Effect of Aluminum Powder Suspended Dielectric and Silver Coated Copper Electrode on Electrical Discharge Machining Characteristics of Inconel 718

N. Hima Varsha(✉) and K. Saraswathamma

Department of Mechanical Engineering, University College of Engineering (A), Osmania University, Hyderabad 500007, India
nomula.hima@gmail.com

Abstract. In accordance to the analyzed performances, the Powder mixed Electric Discharge Machining (PEDM) is learnt to be most often encountered choice for machining hard materials. Complex geometries of hard materials are machined with higher accuracy than with conventional processes. This paper focuses on deducing the effects of Aluminum powder suspended dielectric and Silver coated electrode on Material removal Rate (MRR) and Tool Wear Rate (TWR) of Inconel 718 by varying current as well as pulse on time. And, from these studies, it has been clearly evidenced an improvement in MRR and reduction in TWR with the addition of Aluminum powder to dielectric and Silver coating to the Copper electrode.

Keywords: PEDM · MRR · TWR

1 Introduction

Due to increased demand for energy efficiency and compact mechanical components in energy industries, aerospace, missile and medical industries has contributed to the progress of swift evolution of very high temperature resistant materials, like Nickel based super alloys. The properties that make Nickel based super alloys an extra ordinarily suitable for elevated temperature applications are also root for its hardship of machining [1]. Hence, there is great demand for advanced machining technologies to cut these difficult-to-machine materials with ease and precision.

Electric Discharge Machining (EDM) is a competitive option for machining Nickel based super alloys as it is one of the thermal types of non-traditional machining processes having capability to machine any electrically conductive materials into desired shape with required dimensional accuracy irrespective of material's mechanical strength. In Powder Mixed EDM, the inclusion of well suited fine powdered particles to the dielectric fluid leads to finer surface finish combined with improved MRR [2].

Sengottuvel et al. [3] investigated "the effects of various EDM input parameters as well as the influence of different tool geometry on MRR, TWR and Surface Roughness on machining of Inconel 718 material using copper electrode. ANOVA showed that the current was the most influencing factor, followed by pulse on time and pulse off time.It was

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also observed that the rectangular tool geometry provided better result." To reduce the tool wear rate, Karunakaran and Chandrasekaran [4] focused on "machine-ability studies on EDM of Inconel 800 with Silver Coated Electrolyte Copper Electrode". Jothimurugan et al. [5] focused on comparing "performance of silver coated copper electrode with conventionally used copper tool electrode using optimum proportionate kerosene-servotherm and commercial grade EDM oil in ED Machining of Monel400. It is observed that Ag coated copper electrode has 26.8% increased MRR and 25% decreased TWR decrease than copper electrode." Patel et al. [6] has done experiments of "aluminum oxide powder mixed rotary electric discharge machining on Inconel 718 and observed that MRR is mainly depends on peak current and duty cycle whereas TWR depends on Peak current, slurry concentration. Finer surface roughness is observed at low range of peak current, pulse on time and duty cycle whereas at high range of varying parameters rough surface finish was evidenced." Karunakaran and Chandrasekaran [7] studied the "influence of process parameters in Powder mixed Electrical discharge machining of Inconel 800 with copper electrode and silver coated copper electrode. Coated electrode has significantly increased in material removal rate and tool wear rate. Only minor increment was observed for surface roughness." In order to study effect of different powder suspended dielectric i.e., aluminum oxide, silicon carbide and graphite Mahendra and Deepak [8] conducted Electric Discharge Machining experimentation on Inconel 718 and found that MRR mainly depends on current and graphite powder suspended dielectric having high MRR as well as less TWR.

From the literature it is observed that very less study was focused on combined effect of powder suspended dielectric and coated electrode on Inconel 718. Hence this study concentrated on assessing the performance of Silver coated copper electrode and Aluminum powder suspended dielectric with conventional copper electrode and commercial grade EDM oil by considering current and pulse on time as varying parameters.

2 Research Methodology

2.1 Material Selection

Inconel 718 material is chosen as work piece and dimensions of each sample made into 14 mm × 14 mm × 10 mm. Two different types of tool electrodes were used that are copper and silver coated copper electrode with dimensions of 12 mm diameter and 100 mm length. Silver coating is made on copper electrode using electroplating process of thickness 0.010 mm and length 20 mm. Commercial grade EDM oil and aluminum powder suspended commercial EDM oil of concentration 3 g/lit were used as dielectric fluids.

2.2 Selection of Input Parameters

Peak current: 6 A, 9 A, 12 A and pulse on time: 100 μs, 300 μs, 500 μs were considered as varying input parameters and other fixed parameters are shown in Table 1 for ED Machining.

Table 1. Other fixed machining parameters

Parameters	Values
Gap voltage (V)	60
Pulse-off time (μs)	50
Spark gap (mm)	0.1–0.7
Polarity	Positive

2.3 Experimental Conditions

Following experimental conditions mentioned in Table 2 are used in this study.

Table 2. Experimental conditions

S.no.	Experimental condition
1.	Using copper electrode in EDM
2.	Using silver coated copper electrode in EDM
3.	Powder suspended dielectric medium with copper electrode for EDM
4.	Powder suspended dielectric medium with silver coated copper electrode for EDM

2.4 Experimentation

The experiments were performed on ELECTRA make VM6040 model EDM machine by varying current (6 A, 9 A and 12 A) and pulse on time (100 μs, 300 μs and 500 μs) according to full factorial design. MRR and TWR are calculated using the Eqs. 1 and 2 respectively. Weights of works pieces (Inconel 718) and electrodes (copper and silver coated copper) before and after machining are measured using Digital weighing machine of precision 0.001 gm and machining time is kept constant as 15 min.

$$MRR = \frac{W_{bm} - W_{am}}{t} \quad (1)$$

$$TWR = \frac{E_{bm} - E_{am}}{t} \quad (2)$$

Where,

W_{bm}, W_{am} are weight of material before machining and after machining correspondingly.

E_{bm}, E_{am} are weight of electrode before machining and after machining correspondingly.

't' is the time of machining.

3 Results and Discussion

3.1 Material Removal Rate

Table 3 provides MRR values of EDM and PEDM using copper electrode and silver coated copper electrode.

Table 3. MRR for different experimental conditions

Samples	Run	Current (A)	T_{ON} (µs)	Machining time (min)	Copper electrode		Silver coated copper electrode	
					MRR_{EDM} (g/min)	MRR_{PEDM} (g/min)	MRR_{EDM} (g/min)	MRR_{PEDM} (g/min)
1	9	6	100	15	0.011	0.059	0.047	0.086
2	4	6	300	15	0.015	0.075	0.057	0.113
3	1	6	500	15	0.05	0.116	0.095	0.121
4	6	9	100	15	0.065	0.121	0.072	0.133
5	2	9	300	15	0.095	0.169	0.108	0.147
6	8	9	500	15	0.106	0.179	0.184	0.187
7	3	12	100	15	0.098	0.153	0.139	0.171
8	5	12	300	15	0.130	0.187	0.174	0.188
9	7	12	500	15	0.175	0.193	0.188	0.198

The graphs were plotted between pulse on time (100 µs, 300 µs, and 500 µs) and MRR for different experimental conditions and are shown in Figs. 1, 2 and 3. It is evident from the graphs that, MRR increases with increase in pulse-on time. For low pulse-on time, small amount of material was melted as the time of heating of the workpiece was so small [9].

The graphs were plotted between current (6 A, 9 A and 12 A) and MRR for different experimental conditions are shown in Figs. 4, 5 and 6 and it is interpreted that MRR increases with increase in current. At low current, a little quantity of heat is produced and major portion of it is taken by the surroundings resulting, the amount of utilized energy for melting and vaporizing of the material is not so intense.

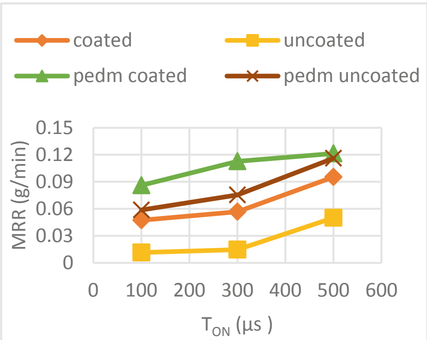

Fig. 1. T_{ON} VS MRR at 6A

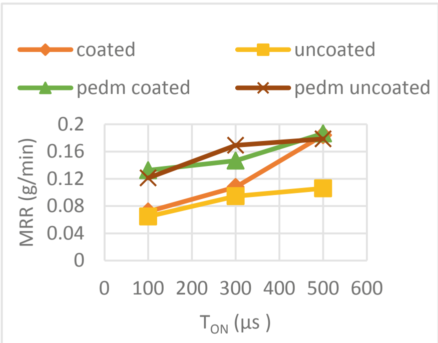

Fig. 2. T_{ON} vs MRR at 9A

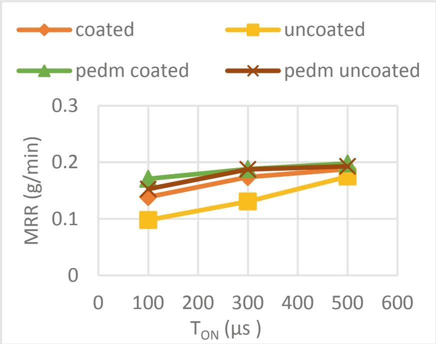

Fig. 3. T_{ON} vs MRR at 12A

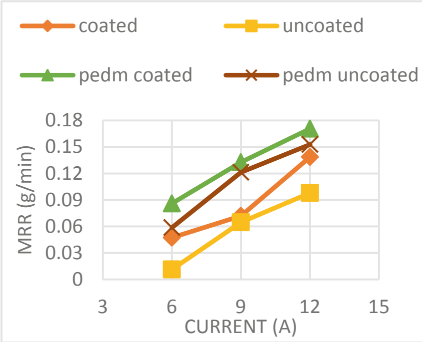

Fig. 4. Current vs MRR at 100 µs

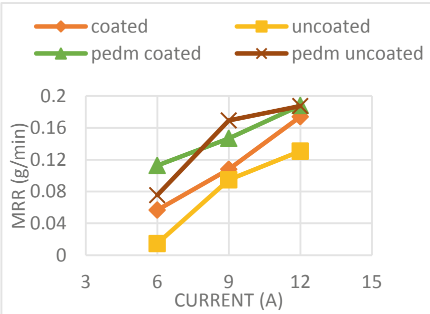

Fig. 5. Current vs MRR at 300 µs

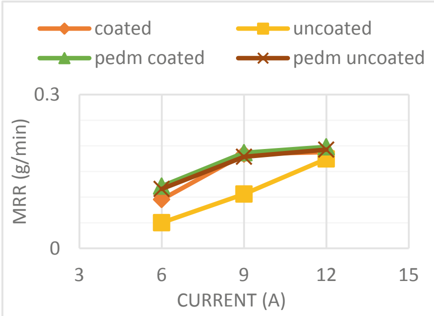

Fig. 6. Current vs MRR at 500 µs

From Figs. 1, 2, 3, 4, 5 and 6 it is also clearly seen that, addition of Aluminum powder in dielectric has significantly increased MRR. For the first discharge in the spark gap, powder particles present in Inter Electrode Gap get energized and move quickly along with positive ions and electrons. These energized powder particles colloid with dielectric molecules and generate more ions and electrons. Thus, more electric charges are produced in PEDM compared to conventional EDM. It is also observed that MRR increased for silver coated copper electrode as silver coated electrode has better electrical and thermal properties compared to copper electrode.

3.2 Tool Wear Rate

Table 4 gives TWR values of EDM and PEDM using copper electrode and silver coated copper electrode.

Table 4. TWR for different experimental conditions

Samples	Run	Current (A)	T_{ON} (µs)	Machining time (min)	Copper electrode		Silver coated copper electrode	
					TWR_{EDM} (g/min)	TWR_{PEDM} (g/min)	TWR_{EDM} (g/min)	TWR_{PEDM} (g/min)
1	9	6	100	15	0.004	0.002	0.003	0.001
2	4	6	300	15	0.005	0.002	0.003	0.003
3	1	6	500	15	0.005	0.003	0.005	0.003
4	6	9	100	15	0.004	0.002	0.003	0.002
5	2	9	300	15	0.005	0.002	0.005	0.003
6	8	9	500	15	0.005	0.004	0.003	0.004
7	3	12	100	15	0.004	0.001	0.003	0.003
8	5	12	300	15	0.005	0.002	0.005	0.003
9	7	12	500	15	0.009	0.005	0.008	0.008

The graphs were plotted between pulse on time (100 µs, 300 µs, 500 µs) and TWR for different experimental conditions and these are shown in Figs. 7, 8 and 9. From these plots, it can be noticed that high pulse on time leads in increasing the TWR. As T_{ON} is increased, electrode gets more time to absorb heat and erodes more material from both electrode and work piece, this reason causes the TWR to increase.

The graphs were plotted between current (6A, 9A, 12A) vs TWR for different experimental conditions are shown in Figs. 10, 11 and 12 and it indicates that TWR increases with increase in current. As the spark energy is proportionate to the input current, with increase in input current, spark energy intensifies between the inter electrode gap. But at constant T_{ON} more spark energy is builds up which is utilized in melting and evaporating the electrode material results in more tool wear.

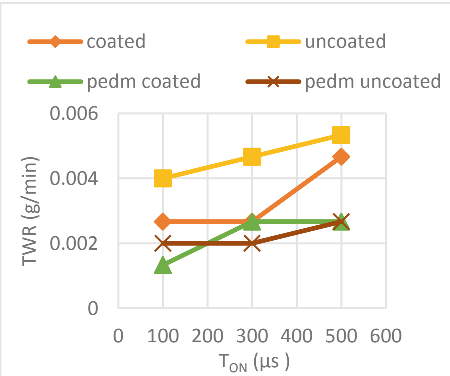

Fig. 7. T_{ON} VS TWR at 6A

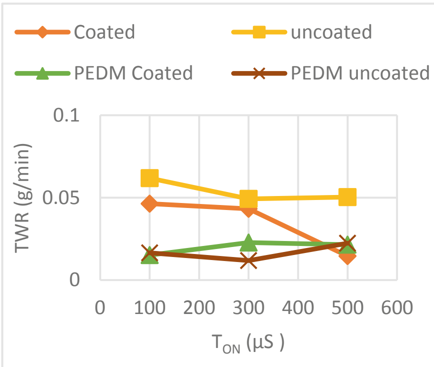

Fig. 8. T_{ON} VS TWR at 9A

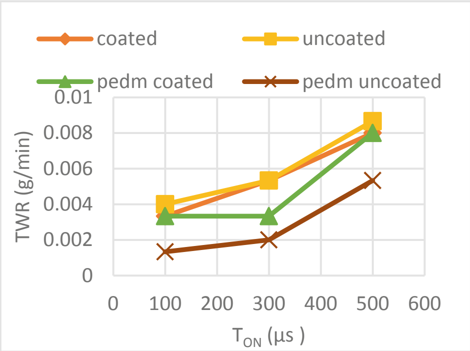

Fig. 9. T_{ON} VS TWR at 12A

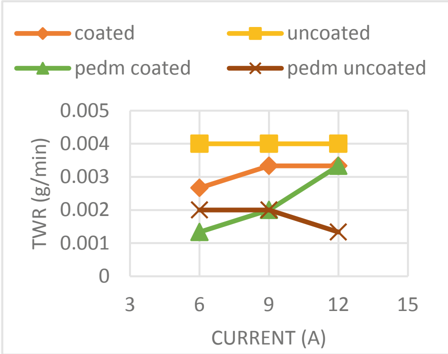

Fig. 10. Current vs TWR at 100 µs

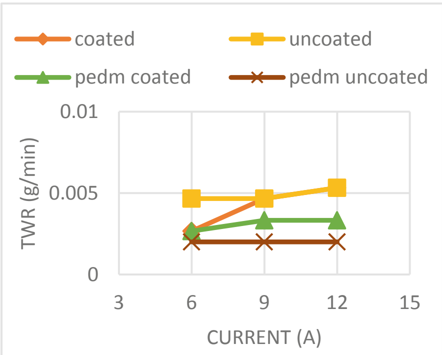

Fig. 11. Current vs TWR at 300 µs

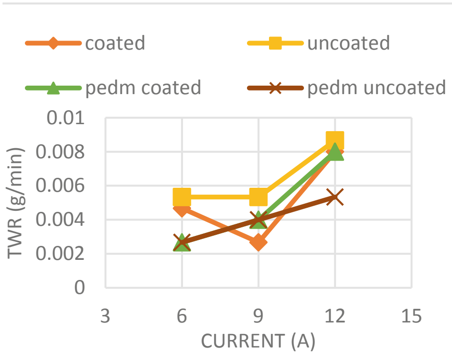

Fig. 12. Current vs TWR at 500 µs

It is also depicted from Figs. 7, 8, 9, 10, 11 and 12 that overall TWR is low for PEDM using Copper electrode and high for Electrical Discharge Machining using Copper electrode.

4 Conclusions

From this comparative experimental study following conclusions were drawn.

- MRR increases with increase in both peak current and pulse-on time.
- MRR was enhanced by 80% for combined effect of aluminium powder suspended dielectric and silver coated copper electrode compared to without suspension of powder in dielectric and uncoated electrode.
- Maximum MRR obtained was 0.198 g/min for aluminium PEDM using silver coated copper electrode at 12 A of Peak Current and 500 µs of pulse on time.
- TWR increases with increase in both current and pulse on time.

- TWR was reduced by 44% for aluminium powder suspended dielectric and uncoated copper electrode compared to without suspension of powder in dielectric and uncoated electrode.
- Minimum TWR obtained was 0.001 g/min for aluminum PEDM using copper electrode at 12 A of Peak Current and 100 μs of Pulse on time.

References

1. Zhe C, Johan M, Peng RL, Johansson S (2016) Surface integrity and fatigue performance of Inconel 718 in wire electrical discharge machining. Procedia CIRP 45:307–310
2. Talla G, Gangopadhayay S, Biswas CK (2016) State of the art in powder-mixed electric discharge machining: a review. Proc Inst Mech Eng Part B: J Eng Manuf 231:2511–2526
3. Sengottuvel P, Satishkumar S, Dinakaran D (2013) Optimization of electrical discharge machining process parameters using desirability approach and fuzzy modeling: international conference on design and manufacturing. Procedia Eng 64:1069–1078
4. Karunakaran K, Chandrasekaran M (2017) Investigation of machine-ability of Inconel 800 in EDM with coated electrode. In: IOP conference series: materials science and engineering, vol 183, no 1, pp 012–014
5. Jothimurugan R, Amirthagadeswaran KS, Daniel J (2012) Performance of silver coated copper tool with kerosene servotherm dielectric in EDM of Monel 400TM. J Appl Sci 12 (10):999–1005
6. Patel S, Thesiya D, Rajurkar A (2018) Aluminum powder mixed rotary electric discharge machining (PMEDM) on Inconel 718. Aust J Mech Eng 16(1):21–30
7. Karunakaran K, Chandrasekaran M (2017) Influence of process parameters in n-PMEDM of Inconel 800 with electrode and coated electrodes. In: MATEC web of conferences 95, Article no. 02002
8. Mahendra GR, Deepak VM (2014) Study on effect of powder mixed dielectric in EDM of Inconel 718. Int J Sci Res Publ 4(11):1–7 ISSN 2250-3153
9. Talla G, Gangopadhyay S, Biswas CK (2015) Effect of powder suspended dielectric on the EDM characteristics of Inconel 625. J Mater Eng Perfomance 25:704–717