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Effect of Aluminum Powder Suspended Distilled Water on Machinability of W304 (Die Steel) in Electric Discharge Machining

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Abstract—*Electric Discharge Machining (EDM) is quite extensively used for machining of hard materials due to controlled erosion through a series of electric spark. This paper investigates the material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR) of W304 (die steel) with electrolytic copper tool using D7120 electric discharge machine. The dielectric used for the present study is aluminum powder suspended distilled water. The attempt shows promising results for MRR, EWR and SR at higher current, higher pulse on time (T_{on}) and higher pulse off time (T_{off}).*

Keywords*: Electric Discharge Machining, MRR, EWR, SR, W304, T_{on}, T_{off}.*

1. INTRODUCTION

EDM has special advantage over other non-conventional processes that it can machine material of any hardness or strength and can provide different shapes but has lower efficiency. Also, the electrical conductivity of materials is the indispensable condition for machining. In spite of notable process capabilities lower material removal and poor surface quality are associated with EDM. In the recent past, powder suspended electric discharge machining has emerged as one of the sophisticated technique in the enrichment of EDM capabilities. The process of powder mixing with dielectric fluid includes various different materials like aluminum, graphite, silicon carbide, chromium etc.

2. EXPERIMENTAL DETAIL

Experiments were conducted on W304 (die steel) by using die sinking EDM. The aluminum powder suspended distilled water has been used as dielectric fluid to reduce the insulating strength of dielectric fluid and to increase the spark gap distance between the tool and workpiece. This made the process stable and thus improves the material removal rate and surface finish.

The sample workpieces of dimension 20mm×40mm×6mm (Fig. 1) were grinded at same rpm and feed rate so that surface finish and integrity could be maintained.

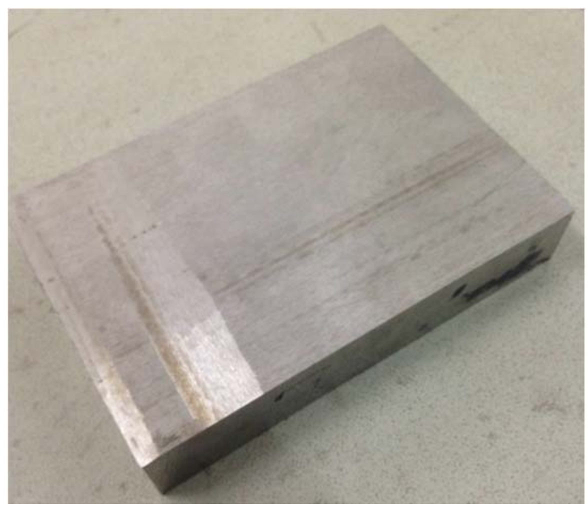


Fig. 1. W304 (die steel) workpiece

The workpiece was cut into small workpieces to accommodate for EDM tank used for dielectric fluid suspended with aluminum water. The chemical composition (Table 1) of W304 is given as:-

Table 1. Composition of W304

ELEMENTS	%age
Chromium	18 – 20%
Nickel	8 – 12%
Manganese	2%
Carbon	0.08%
Phosphorous	0.045%

The initial hardness for all the workpieces have been recorded and compared with the final hardness which could be used to define the cast layer for different machining parameters. The average initial hardness of W304 workpieces was HR 20. The Rockwell hardness machine was used for defining the hardness of W304 has the following specifications:-

Table 2. Specification of Rockwell Hardness Machine

CAPACITY : 250 kgf
Major Load : 150 kgf
Minor Load : 10 kgf
Indenter Type : Diamond Indenter
Angle : 120°
Diameter Of Diamond Indenter : 2.58mm

The following machine parameters were used for the experiment:-

Table 3: Machine Parameters

Current : 7 to 12 Ampere
Pulse On Time (T_{on}) : 180 to 380 µs
Pulse Off Time (T_{off}) : 8 to 10 µs

The machine tool used for the experiments was D7120 die sinker EDM(Fig. 2). A setup (Fig. 4) was used in order to accomplish experiments.

Fig. 2: D7120 Die Sinker EDM

Fig. 3: Setup used for EDM

The setup ensures full flow of suspended powder dielectric fluid on the surface of die steel which takes away the carbon and chips and let the spark to form a circular cut with equal dimensions.

Table 4. Machine Specifications

Specification	D7120
X,Y travel size (mm)	200×160
Working table size (mm)	400×250
Principal axis travel (mm)	200
Head travel of principal axis (mm)	——
Principal axis load (kg)	25
Max. workpiece weight (kg)	150
Chief axis connect board to working table (mm)	420
Work tank internal size (mm)	650×400×230
Overall weight (kg)	700
Overall Dimensions (mm)	1200×1000×1800
Electric Cabinet Parameter and Specification	BH20AMP
Max. processing current (A)	20
Max. processing speed (mm/min)	100
Min Electrode Consumption	≤0.2%
Optimum roughness (um)	Ra<0.3
Max. power Consumption (kw)	2
Net weight (kg)	——
Overall dimensions (mm)	——

3. EXPERIMENTAL DESIGN

A simple, efficient and systematic Taguchi method was used for the design of experiment. L14 OA was used to optimize the machining parameters for die steel to get higher MRR with lower EWR and optimum surface roughness. The following experimental settings (Table 5) were used:-

Table 5. Experimental Settings

Dielectric flow rate	2l/s
Dielectric pressure	0.5kg/cm^2
Polarity	Positive

4. CALCULATION OF MRR, EWR & SR

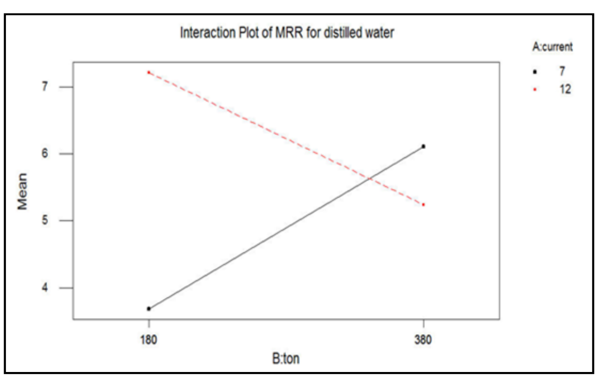
Table 6: MRR Calculations for Distilled Water

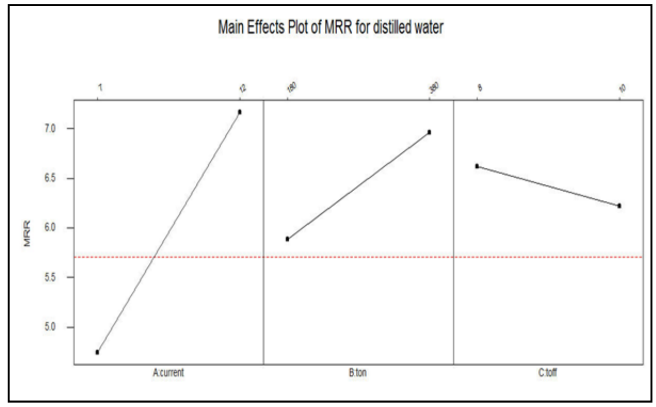
Exp No.	I	T_{on}	T_{off}	MRR	EWR	SR
1	9	280	9	4.0566	1.415	4.506
2	7	180	8	2.6744	1.279	4.602
3	12	180	10	4.333	2.166	2.735
4	9	280	9	3.2	2.4	6.186
5	12	180	8	10	5.192	5.312
6	7	380	10	5.555	2.111	6.496
7	9	280	9	6.538	2.596	5.192
8	7	380	8	6	2.375	5.282
9	9	280	9	4.466	1.941	4.387
10	9	280	9	5	2.450	4.643
11	8	380	8	7.8	4.4	4.452
12	9	280	9	5.3	2.3	5.322
13	10	180	10	6.521	2.826	4.264
14	10	380	10	8.478	5	5.616

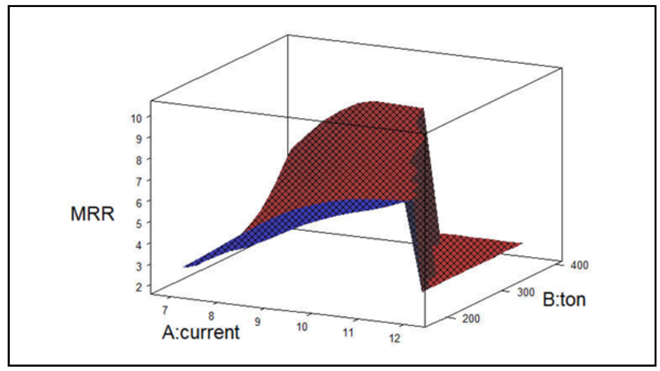
T_{on} = Pulse on time (microseconds)
T_{off} = Pulse of time (microseconds)
MRR = Material removal rate (mg/min)

Fig. 4: EDM operated Die Steel Workpieces

5. RESULTS & DISCUSSIONS







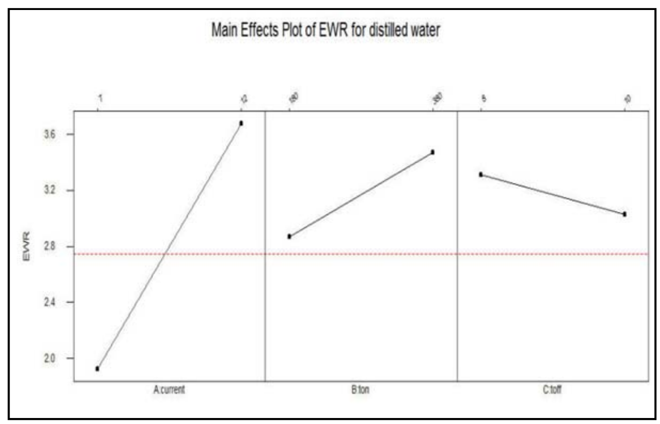
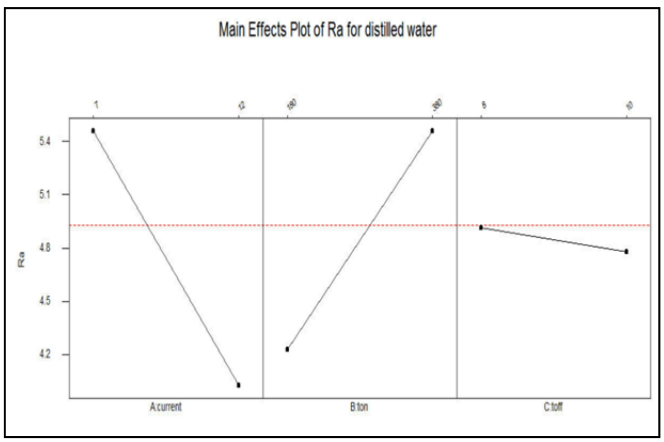


Fig. 5. MRR Surface Plot

A comparative experimental study of present work, an addition of aluminium powder mixed in distilled water resulted in moderate MRR, good surface finish when compared with pure dielectric. Both MRR and EWR apparently increase with the increase of the peak current and pulse on time. The result obtained from the present study is extremely helpful for selecting the optimum machining conditions for W304 die-steel work material, which is extensively used in moulds and dies making industries. Within the range of parameters selected the following specific conclusions are drawn from the experimental results.

- The material removal rate decreased by mixing powder in the distilled water as compared with conventional EDM process.
- Electrode wear rate in PMEDM is higher as compared with the conventional EDM Process.
- Material removal rate is maximum affected by the increase of peak current.
- Material Removal Rate has been decreased by increasing the pulse off time.
- The optimum powder concentration and size of powder particles to achieve the highest efficiency of EDM process.
- Surface roughness is less using powder mixed distilled water as compared to conventional EDM process.
- Higher peak currents produce more rough surfaces in EDM process.



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