THE EFFECTS OF CRYOGENIC COOLING ON RADIAL OVERCUT IN EDM PROCESS

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Abstract

The work presented in this paper is carried out to study the effect of the cryogenic treatment on the electrode material to improve the tool life. The experiments were performed in H13 material using untreated electrode and cryogenic treated electrode. The input process parameters studied for different level of interactions are discharge current, Voltage and pulse on time. L9 Taguchi method of optimization was used for these input parameters to see their effect on the Radial Over with different treatments to the tool. Discharge current is found to be the most contributing factor for Radial Ove in both untreated and treated electrode. The experiment has established an improvement of 17% in Radial Overcut

Keywords: - Cryogenic Treatment, Electrical Discharge Machining (EDM), Radial Overcut(ROC)

1. Introduction

In 1766, Joseph Priestley, an English theologian and chemist, first noted the craters formed on the cathode(metal) surface due to electric sparks. In 1943, two Russian brothers Boris and Natalya Lazarenko were the pioneers who used the electric spark to remove metal. Electrical Discharge Machining (EDM) is a non-conventional machining process used to remove metal by a controlled disintegration of electrically conductive materials by the commencement of fast and repetitive spark releases between the anode and workpiece isolated by a little distance. EDM is a vital and powerful method of machining electrically conductive materials which are extremely difficult and fragile. In this process the electrode and workpiece are always maintaining a distance between themselves, therefor operator need not have to worry about the cutting forces acting on workpiece[1]. A slight gap about 0.025mm is kept by a servo system shown in Figure 1inbetween the EDM tool and workpiece. Dielectric fluid is used to envelope the EDM tool and work piece in the work pan. EDM oil/ Kerosene/deionized water are normal kind of dielectric liquids although gaseous dielectrics are additionally utilized in specific cases. At the point when a distinction of potential is applied between two conductors submerged in a dielectric liquid the liquid will ionize if the potential contrast arrives at a sufficiently high worth, a spark will happen. For tool and die industries which require working with hard material, EDM technique is the first choice and now it is turning a common approach to utilize EDM for prototyping and low volume production of parts especially in the aerospace and aircraft. Any conductive material of any hardness can be easily machined.

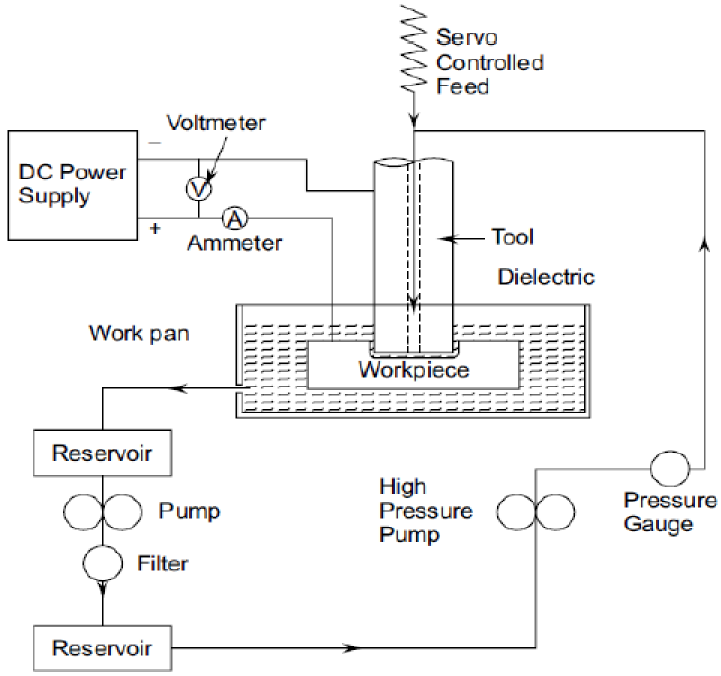

Figure 1: Set up of EDM. [1]

2. Literature Review

Pandey et al [2] first carried out the optimum process parameters for a high removal rate and a good surface quality for the ceramic material. S. Mahendran et al [3] proposed increasing the electrical conductivity of SiC by adding particles of TiB_2 and Tin in the EDN process. H. Ramasawmy et al [4] investigated the EDM process of Al_2O_3 doped with TiC to improve its electrical conductivity. G. C. Onwubolu et al [5] proposed to improve metal removal rates and for fine surface finish by optimizing the carbide contents on the ceramics ZrO_2 and Al_2O_3. Suleiman Abdulkareem et al [6] reported the increase in MRR, SR, ROC for higher values of pulse current by using a Cu-W tool electrode on AISI 1045 alloy steel. R Mohandass et al [7] his research revealed that Cu electrode played a major role in improving material removal rate and radial overcut. Simarpreet Gill et al [8] research revealed the effect of DCT on machinability of Ti 6246 alloy in electric discharge drilling (EDD) by doing experimental investigations on the electrolytic copper electrode. He revealed that there was a drilling time breakeven point beyond which the MRR increases for deep cryogenically treated Ti 6246 alloy than that of non-treated alloy. Our experimental work was focused on the electrical discharge machining of tool steel with Cu(99%) tool electrode when cryogenic cooled and without cryogenic cooled and an attempt has been made to obtain optimal setting of the process input parameters for minimum overcut with EDM oil as dielectric fluid.

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3. Experiment Details

3.1 Substrate Materials

The substrate material selected for the study was commercially pure Cu (cooper) of 13mm diameter as electrodes. The electrode samples were cut into 13mm diameter and 40mm length for the experiments. The work piece material is H13 electrode steel. The workpiece material is cut into 200mm×150mm×20mm.

Table 1: Chemical Composition (Wt. %) of Copper Electrode

Cu	Zn	Pb	Sn	P	Mn	Fe	Ni	Si	Mg	Cr	Al
99.5	0.165	0.216	0.0772	0.014	0.004	0.0894	0.006	0.0055	0.0013	.0020	.0079

3.2 Input-Output Parameters

This research was carried out with selected combinations of electrodes and workpiece by selecting different levels of current, voltage and pulse on time using L9 orthogonal array of Taguchi design approach. Cryogenic treatment was performed at -180°C. EDM experiments were carried on SPARKONIX EDM machine. Dielectric medium used is Kerosene Oil. The experiments have been carried out maintaining those system parameters at diverse levels. The range of the discharge current was decided between 5A to 8A, pulse-on-time was decided on between 4µs to 6 µs and gap voltage decided between 30V to 50 V. The variety of method parameters had been given in table 2.Total 18 experiments has been carried out in this study.

Table 2: Range Of Process Parameters

Parameters	Level 1	Level 2	Level 3
Discharge current(A)	5	8	12
Voltage(V)	30	40	50
Pulse on time(µs)	4	5	6

The thin line represents the cooling rate. Cooling rate is one of the most crucial parameter which should never again surpass 20-30 °C/hr with the aim to spare you the burst of the segments due to the cooling stresses. The ramp down time is 1°C/ hr. A temperature of –180 °C is achieved in 7 hours. After cryogenic treatment tempering is done at 140°C for 4 hours and after it is air cooled to room temperature. Figure 2: shows the cryogenically cycle which is used for cryogenic treatment of copper.

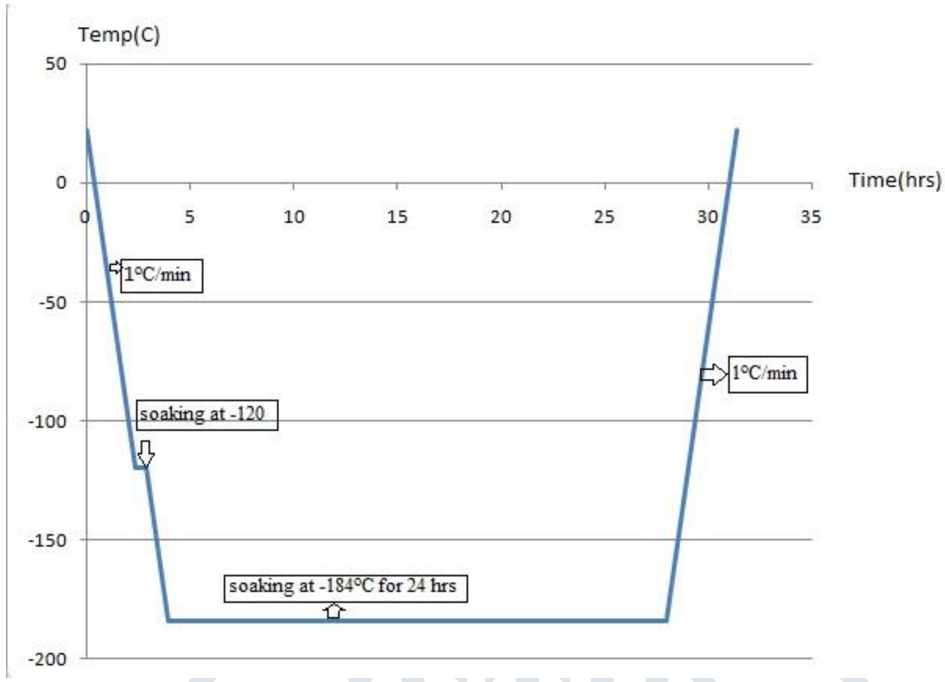

Figure 2: Cryogenic Cycle

3.3 Experiment Procedure

While doing the machining by EDM the cavities are produced somewhat greater than the electrode size, which result in radial overcut (ROC). ROC is important when close tolerance is required in production of components. ROC is the half the difference of diameter of the hole produced in workpiece to the electrode diameter that is shown by the equation.

$$ROC = (Djt-Dt)/ 2$$

Table 3: Orthogonal array L9 matrix

Experiment	Current(A)	Voltage(V)	Pulse on time(µs)
1	5	30	4
2	5	40	5
3	5	50	6
4	8	30	5
5	8	40	6
6	8	50	4
7	12	30	6
8	12	40	4
9	12	50	5

Table 4: Non-cryogenic cooled electrode ROC value

Run	Peak current(Amp)	Voltage(V)	Ton	ROC
1	5	30	4	0.612
2	5	40	5	0.446
3	5	50	6	0.236
4	8	30	5	0.691
5	8	40	6	0.621
6	8	50	4	0.697
7	12	30	6	0.642
8	12	40	4	0.732
9	12	50	5	0.663

Table 5: Cryogenic cooled electrode ROC value

Run	Peak current(Amp)	Voltage(V)	Ton	ROC
1	5	30	4	0.3032
2	5	40	5	0.3333
3	5	50	6	0.1212
4	8	30	5	0.4820
5	8	40	6	0.7120
6	8	50	4	0.6240
7	12	30	6	0.7850
8	12	40	4	0.8240
9	12	50	5	0.3490

4. Result and Discussions

The mean effect plots of the S/N ratios for the overcut were obtained using Minitab 14.1 software.. The average values of S/N ratios for overcut at different levels are plotted in Figure 3. It is clear from the Figure 3 that the radial over cut increases with the increase in Peak current. Peak current is the most significant on the radial over cut. The ROC is unavoidable though adequate compensation is provided at the time of tool design. We have to reduce the value of radial over cut to achieve accuracy, therefore factors affecting the ROC is essential to measure. The graph represents that current is directly proportional to the ROC. Increasing in the discharge current from 5 to 8A the ROC is increasing sharply and after increasing the current from 8 to 12A there is slight increase in the ROC. ROC decreases with the increase in gap voltage.

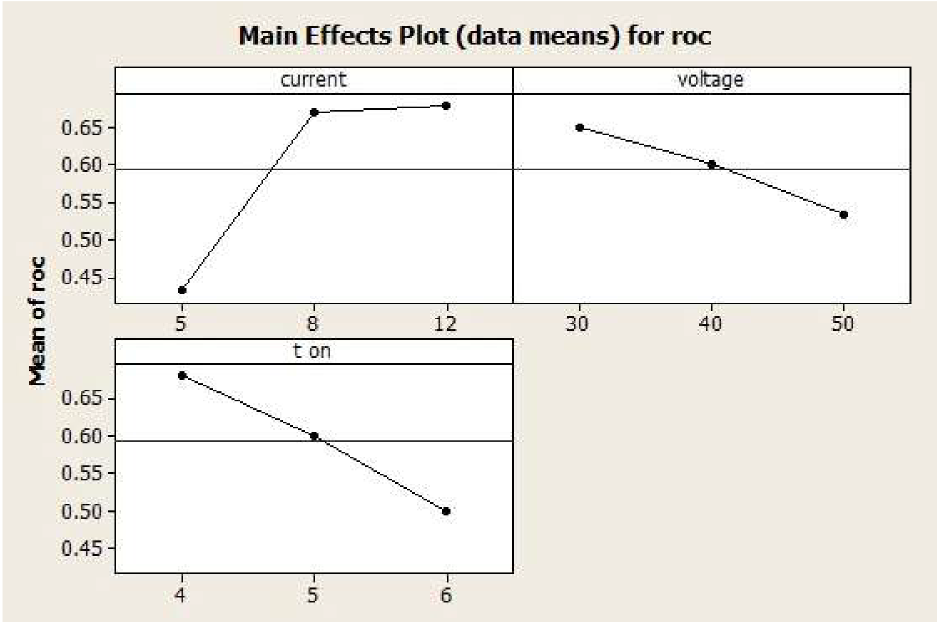

Figure 3: Effects of process parameters on Radial Overcut for Non-Cryogenic Cooled Electrode

From the Table 6 it can be seen that the most significant factor is peak current. In ANOVA table shows that the peak current (F 12.58value), voltage (F 2.18 value), pulse on time(F5.21value) are the factors that significantly affect the ROC.

Table 6: ANOVA table for Non-Cryogenic Cooled Electrode

Source	D.O.F	SS	Variance	F	P	% contribution
Current	2	0.118467	0.059234	12.58	0.074	60.06
Voltage	2	0.020481	0.010240	2.18	0.035	10.37
Ton	2	0.049060	0.024530	5.21	0.061	24.8
Error	2	0.009416	0.004708			
Total	8	0.197424				
S = 0.0686155			R-Sq. = 95.23%			R-Sq.(adj) = 80.92%

It is seen in Figure 3 peak current is the most significant on the ROC. The graph represents that current is directly proportional to the ROC. Increase in the peak current from 5 to 8A the ROC is increasing sharply and after further increasing the current from 8 to 12A there is slight increase in the ROC. When the voltage is at level 1 and further increased to level 2 there is increase in ROC and when the voltage is increased from level 2 to level 3 the ROC is decreased with the increase in gap voltage because with increase in the gap voltage the average discharge gap gets widened resulting into better surface accuracy due to stable machining. Significant effect of pulse on time is also seen in Figure 4 when the pulse on time is increased from level 1 to level 2 there is decrease in ROC further increase in pulse on time decrease ROC because due to plasma form between the gap of electrode and workpiece the lesser energy is transferred to workpiece due to which ROC decreases with increase in pulse on time.

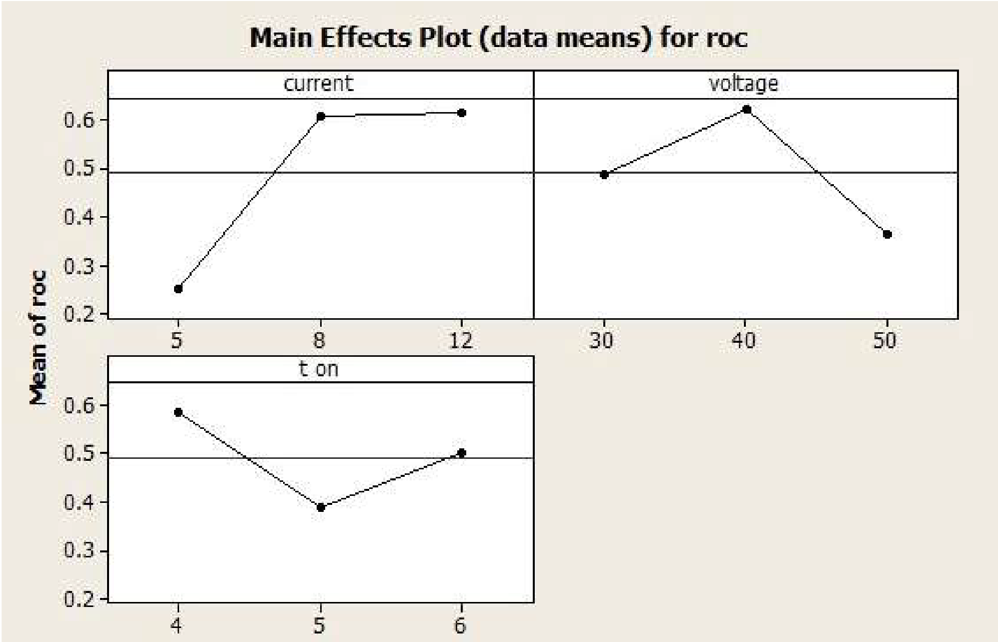

Figure 4: Effects of Process Parameters on Radial Overcut of Cryogenic Cooled Electrode

In ANOVA table it is clear that the significant factors are peak current and voltage. In Table 7 the variation data for each factor and their interactions were F-tested to find significance of each.

Table 7: ANOVA table for Cryogenic Cooled Electrode

Source	D.O.F	SS	Variance	F	P	% contribution
Current	2	0.257434	0.128717	19.67	0.048	60.046%
Voltage	2	0.100207	0.050103	7.65	0.016	23.3%
Ton	2	0.057995	0.028997	4.43	0.018	13.5%
Error	2	0.013091	0.006545			
Total	8	0.428726				
S= 0.0809039		R-Sq. = 96.95%		R-Sq.(adj) = 87.79%		

ANOVA Table 7 shows that the peak current (F 19.67value), voltage (F 7.65 value), pulse on time (F 4.43value) are the factors that significantly affect the SR. The parameter R2 (amount of variation) = 96.95%, Adj R2 = 87.79%, and the standard deviation of error in the modeling S= 0.0809039. The second level of pulse on time (i.e. 5µs) seems to be optimal. Figure: 3 further suggest that third level of gap voltage (i.e.50V) gives optimal results.

5. Conclusion

1. For radial overcut the most important factor is discharge current then voltage and after that pulse on time.

2. Radial overcut is critical parameter in EDM. Since cryogenic treatment has a significant positive effect this parameter it can be recommended that cryogenically treated electrodes can be efficiently machined through EDM.

3. The optimum condition for machining the 12.5mm electrode is at 5A current and at 50V whereas the effect of pulse on time is almost negligible for 12.5mm electrode.

4. In cryogenic treated electrode improvement in surface roughness is also reported.

References

[1] P. N. Rao, “Manufacturing Technology, Vol-2”, pp. 295-315, 2nd Ed (2012).

[2] Anand Pandey and Shankar Singh, “Current Research Trends in Variants of Electrical Discharge Machining: A review”, Vol.2(6), 2010, 2172-2191.

[3] S. Mahendran, R. Devranjan, T Nagarajan and A. Majidi, “A review of micro EDM”, vol.2, 2010.

[4] H. Ramasawmy, L. Blunt, “Effect of EDM process parameters on 3D surface topography,” J. Mat. Process. Tech., vol. 148, pp. 155-164, 2004.

[5] G. C. Onwubolu, A note on “Surface roughness prediction model in machining of carbon steel by PVD coated cutting electrodes,” Amer. J. App. Sci., vol. 2 no. 6, pp. 1109-1112, 2005.

[6] Suleiman Abdulkareem, Ahansan Ali khan and Mohamed Konneh, “cooling effect on electrode and process parameters in EDM”, materials and manufacturing process, 2010, pp. 462-466.

[7] R Mohandoss, “Mechanical behaviour of cryogenically treated EN-19 alloy steel”, International Journal of Power Control Signal and Computation” vol. 1, ISSN : 0976-268X, 2012.

[8] Simarpreet Singh Gill and Jagdev singh, “Effect of Deep Cryogenic Treatment on Machimability of Titanium alloy (Ti-6246) in Electric Discharge Machining”, Materials and Mannufacturing Processes, 25: 378-385, 2010.