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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

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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 300µm 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 0.1µm/s, 0.5µm/s and 1µm/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 (µm/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 (µm/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.