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Influence of coated tool electrode on drilling Inconel alloy 718 in Electrochemical micro machining

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Abstract

Since Inconel-718 alloy is high hardened material, it is very difficult to machine the alloy with complex shape using conventional machining process. In the present study, an endeavor has been made to drill the Inconel alloy 718 in micro level using electro chemical machining processes. It has been attempted to find the influence of coatings over copper tool electrode on performance criteria for enhancing the ECM process. From the experimental results, it has been observed that nickel coated copper electrode has produced 7.2% higher material removal whereas chromium coated electrode has produced 19% lower surface roughness over machined alloy specimens.

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Keywords: Electro chemical machining(ECM); Micro machining; Roughness; SEM.

1. Significance of the study

Inconel 718 is austenite nickel-chromium based super alloy. It is used for fabricating gas turbine blades, turbocharger rotors and seals[1]. Since it is very strengthen material, it is very difficult to machine such material with intricate shapes using conventional machining processes. Among the unconventional processes, Electrical discharge machining (EDM), electro chemical machining (ECM) and water jet machining are generally used to machine very hardened materials. Since the electrochemical machining process involves with no heat affected zone, less taper and no tool wear. It can be used to machine titanium alloy with complex shape for enhancing the machinability[2].

Nomenclature

MRR	Material removal rate
R _a	Surface roughness

Owing to its ability of producing micro level of material removal, micro machining can produce better surface finish than conventional machining process. Coated tools have improved the performance of both traditional and non-traditional machining processes and have resulted in higher material removal and better surface finish[3]. Even though many publications are available on machining of Inconel 718 alloy, only very little attention has been given to machine the material using electro chemical micro machining (ECMM) process with coated electrodes. Hence the present investigation has been carried out[4].

1.1. Objectives of the study

The main objectives of the present study are as follows:

- To analyze the influence of coated electrodes on performance criteria such as material removal rate and surface roughness
- To investigate the effects of process parameters on machining characteristics

2. Experiments and methods

2.1. Selection of tool electrodes and performance criteria

Due to its importance in manufacturing industries, Inconel 718 alloy has been used as workpiece specimen material in the present study. In ECMM process, the material removal is happened owing to the anodic dissolution by applying pulsed DC pulses between tool and the work piece. The selection of tool electrode plays an important role in ECMM process. The tool electrode should have diverse physical properties such as good electrical conductivity and highly corrosion resistance material. The coating is provided over the electrode to enhance the machinability in ECM. Normally nickel and chromium are being used for coating purpose. In the present study, the experiments have been conducted in the TTECM-10 setup. In this study, nickel coated copper tool electrode (Ni-Cu) and chromium coated copper tool electrode (Cr-Cu) by electro deposition method have been selected with diameter of 799 μm to analyze their influence on performance measures such as material removal rate (MRR) and surface roughness (R_a) in ECMM process[4]. MRR is measured by finding the volume difference of the workpiece before and after the machining process and it is normally represented in mm^3/min . The average surface roughness (R_a) has been computed using TALYSURF non-surface roughness tester as per ISO 4287 standard. The selection of electrolyte plays a most significance role on determining the machinability in ECMM process. Hence sodium nitrate (NaNO_3) has been utilized as electrolyte medium in the present investigation.

2.2. Selection of input process parameters

Owing to the importance of the process parameters in the ECMM process, applied voltage (V), electrolyte concentration (EC), micro-tool feed rate (MF) and duty Cycle (DC) have been selected as the input process parameters for the present study. The electrical energy has been supplied in terms of pulsed DC supply. The blind hole drilling has been carried out for a depth of 300 μm on workpiece using ECMM process with 50 micron as working gap. The pulse duration has been fixed as 500 milli seconds. The flushing pressure has been fixed at 2 bar. Since the trial experiments have to be conducted in smaller, medium and larger level rating of electrical energy, applied voltage has been selected as 6V, 8V and 10V with duty cycle of 33%, 50% and 66%. The electrolyte concentration has been chosen as 20g/l, 25g/l and 30g/l. The micro-tool feed rate has been selected as 0.1 $\mu\text{m/s}$, 0.5 $\mu\text{m/s}$ and 1 $\mu\text{m/s}$.

2.3. Selection of design of experiments

The selection of orthogonal array (OA) is the important factor while designing the experiments using Taguchi method which has been used to conduct experiments in the present study. Since four process parameters have been chosen with number of levels equal to three, L_9 orthogonal array has been selected as per Taguchi's design of experiments theory[5].

3. Results and discussion

In the present section, the influence of input coated electrodes process parameters on performance measures such as surface roughness (R_a) and material removal rate (MRR) has been analyzed. Table 1. and Table 2. shows the combinations of input factors with their MRR and R_a under L_9 OA based Taguchi design of experiments respectively.

Table 1. MRR with different tool electrodes under L_9

Trial number	V (V)	EC (g/l)	MF ($\mu\text{m/s}$)	DC (%)	MRR (mm^3/min)	
					Ni-Cu	Cr-Cu
1	6	20	0.1	33	0.092622	0.081234
2	6	25	0.5	50	0.048516	0.042857
3	6	30	1.0	66	0.010303	0.009467
4	8	20	0.5	66	0.018844	0.016787
5	8	25	1.0	33	0.092459	0.090495
6	8	30	0.1	50	0.080962	0.078849
7	10	20	1.0	50	0.058112	0.052859
8	10	25	0.1	66	0.070606	0.068659
9	10	30	0.5	33	0.109462	0.102485

Table 2. R_a with different tool electrodes under L_9

Trial number	V (V)	EC (g/l)	MF ($\mu\text{m/s}$)	DC (%)	R_a (μm)	
					Ni-Cu	Cr-Cu
1	6	20	0.1	33	1.180	0.967
2	6	25	0.5	50	0.568	0.480
3	6	30	1.0	66	0.283	0.155
4	8	20	0.5	66	0.868	0.829
5	8	25	1.0	33	0.386	0.378
6	8	30	0.1	50	1.690	1.390
7	10	20	1.0	50	0.455	0.437
8	10	25	0.1	66	3.010	1.840
9	10	30	0.5	33	0.654	0.629

3.1. Influence of coated electrodes on MRR

In ECMM process, the material removal rate is mainly influenced by the current density. The current density is mainly determined by the potential difference happened between tool and workpiece. The electrical conductivity of tool electrode determines the potential difference in ECMM.

Figure 1 shows the effect of coated electrodes on material removal rate in ECMM process. Since the nickel coated copper tool electrode has the higher electrical conductivity than the chromium coated copper tool electrode, it has been observed that nickel coated electrode has produced 7 % higher material removal rate in electro chemical micro machining process under all the input process parameter combinations of L_9 orthogonal array.

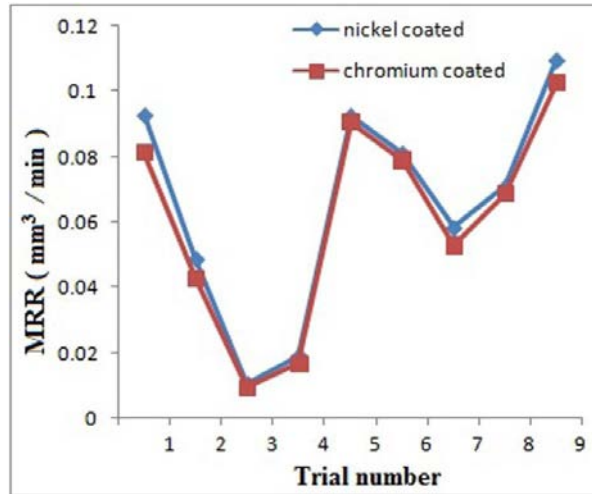


Fig. 1. Effect of coated electrodes on MRR

3.2. Influence of process parameters on MRR

The main effect plot is used to find the influence of the process parameter in any process. The deviation from the horizontal line indicated the higher influence of input process parameter on the response parameter. Figure 2 shows the influence of process parameters on material removal rate of machined Inconel 718 alloy in ECMM process using Minitab software package. The liberation of anodic part is determined by the current density. From Figure 2, it has been understood that the duty cycle has the most influential nature on MRR in ECMM process due to its importance on determining material removal during the machining process.

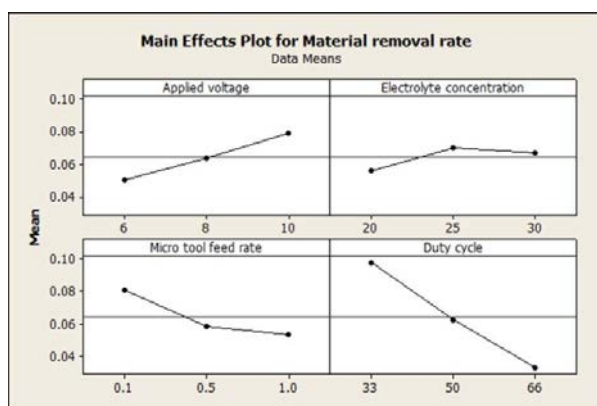


Fig. 2. Main effect plot of process parameters on MRR

3.3. Influence of coated electrodes on R_a

In ECMM process, the surface roughness is mainly influenced by the crater size developed during the machining process and tool electrode surface. Figure 3 shows the effect of coated electrodes on surface roughness in ECMM process. Since the nickel coated copper tool electrode has created larger craters and better tool surface than the chromium coated copper tool electrode, it has been observed that nickel coated electrode has produced 19% higher surface roughness in electro chemical micro machining.

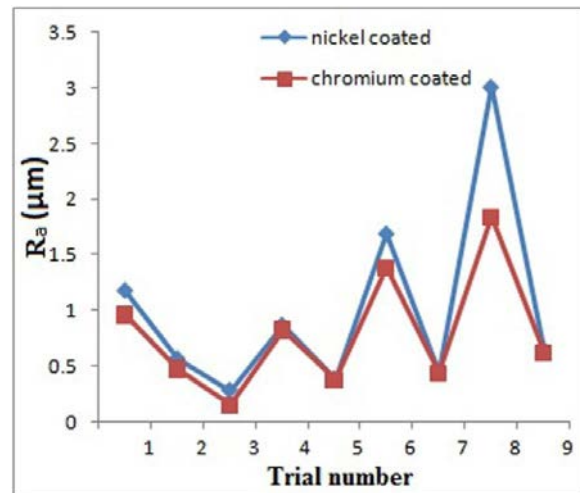


Fig. 3. Effect of coated electrodes on R_a

3.4. Influence of process parameters on R_a

The main effect plot is used to find the influence of the process parameter in ECMM process. Figure 4 shows the influence of process parameters on material removal rate of machined Inconel 718 alloy in ECMM process using Minitab software package. From Figure 4, it has been understood that the micro tool feed rate has the most influential nature on R_a in ECMM process due to its importance on determining crater size during the machining process.

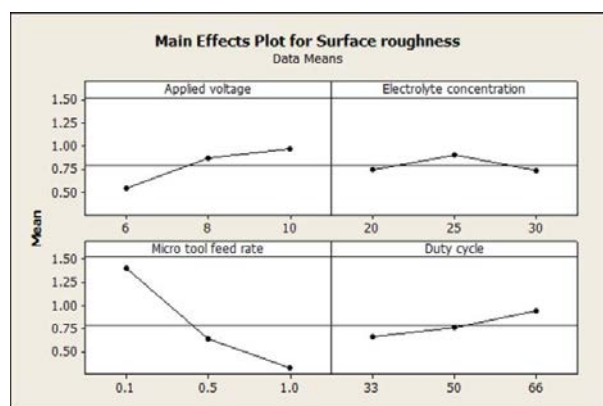
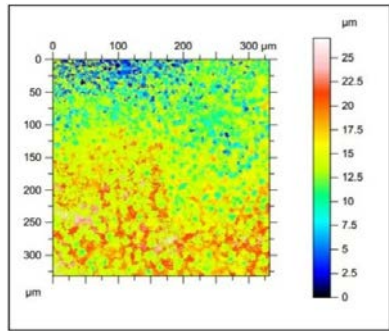


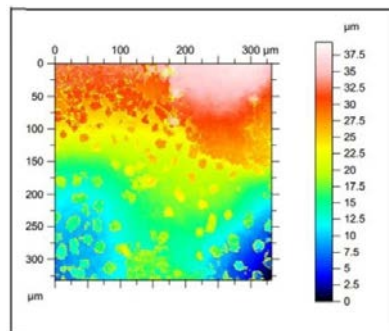
Fig. 4. Main effect plot of process parameters on R_a

3.5. Surface topography analysis of machined workpiece

The chromium coated copper tool electrode has produced lower surface roughness than the nickel coated copper tool electrode as shown in Figure 5 and Figure 6. It has been noticed that from two dimensional surface profile diagram of machined workpiece. Figure 7 and Figure 8 shows the micro structure analysis of machined specimens using scanning electron microscope (SEM) with chromium and nickel coated tool electrodes respectively. Owing to its higher corrosive resistance property and ability to produce lower crater size, chromium coated tool electrode has produced lower surface roughness.



With nickel coated electrode



With chromium coated electrode

Fig. 5. R_a measurement of machined workpiece

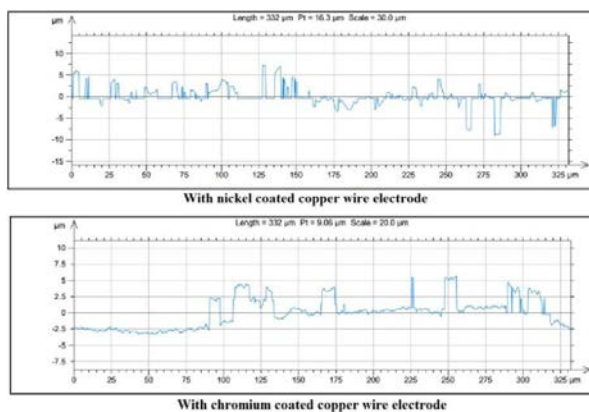


Fig. 6. Two dimensional surface profile of machined workpiece

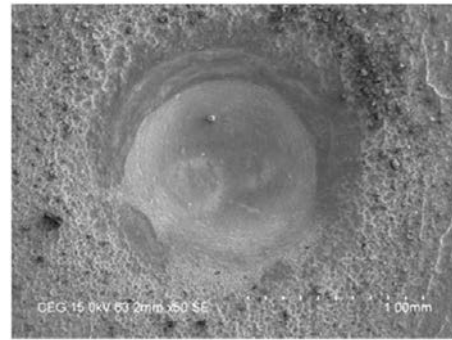


Fig. 7 Surface topography of specimen with Cr-Cu

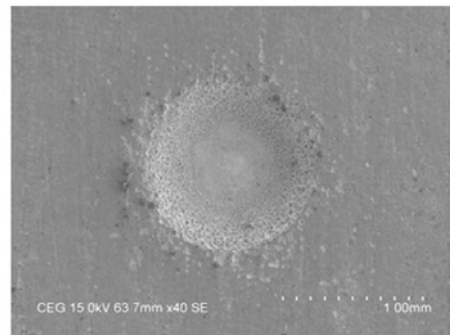


Fig. 8 Surface topography of specimen with Ni-Cu

4. Conclusion

In the present study an experimental investigation made to analyze the effects of coated electrodes and process parameters on machining Inconel 718 alloy using ECM process. From the experimental results the following conclusions have been made.

- Nickel coated copper electrode can produce higher MRR whereas chromium coated electrode can produce lower R_a .
- Duty cycle has higher significant on MRR whereas Micro tool feed rate has most influence on R_a .

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