aerospace and automobile.[3,5] Figure 1a and 1b represent the working of Cu nano powder based electro discharge machining process.

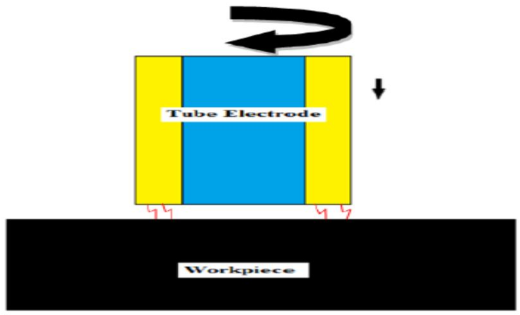

Fig. 1a Working principle of electro discharge machining

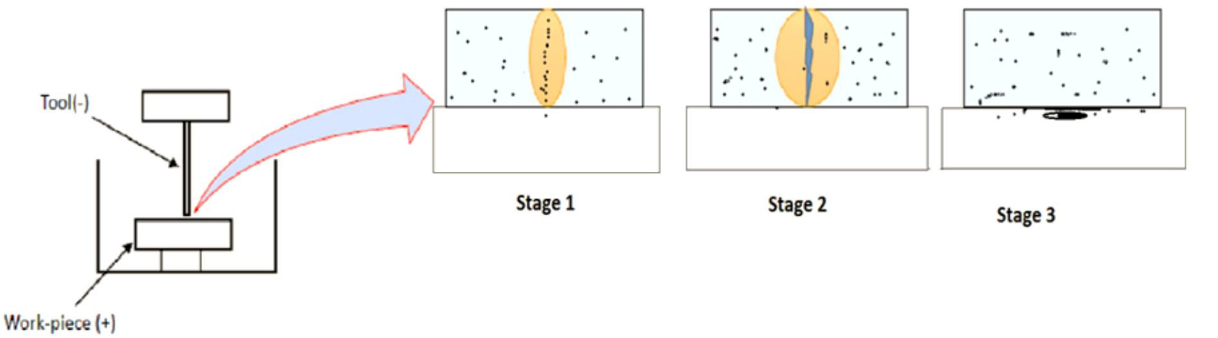

Fig. 1b Stage-wise EDM process. [5]

II. SELECTION OF INPUT PARAMETER AND EXPERIMENT METHDOLOGY

Titanium matrix composite is a newly developed, MCs that possess superior mechanical properties than metal such as high toughness, high resistance to mechanical and chemical wear. This MC is prepared by high-temperature reaction sintering. In this research, an attempt has been made to fabricate micro-holes of high aspect ratio i.e. 10 by micro EDM. Experiments are performed on the Sparkonix EDM drill. A Taguchi L16 orthogonal array is used to design the experimentations.

Selection of the parameter are based on the pilot test and literature review. Table 1 shown the selected parameter range. Material removal rate (MRR) and Tool wear rate are selected as the response output parameter. These both are calculated in mm^3/min. MRR is defined as the loss of workpiece material volume before machining and after machining. TWR is defined as the loss of volume f tool during the machining operation. Flowchart for experimentation methodology shown in figure 2.

Table 1 Input parameters

Parameter(Unit)	Level of input parameters			
Speed(rpm)	700	900	1100	1300
Gap Voltage(volt)	60	75	90	105
Concentration(g/l)	0	0.2	0.4	0.6

Experimental methodology explain the complete experiment process. In the first step we select the work-piece and tool material. After selection of material we perform pilot test and specify the range of parameter on which response parameter depends. At the same time L16 table is prepared for the experiment run on the basis of selected parameter levels. Then after we calculated the S/N ratio and then perform ANOVA test to check the significance level of the experiments. Volume concentration of Cu powder is prepared with the help of sonicator bath for the duration of total 32 hours.

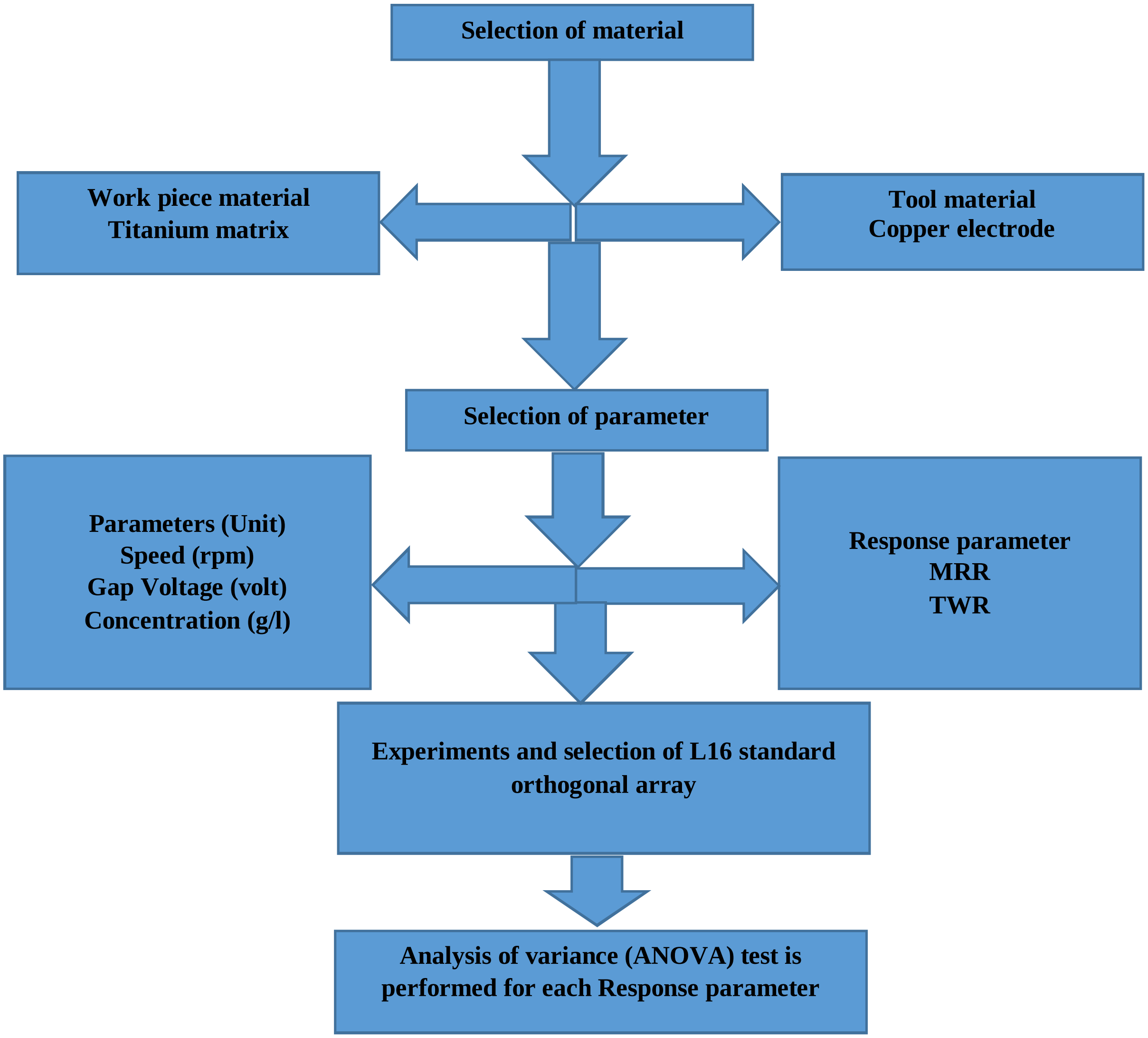

Fig.2. Methodology flowchart

III. RESULTS AND DISCUSSION

Taguchi L16 orthogonal array used to design the experiment. Speed, gap voltage and concentration are selected as the input parameter and four levels of these parameters are selected. Material removal rate (MRR) and tool wear rate (TWR) are considered as a response parameter. Tool wear rate is based on the reduction in the weight of tool after each round of machining.

“Larger is Better” based signal to noise ratio is used for MRR and “Smaller is better” based signal noise ratio is used for the TWR.

Empirical relation for “larger is better” shown by equation 1 and relation for the

“Smaller is better” shown by equation 2.

$$\left(\frac{S}{N}\right) ratio = \log_{10} \frac{\sum_{i=1}^{n} {}^{1}/_{Y^2}}{n} \quad (1)$$

$$\left(\frac{S}{N}\right) ratio = \log_{10} \frac{\sum_{i=1}^{n} Y_i^2}{n} \quad (2)$$

Table 2 shown the S/N ratio with regarding selected-response parameter (MRR and TWR). MRR and TWR main effect plot are shown in figure 2. Figure 2(a) is shown the main effect plot of MRR and 2(b) shown the main effect plot of TWR. From figure 2(a) indicates that a high concentration of Cu powder leads to enhancement of MRR due to high conductivity and minimum discharge gap. But this high concentration also leads to high TWR as shown in figure 2(b), because high concentration leads to high-temperature rise at tooltip and this leads to high erosion of tool and result as high TWR. Due to the presence of Cu powder tool is not capable to maintain its tip shape and size and it's diverted from its original shape and sometimes damage also these factors also lead to high TWR. For MRR concentration is rank highest followed by voltage and speed. On the other side for TWR concentration is rank last due to high tool wear, and most suitable parameter speed mark as rank 1 and followed by voltage.

Table 2 Experiment flow as per selected parameter based on standard L16 taguchi table.

Speed	Gap voltage	Concentration	MRR (mm^3/min)	TWR (mm^3/min)	S/N Ratio (MRR)	S/N Ratio (TWR)
700	60	0	0.022957	0.028830	-32.8334	32.5249
700	75	0.2	0.024980	0.027640	-35.0965	30.8433
700	90	0.4	0.026840	0.028850	-31.4700	31.2107
700	105	0.6	0.034980	0.026880	-29.1610	30.8372
900	60	0.2	0.027577	0.024956	-31.2338	31.4538
900	75	0	0.030238	0.022245	-30.4306	32.1014
900	90	0.6	0.036850	0.025835	-28.7072	33.1045
900	105	0.4	0.027572	0.023880	-31.2354	31.7995
1100	60	0.4	0.026549	0.025583	-31.5651	32.4858
1100	75	0.6	0.033859	0.035920	-29.4448	31.8850
1100	90	0	0.025497	0.035729	-31.9178	28.9250
1100	105	0.2	0.029956	0.025573	-30.7782	28.9739
1300	60	0.6	0.034889	0.024682	-29.1837	31.8884
1300	75	0.4	0.027998	0.039860	-31.1017	32.1977
1300	90	0.2	0.028748	0.034600	-30.6711	28.0211
1300	105	0	0.028004	0.028830	-31.0998	29.2530

Table 3a Response table for the signal to noise ratios (MRR- Larger is better)

Level	Speed	Voltage	Concentration
1	-31.39	-31.29	-31.60
2	-30.59	-30.86	-31.23
3	-31.02	-30.83	-31.43
4	-30.65	-30.76	-29.32
Delta	**0.8**	**0.53**	**2.28**
Rank	**2**	**3**	**1**

Table 3b TWR- Smaller is better

Level	Speed	Voltage	Concentration
1	31.44	32.18	25.79
2	32.20	31.85	24.94
3	20.68	25.31	32.01
4	30.10	25.26	32.02
Delta	**11.52**	**6.92**	**7.08**
rank	**1**	**2**	**3**

Fig.3a Main effect plot of S/N ratio for MRR in relation with Speed, Voltage and Concentration

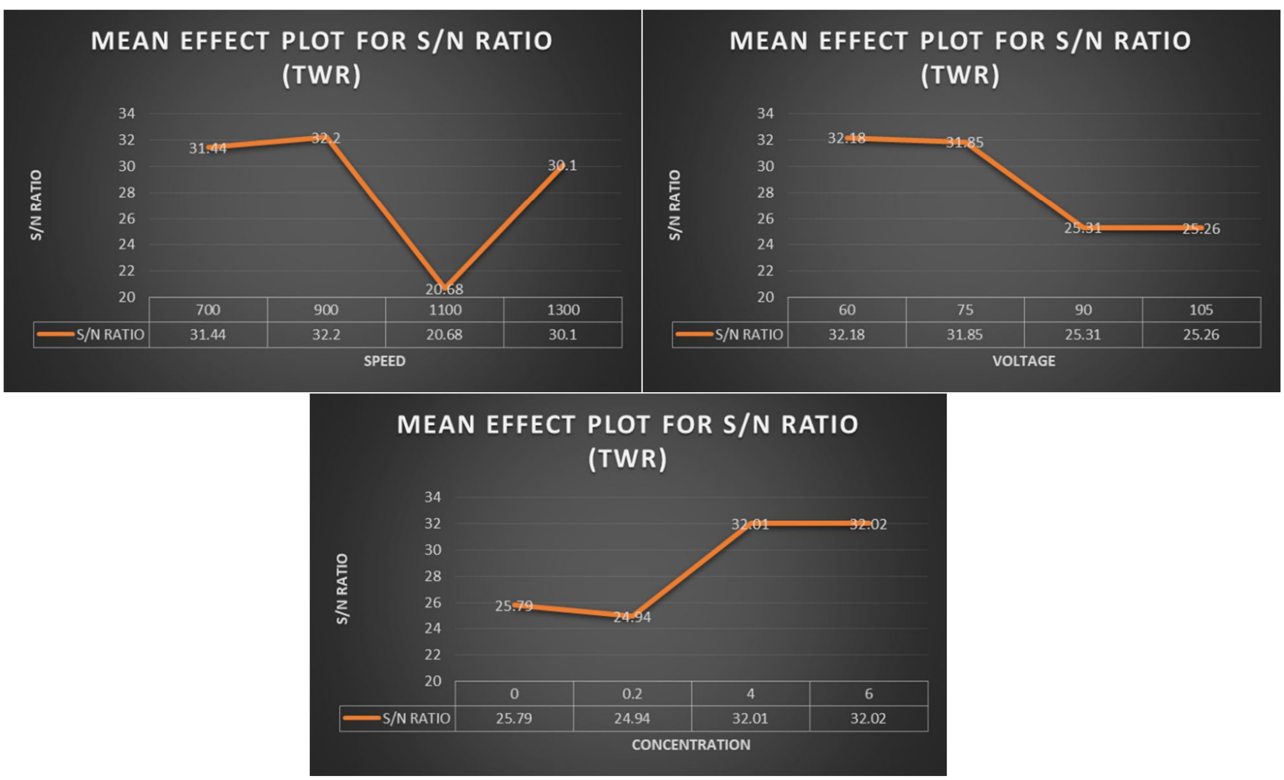

Fig.3b. Main effect plot of mean of S/N ratio for TWR in relation with Speed, Voltage and Concentration

Table 4 MATERIAL REMOVAL RATE (MRR) ANOVA TABLE.

ANOVA table for MRR						
Parameter	**DOF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Speed	3	0.0000236	0.0000236	0.0000085	3.08	0.128
Voltage	3	0.0000091	0.0000091	0.0000037	1.17	0.440
Concentration	3	0.0001936	0.0001936	0.0000652	25.44	0.011
Error count	6	0.0000162	0.0000162	0.0000035		
Total	15	0.0002395				
S= 0.00159173		R-Sq=93.71%	R-Sq(adj)=84.17%			

Table 5 TOOL WEAR RATE (TWR) ANOVA TABLE

ANOVA table for TWR						
Parameter	**DOF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Speed	3	0.0000979	0.0000969	0.0000333	7.80	0.028
Voltage	3	0.0001383	0.0001383	0.0000468	11.09	0.018
Concentration	3	0.0001517	0.0001529	0.0000516	12.17	0.016
Error count	6	0.0000262	0.0000262	0.0000052		
Total	15	0.0004122				
S= 0.00204826		R-Sq=93.98%	R-Sq(adj)=84.76%			

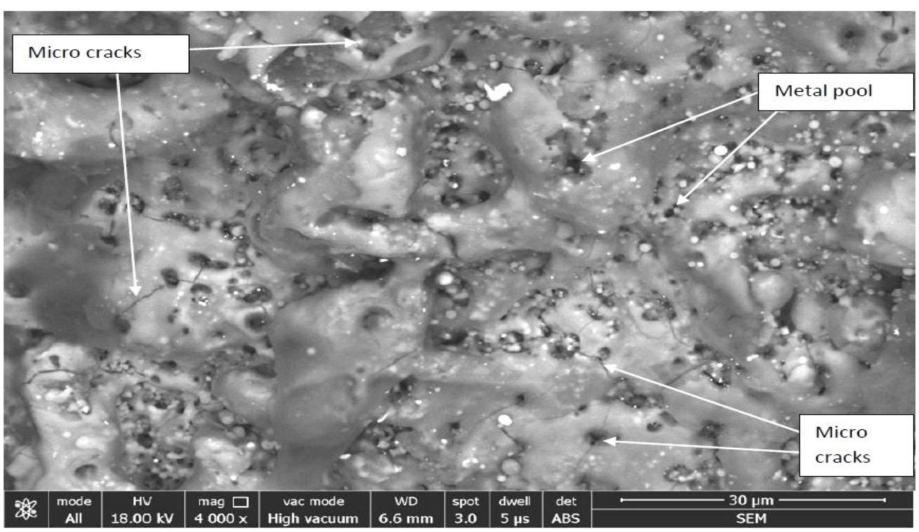

Fig. 4 SEM images of the machined surface

The ANOVA results are given in Table 4 and Table 5. ANOVA results are shown in Tables 4 and 5. From these following prediction interpretation come out:

a. MRR and TWR both are significantly influenced by Cu power concentration.
b. MRR and TWR both are affected by all the selected parameters.
c. Determination coefficient for MRR is equal to 0.9361 and TWR is equal to 0.9398.
d. The Adjusted determination coefficient for MRR is equal to 0.8417 and TWR is 0.8476.
e. Adjusted coefficient is enough high and close to the determination coefficient, this indicates the significance of the selected model.

Scanning Electrode microscopy (SEM) shown in figure 4, the internal surface of micro-holes is seen by SEM. SEM image has shown the micro-cracked which is generated in the melted metal pool.

Presence of cracks and debris is confirmation of the principle of EDM process in the form of melting and vaporization in the machined zone.

Thermal spalling is responsible for the material removal by thermal cracking and the flakes removal.

IV. CONCLUSIONS

In this research, the micro-electro-discharge machining process is carried out with Cu powder mixed dielectric for machining of TMCs.

On the basis of the result following conclusions has been carried out:

1. The concentration of Cu influenced both response parameter MRR and TWR.
2. The concentration of Cu plays the most significant role in the enhancement of MRR in comparison to speed and voltage.
3. The concentration of Cu put negative impact in TWR and it also increases with parallel to the MRR.
4. TWR is influenced by concentration and voltage.
5. Presence of Cu particle increases the discharge frequency and due to this continues sparking take place which leads to high MRR
6. From the above experiments we can suggest that Cu powder-based electro-discharge machining is suitable for hard to cut material like TMCs.

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