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Investigation of Machinability on AISI D3 Steel Using Silver Coated Copper Electrodes in Electrical Discharge Machining

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Abstract: Electrical Discharge Machining is an established technique in machining of die steels, however the process is slow and large number of factors affect the machining process. This work aims to determine the effectiveness of silver coated copper electrodes on machining of AISI D3 steel using EDM. Performance of silver coated electrode is compared with electrolytic copper electrode by varying the machining parameters in EDM. Current, pulse on time and voltage are varied keeping the other parameters constant and it is found that current is playing major role in material removal rate and surface roughness. The experiments are designed by using Taguchis L9 orthogonal array. Optimized process parameters are established for MRR and SR and their contribution is calculated using ANOVA technique. The silver coating on copper gave better material removal rate and surface finish for most of the input parameters. silver coated electrode gave higher MRR at high currents which shows silver coating helped in stabilized sparking at higher currents. Surface finish of surface machined with sliver coated electrode is better at all parameters.

Key words: Electric Discharge Machining, electrolytic copper electrode, silver coated electrode, surface roughness, ANOVA,

Introduction

Electrical Discharge Machining is used in machining of extremely hard conducting materials using a soft electrode material. Copper, Graphite and brass are commonly used electrodes in the machining of Die steels and other hard temperature resistant alloys. Proper selection of electrode material plays significant effect on the discharge spark and there by influencing the machining characteristics [1]. Electrical conductivity, Density, melting point temperature, strength and cost are major factors considered in the selection of electrodes. Both copper and silver satisfies the conditions to use them as electrodes for EDM process. Silver is used as a coating material so that the cost of the core is significantly reduced. [2] Electrolytic copper and silver coated copper are used as electrodes for machining of AISI D3 steel.

Literature Review:

Literature available on the use of coated electrodes in Electrical Discharge Machining is very limited. The available literature suggests that use of coated electrodes gave better material removal rate, surface finish and improved tool wear resistance. J. Prasanna [1] has investigated on machining of Ti6Al4V using copper and Al2O3-TiO2 coated copper electrodes. They have reported 92% decrease in tool wear rate of Al2O3-TiO2 coated copper electrode compared to the copper electrode. T.R. Ablyaz [2] has reported substantial increase in productivity of copper coated Aluminum electrodes over aluminium electrodes for machining of 38X2H2MA steel. S.S. shirgupikar [3] has investigated on machining of Al 7075 alloy using CNT coated copper electrodes. They have reported that current and pulse on time are influencing parameters and CNT coated copper electrodes gave better performance both in terms of material removal rate and tool wear rate over uncoated copper electrodes. J. Jeykrishnan[4] used Nickel coated copper electrode for machining of Inconel 825 alloy for which current was significant factor effecting the surface roughness of the machined surface. K. Karunakaran [5] investigated on the use of silver coated electrolytic copper electrode in machining of Inconel 800 alloy for better tool wear. Shantisagar Biradar[6] has optimized the process parameters in EDM for machining of high carbon high chromium steel by TIN coated copper electrodes using grey relational analysis. They have reported that current in the most influencing parameter followed by pulse on time. N. Raghu Ram [7] has used taguchis orthogonal array for conducting parametric analysis on EDM and reported that duty factor played a significant effect on MRR and surface roughness.

Experimental Procedure:

Copper electrodes of 12 mm diameter are taken and silver is coated on the copper electrode by using electroplating process. A silver coin of diameter 25cm weighing 1 gm is used in electroplating. 0.5 gm if silver Nitrate(AgNo3) is mixed with 500 ml of distilled water which is used as electrolyte for the process. Positive and Negative terminals of DC power supply were connected to Silver and Copper respectively. Current and voltage are adjusted to 0.1A and 10V. Dielectric medium is stirred manually for every 2mins to distribute the liberated silver ions from anode uniformly over the beaker. The process is continued by 25 minutes. Copper bar is taken out from the beaker and cleaned to remove the black layer which was formed as a sludge, because of Cu (NO3)2. Microscopic examination shows that the silver is coated on the copper electrode and thickness of the coating is around 5µm.

Figure1 : Electroplating of silver on copper electrode

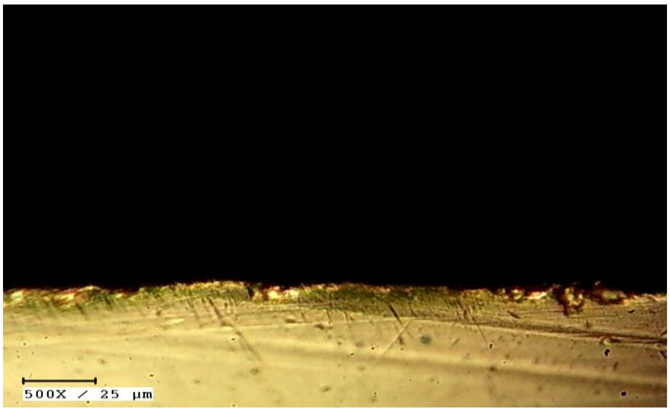


Figure 2: Microscopic view if silver coating using optical microscope

Die sinking EDM machine of type SPARKONIX S25 of maximum current of 25A manufactured by SPARKONIX (I) PVT.LTD. The experimental set up is as shown in the figure. The machine is provided with a jet flushing system to ensure the adequate flushing of the debris from the gap zone. The pressure of the dielectric fluid and flushing are adjusted manually at the beginning of the experiment. The dielectric fluid used for the EDM machine is commercially available EDM oil.

Figure 3: Electrical Discharge Machine used for the machining of AISI D3 steel

In this experimental work, Copper of length 75mm are taken as the electrode material which is having good electrical properties. AISI D3 die steel with dimensions 150*150*10mm3 is used as work piece for machining.


Figure 4: copper electrode and silver coated copper electrode used for EDM process

Design of Experiments

Before finalizing the levels of input factors some trial experiments were carried out to get a picture on the effects of current, voltage, pulse on time and pulse off time. After the trial experiments 3 factors each at 3 different levels are selected for the experimentation. The 3 factors and its levels are tabulated as below. The experiments are framed according to the L9 orthogonal array. Pulse off time is fixed at 30μsec and positive polarity was used.

Table Factors and levels finalized for the experimentation

S.No	Level 1	Level 2	Level 3
1 current(A)	6	9	12
2 pulse on time(μs)	50	100	150
3 Voltage(V)	20	30	40

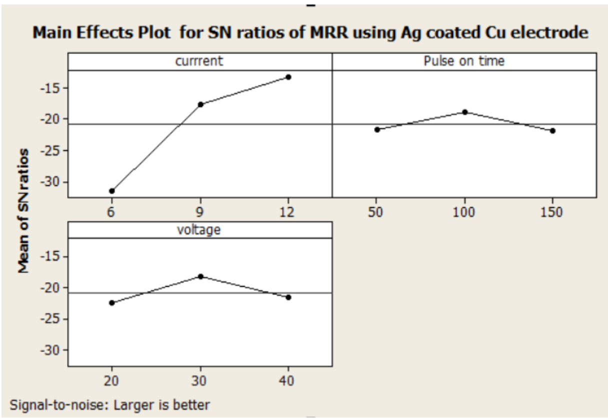
Results and discussion:

Material Removal Rate:

The material removal rate is expressed as the ratio of the difference of the weight of the work piece before and after machining to the time taken for machining.

Figure 5: AISI D3 steel after machining

The results for both the electrodes are tabulated as below:



S.No	current	Pulse on time	voltage	M.R.R (gm/min) Silver coated Cu	SN Ratio	M.R.R (gm/min) Cu	SN Ratio
1	6	50	20	0.0213	-33.4324	0.0198	-34.0667
2	6	100	30	0.0420	-27.5350	0.0384	-28.3134
3	6	150	40	0.0211	-33.5144	0.0197	-34.1107
4	9	50	30	0.1564	-16.1153	0.1537	-16.2665
5	9	100	40	0.1593	-15.9557	0.1564	-16.1153
6	9	150	20	0.0915	-20.7716	0.0894	-20.9732
7	12	50	40	0.1705	-15.3655	0.1611	-15.8581
8	12	100	20	0.2169	-13.2748	0.2018	-13.9016
9	12	150	30	0.2770	-11.1504	0.2529	-11.9410

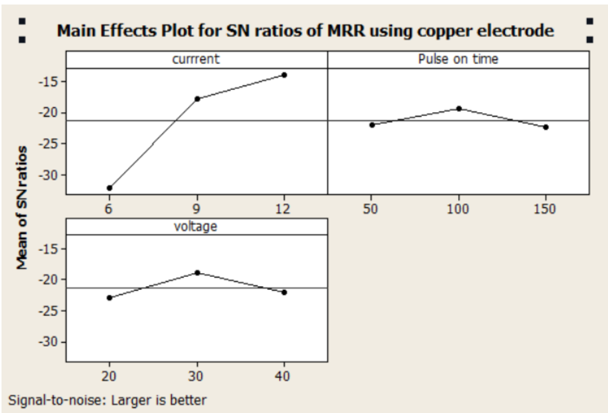


Figure 6: Main effect plots for material removal rate of AISID3 work piece using silver coated copper electrode and electrolytic copper electrode.

From the main effects plot it is interpreted that the material removal rate is increasing as the current increases from 6A to 12A. This is expected as the increase in current produces strong spark, which produces the high temperature, causing more material to melt and erode from the work piece. It is also observed that the increase in the MRR is particularly high in between the 6 to 9A. The effect of pulse on time and voltage are less compared to the current however maximum MRR is obtained at 100 µs pulse on time and voltage at 30V

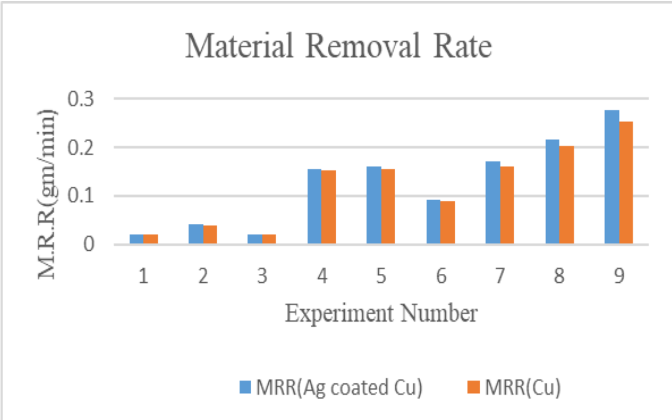


Figure 7: Comparison of MRR between Ag coated Cu and Cu electrodes.

Surface Roughness:

The surface roughness of the machined surface is measured using the Talysurf with least count 0.01µm. As smaller is better in the case of surface roughness the diminishing characteristics of the output results in the improved performance. The surface roughness of the AISID3 work piece using silver coated copper and copper electrodes is evaluated and the experimental values are tabulated.

S.No	current	Pulse	voltage	SR(µm) Ag coated Cu	SN Ratios	SR(µm) Cu electrode	SN Ratios
1	6	50	20	2.58	-8.232	2.94	2.94
2	6	100	30	3.51	-10.906	3.81	3.81
3	6	150	40	3.10	-9.827	3.40	3.40
4	9	50	30	4.10	-12.255	4.95	4.95
5	9	100	40	4.90	-13.803	5.15	5.15
6	9	150	20	4.14	-12.340	4.56	4.56
7	12	50	40	5.16	-14.253	5.85	5.85
8	12	100	20	5.54	-14.870	6.24	6.24
9	12	150	30	5.20	-14.320	6.10	6.10

The surface roughness showed a large difference from almost 2.58µm to 5.54µm in case of silver coated copper electrode and it varied from 2.94µm to 6.24 µm in case of copper electrode.

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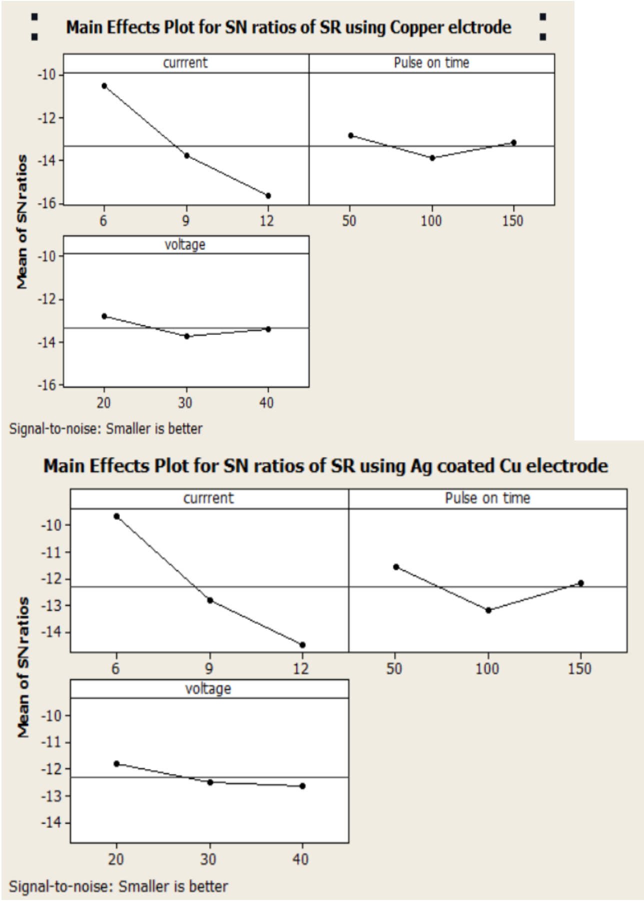

Figure 8: Main effect plot for surface roughness of AISID3 work piece using silver coated copper electrode and electrolytic copper electrode.

From the main effect plot it is observed that the current and the surface roughness showed an inverse relation at all levels.

It is also observed that the increase in the surface roughness is almost linear between the 6 to 12A. Pulse on time showed effect in the case of silver coated copper electrode in which 50µs gave better finish and the effect of voltage is almost negligible still 20V gave better surface finish.

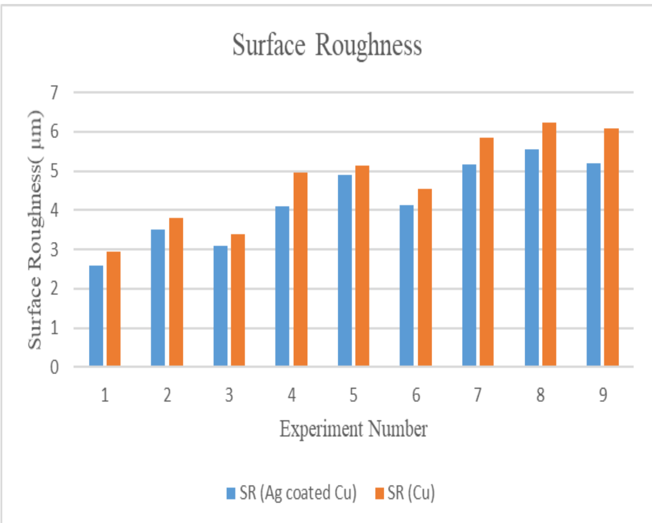

Figure 9: Comparison of SR between Ag Coated Cu and Cu electrodes.

The figure indicates that surface finish is better in case of silver coated electrode at all levels and the coating is effective particularly at higher currents

Conclusions:

Optimized parameters for Material Removal Rate for both the electrodes are 12A current, 100µsec pulse on time and 30V voltage, whereas the optimal conditions for Surface Roughness are 6A current, 50µsec pulse on time and 20V voltage.

Silver coating on copper gave better Material Removal Rate and surface finish at all levels

Current played as significant factor in both material removal rate and surface roughness.

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