ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Application of Taguchi Technique for Optimization of EDM Process Parameters Using P/M Processed Metal Matrix Composite as Tool

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ABSTRACT

The present work investigates the effect of input parameters like peak current (I_p), pulse on time (T_{on}), duty cycle (DC) and gap voltage (V_g) on the output responses like material removal rate (MRR), tool wear rate (TWR), diametral overcut (DOC) and surface roughness (SR) during the ED machining of H11 die steel using conventional copper and powder metallurgy processed Cu-Cr metal matrix composite as tool electrode. Single objective optimization was done using Taguchi's technique and L_9 orthogonal array was selected to perform the experiments. S/N ratio was calculated and the results show that copper tool gives higher MRR than Cu-Cr tool. Also a layer of chromium was deposited on the machined surface which shows excellent corrosion resistant properties.

KEY WORDS: EDM, Taguchi, Material removal rate, tool wear rate, surface roughness, diametral overcut, powder metallurgy.

1. INTRODUCTION

Over the last few decades, EDM has most commonly been used in die-making and extrusion industries due to its ability to machine complex shapes with higher accuracy and precision. EDM is an electro-thermal machining procedure in which the tool and the work piece attached to two electrodes are separated by a dielectric fluid at the smallest inter electrode gap. The material removal is carried out by a series of discrete sparks due to which a plasma channel is induced between the tool and the work piece and a high temperature of about 8000-12000°C is generated which melts and erodes the work piece surface. Generally the EDM electrode materials are copper, graphite, tungsten and brass (Arthur, 1996). Copper is the most commercial and adaptable electrode material due to its brilliant electrical and thermal conductivity (Davis, 1998; ASM, 1990). In this experiment, conventional copper and metal matrix composite Cu-Cr has been used as the tool electrode to compare the effect of input parameters on the response variables. During the EDM process the Cu and Cr particles migrate to the work piece surface with improved corrosion resistance because Cr is distributed uniformly in the Cu matrix (Ming and He, 1995). The work piece material taken is the H11 die steel which is also known as chromium hot work steel.

Singh (2012), used copper tool to machine H11 steel and the results show that polarity of tool electrode, peak current and suspension of powder particles in dielectric fluid influence the surface characteristics in EDM process. Khanra (2007), developed ZrB_2-40%wt. Cu MMC to obtain an optimal setting of wear resistance, electrical and thermal conductivity. Beri Naveen (2012), studied the influence of current and polarity while machining Inconel 718 using CuW P/M processed tool electrode in EDM process. Bhattacharya (2012), gave optimal combination of input parameters for rough and finished machining of H11, EN31 and HCHCr steels in powder mixed EDM using graphite powder. Tsai (2003), used a new technique of preparing tool electrodes by mixing copper powders containing resin with Cr powders. Mathew (2014), study, the effect of input parameters of EDM process i.e on MRR of H11 steel are experimentally investigated.

From the previous researches it can be seen that some more experimental investigation is required for the application of P/M processed tool in the industries. Therefore experiment is conducted to get better results using Cu-Cr tool. Taguchi's L_9 orthogonal array is used to conduct the experiments. Four input parameters namely peak current, pulse on time, duty cycle and gap voltage are taken. The Taguchi design is analysed and S/N ratio is calculated.

2. MATERIALS AND METHODS

In the present investigation, experiments are conducted on H11 die steel using copper and P/M processed metal matrix composite tool electrode. The metal matrix composite was composed of Cu-Cr with weight percentage of 80% Cu, 20% Cr. Sieve analysis was done for the grain size determination and powder materials less than 53µ were taken for tool preparation. So the tool electrodes (ϕ 10 mm) used are made of electrolytic copper powder (80% pure) with chromium powder weight percentage (wt.20%) using the powder metallurgy route (Max. load: 4 ton and sintering temperature: 650^0C). The independent machining parameters chosen for this experimentation are tool peak current (I_p), pulse on-time (T_{on}), duty cycle (DC) and discharge voltage (V_g). The machining time taken is 15 minutes and is kept constant for all experiments. The machining was done in die sinking type Electrical Discharge machine (EDM) of model Electronica Smart ZNC with servo-head and positive polarity for electrode. The MRR, TWR and DOC were calculated. And surface roughness was measured by the device profilometer.

Optimization Technique: Taguchi technique is used for design of experiments. Taguchi standard orthogonal array (OA) L_9 with 8 degrees of freedom is identified as the appropriate array for the combination of three levels and four

factor experimental designs. The SN ratios were calculated for MRR (larger is better) and TWR, DOC and SR (smaller is better). To analyse the influence of each parameter on the output response, the S/N ratio has to be evaluated for each experiment.

In case of minimizing the output response, the SN ratio can be evaluated using equation (1):

$$SN_i = -10\log\left(\sum_{u=1}^{N_i} \frac{{y_u}^2}{N_i}\right) \qquad (1)$$

In case of maximizing the output response, the SN ratio can be evaluated using equation (2):

$$SN_i = -10\log\left[\frac{1}{N_i}\sum_{u=1}^{N_i} \frac{1}{{y_u}^2}\right] \qquad (2)$$

The main effect plots for SN ratios obtained for MRR, TWR, DOC and SR for copper tool and Cu-Cr are shown below:

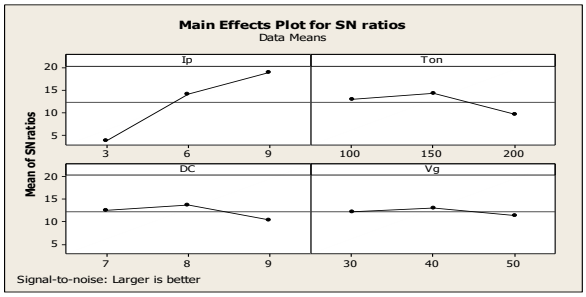

Fig.1. S/N ratio plots for MRR for Cu tool

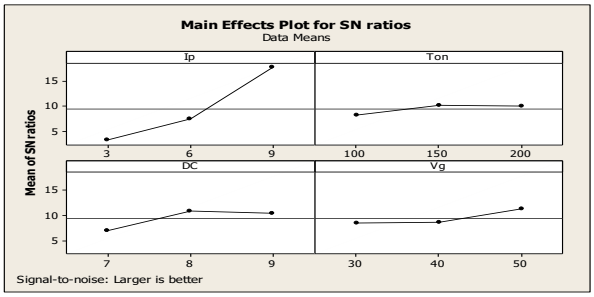

Fig.2. S/N ratio plots for MRR for Cu-Cr tool

From the main effect plot for S/N ratio as shown in fig.1 and fig.2, it can be observed that MRR being 'higher the better' type of quality characteristic, the higher values of MRR are considered to be the optimum.

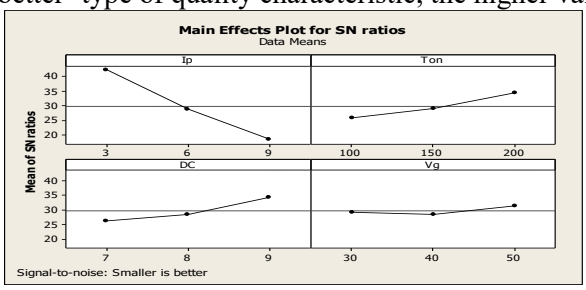

Fig.3. S/N ratio plots for TWR for Cu tool

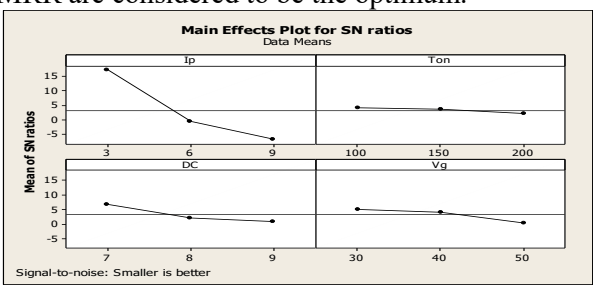

Fig.4. S/N ratio plots for TWR for Cu-Cr tool

From the main effect plot as shown in fig.3 and fig.4, it can be observed that TWR being 'smaller the better' type of quality characteristic, the lower values of TWR are to be considered to be the optimum.

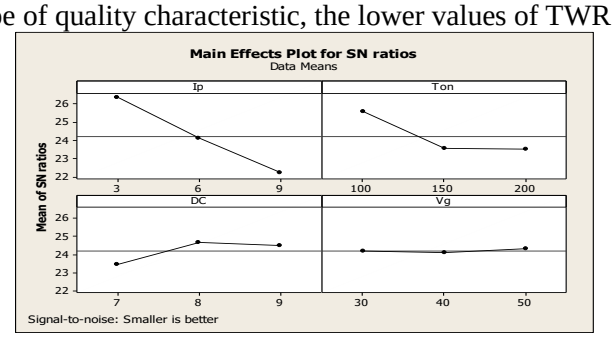

Fig.5. SN ratio plots for DOC for Cu tool

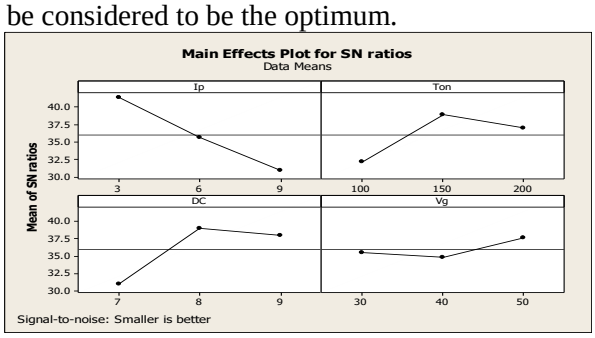

Fig.6. S/N ratio plots for DOC for Cu-Cr tool

From the main effect plot as shown in fig.5 and fig.6, it can be observed that DOC being 'smaller the better' type of quality characteristic, the lower values of DOC is to be considered to be the optimum.

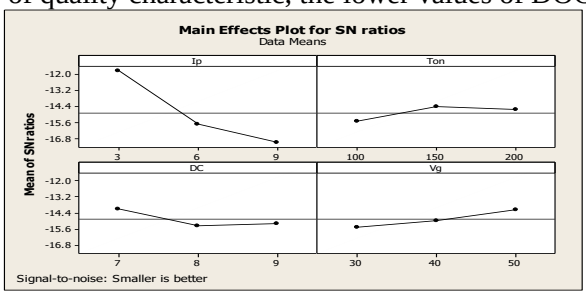

Fig.7. S/N ratio plots for SR for Cu tool

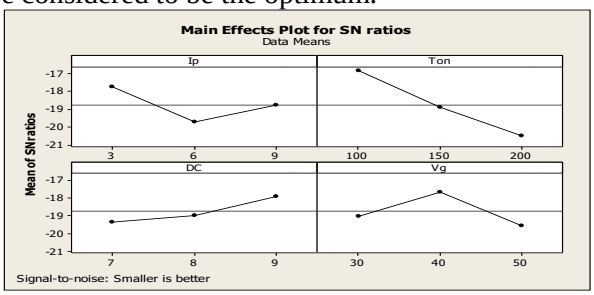

Fig.8. S/N ratio plots for SR for Cu-Cr tool

From the main effect plot as shown in fig.7 and fig.8, it can be observed that SR being 'smaller the better' type of quality characteristic, the lower values of SR is to be considered to be the optimum.

3. RESULTS AND DISCUSSION

3.1 Effect of machining parameters on Material Removal Rate: Fig.9, and fig.13 show the variation of MRR with input current. Fig.10 and fig.14 shows the variation of MRR with T_{on}. Fig.11 and fig.15 show the variation of MRR with DC. Fig.12 and fig.16 show the variation of MRR with V_g.

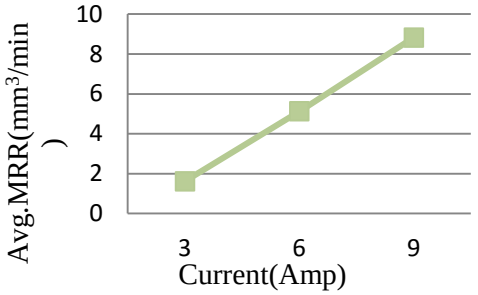

Fig.9. Effect of current on MRR for Cu tool

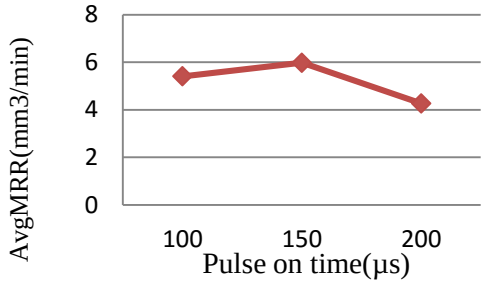

Fig.10. Effect of pulse on time on MRR for Cu tool

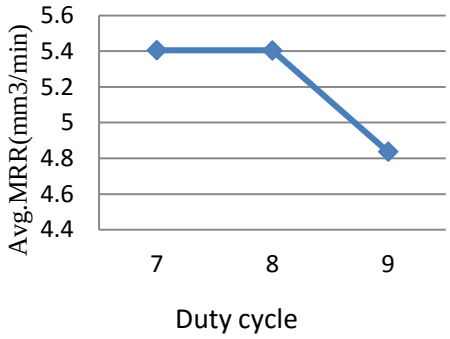

Fig.11. Effect of duty cycle on MRR for Cu-tool

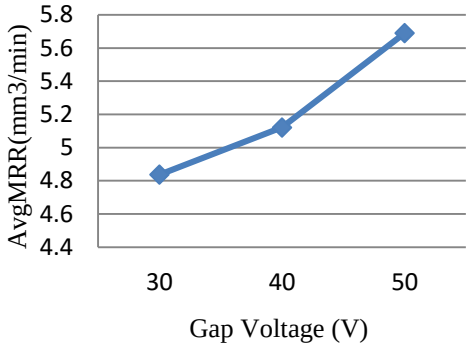

Fig.12. Effect of gap voltage on MRR for Cu-tool

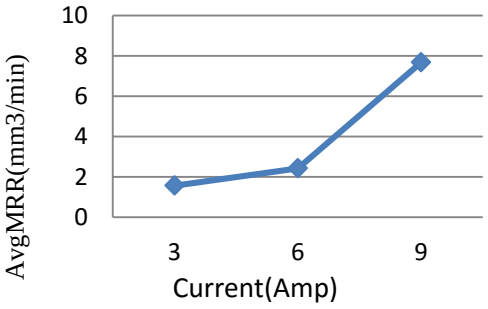

Fig.13. Effect of current on MRR for Cu-Cr tool

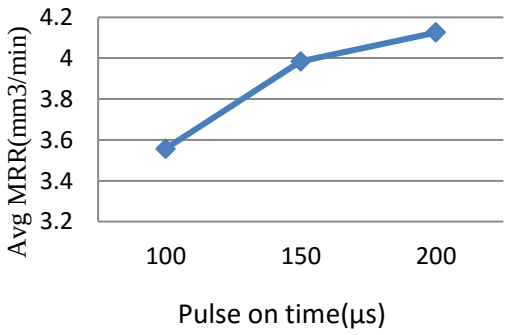

Fig.14. Effect of pulse on time on MRR for Cu-Cr tool

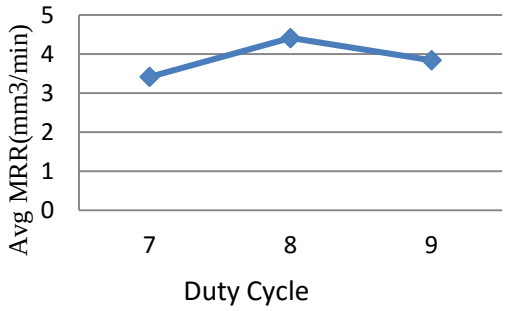

Fig.15. Effect of duty cycle on MRR for Cu-Cr tool

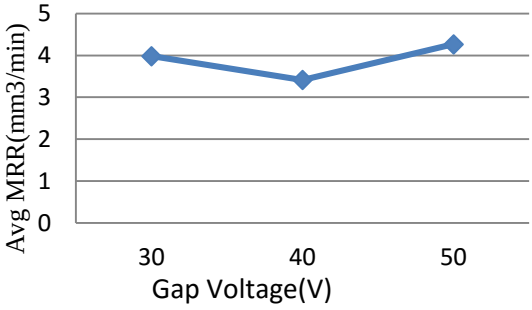

Fig.16. Effect of gap voltage on MRR for Cu-Cr tool

3.2 Effect of machining parameters on Tool Wear Rate: Fig.17 and fig.21 shows the variation of input current with TWR. Fig.18 and fig.22 show the variation of T_{on} with TWR. Fig.19 and fig.23 show the variation of TWR with DC. Fig.20 and fig.24 show the variation of V_g with TWR.

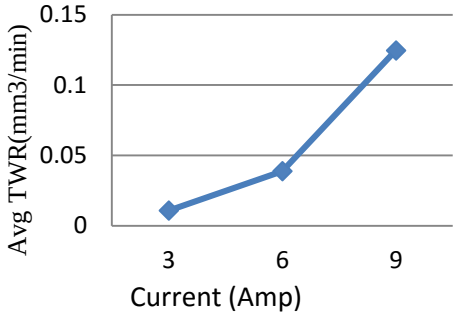

Fig.17. Effect of current on TWR for Cu tool

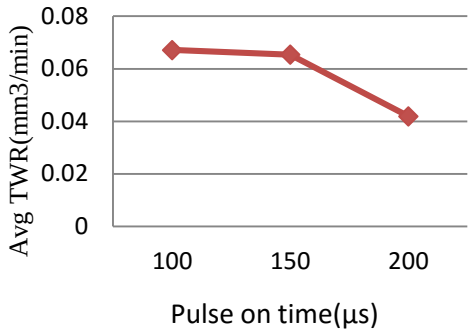

Fig.18. Effect of pulse on time on TWR for Cu tool

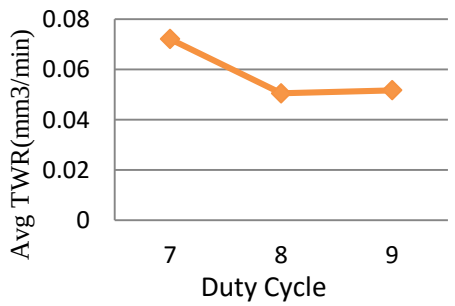

Fig.19. Effect of duty cycle on TWR for Cu tool

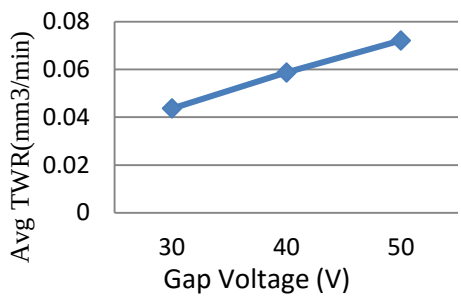

Fig.20. Effect of gap voltage on TWR for Cu tool

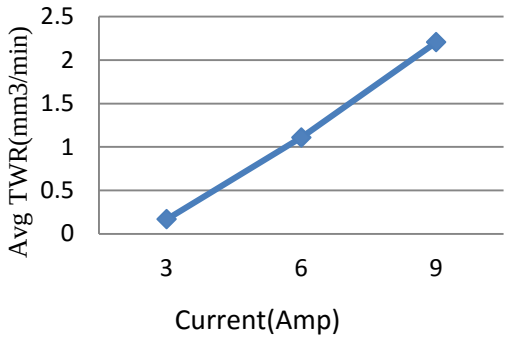

Fig.21. Effect of current on TWR for Cu-Cr tool

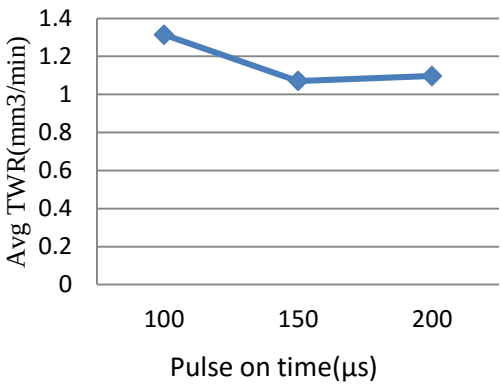

Fig.22. Effect of pulse on time on TWR for Cu-Cr tool

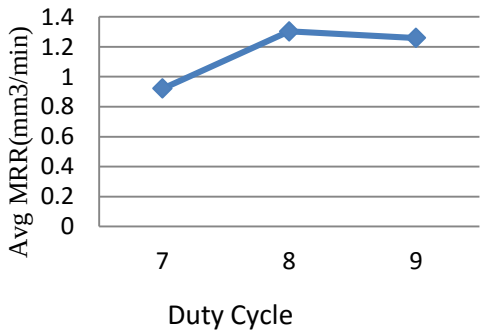

Fig.23. Effect of duty cycle on TWR for Cu-Cr tool

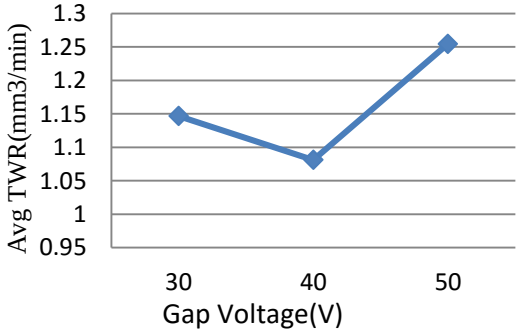

Fig.24. Effect of gap voltage on TWR for Cu-Cr tool

3.3 Effect of machining parameters on Diametral overcut: Fig.25 and fig.29 show the variation of input current with DOC. Fig.26 and fig.30 shows the variation of T_{on} with DOC. Fig.27 and fig.31 show the variation of DOC with DC. Fig.28 and fig.32 show the variation of V_g with DOC

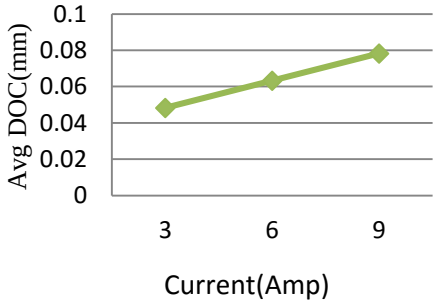

Fig.25. Effect of current on DOC for Cu tool

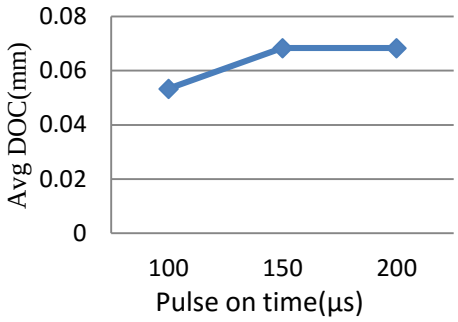

Fig.26. Effect of pulse on time on DOC for Cu tool

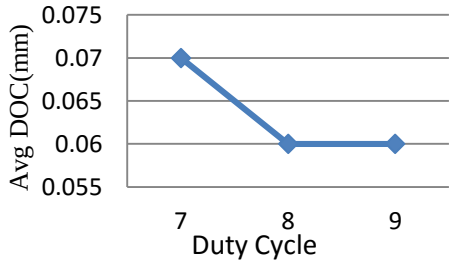

Fig.27. Effect of duty cycle on DOC for Cu tool

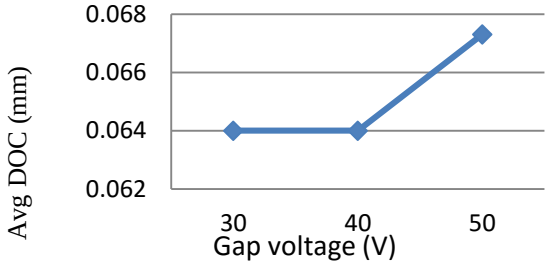

Fig.28. Effect of gap voltage on DOC for Cu tool

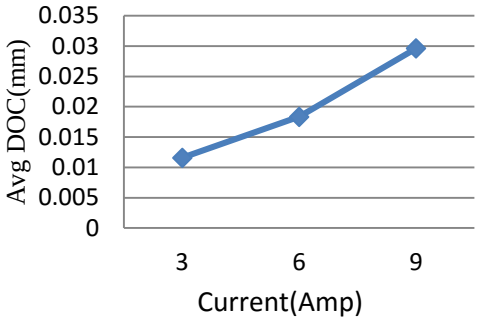

Fig.29. Effect of current on DOC for Cu-Cr tool

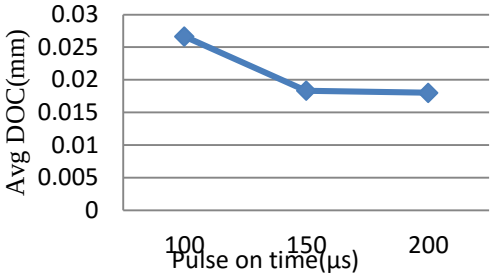

Fig.30. Effect of pulse on time on DOC for Cu-Cr tool

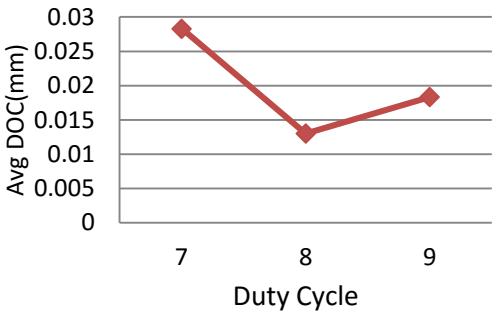

Fig.31. Effect of duty cycle on DOC for Cu-Cr tool

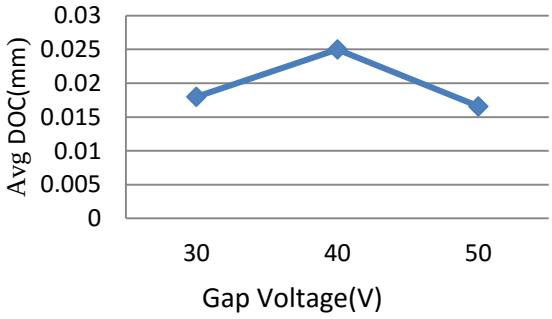

Fig.32. Effect of gap voltage on DOC for Cu-Cr tool

3.4 Effect of machining parameters on Surface Roughness: Fig.33 and fig.37 show the variation of input current with SR. Fig.34 and fig.38 show the variation of pulse on time with SR. Fig.35 and fig.39 show the variation of SR with duty cycle. Fig.36 and fig.40 show the variation of gap voltage with SR.

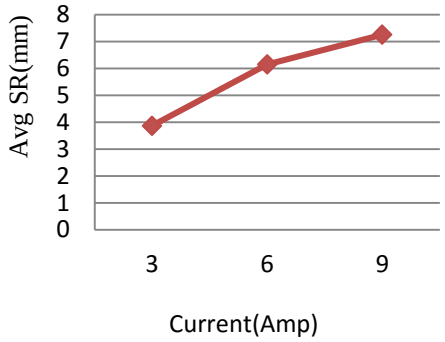

Fig.33. Effect of current on SR for Cu tool

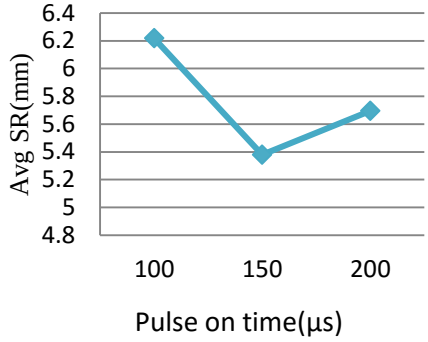

Fig.34. Effect of pulse on time on SR for Cu tool

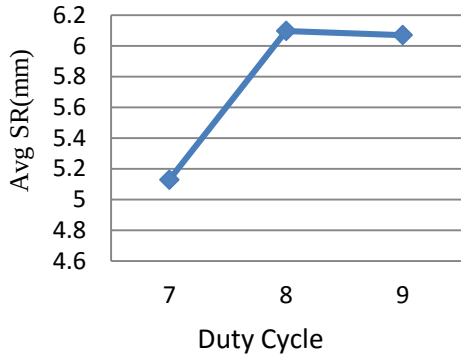

Fig.35. Effect of duty cycle on SR for Cu tool

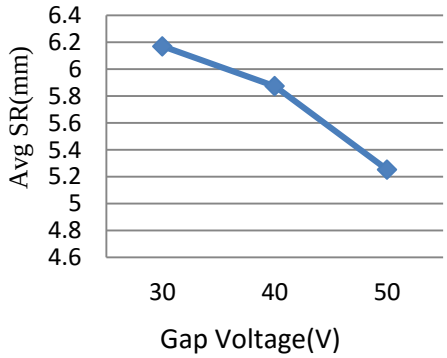

Fig.36. Effect of gap voltage on SR for Cu tool

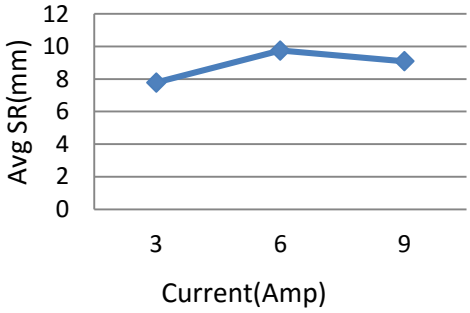

Fig.37. Effect of current on SR for Cu-Cr tool

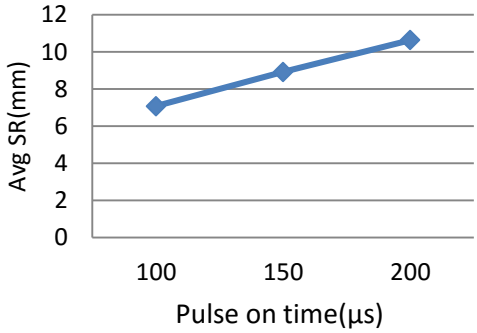

Fig.38. Effect of pulse on time on SR for Cu-Cr tool

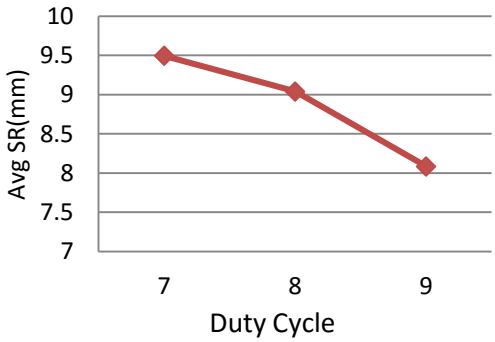

Fig.39. Effect of duty cycle SR for Cu-Cr tool

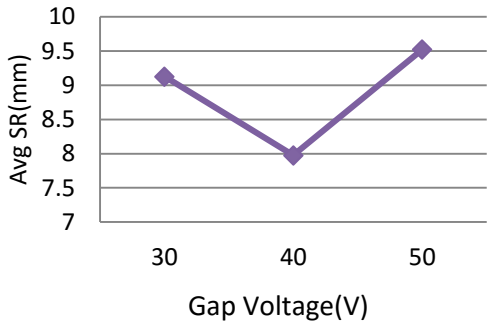

Fig.40. Effect of gap voltage on SR for Cu-Cr tool

4. CONCLUSIONS

The present study investigates the optimum parameter settings in EDM machining of H11 tool steel by using conventional copper and P/M tool electrode made of copper-chromium powders. From the experiments it can be concluded that the input parameters have a huge effect on the output responses during machining using electric discharge machine (EDM). Taguchi's design is proposed to locate the optimal combination of input variables to give better machining characteristic and minimize the set of experiments.

a) The optimal set of parameters for Cu tool are given as follows:

From the main effect plot for S/N ratio, the highest value of MRR was found to be at I_p = 9 A, T_{on} = 150 µsec, DC = 80%, V_g = 40 V. The lowest value of TWR was found to be at I_p = 3 A, T_{on} = 200 µsec, DC = 90%, V_g = 50 V. The lowest value of SR was found to be at I_p = 3 A, T_{on} = 150 µsec, DC = 70%, V_g = 50 V and The lowest value of DOC was found to be at I_p = 3 A, T_{on} = 100 µsec, DC = 80%, V_g = 50 V.

b) The optimal set of parameters for Cu-Cr are given as follows:

From the main effect plot for S/N ratio, the highest value of MRR was found to be at I_p = 9 A, T_{on} = 150 µsec, DC = 80%, V_g = 50 V. The lowest value of TWR was found to be at I_p = 3 A, T_{on} = 100 µsec, DC = 70%, V_g = 30 V. The lowest value of SR was found to be at I_p = 3 A, T_{on} = 100 µsec, DC = 90%, V_g = 40 V and The lowest value of DOC was found to be at I_p = 3 A, T_{on} = 150 µsec, DC = 80%, V_g = 50 V.

c) It has been found that peak current is the most contributing parameter towards surface roughness whereas; duty factor does not affect the surface roughness significantly. So it can be stated that parameters related to discharge energy affects the surface roughness significantly in case of machining with Cu-Cr tool.

d) The machined surface of H11 work piece results contain traces of chromium deposits that migrated from the tool, during machining, thereby increasing the machinability of the work piece.

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