Experimental Investigation of Changing Polarity in Powder Mixed Electric Discharge Machining (PM-EDM)

Mr. Pankaj B. Gavali*, Mr. Chandan A.Waghmare** and Dr. S. S. Kalashetty***
*Assistant Professor Sanjay Ghodawat Institute, Atigre, Kolhapur, 416118.
** Assistant Professor Rajarambapu Institute of Technology, Rajaramnagar, Islampur 415409.
*** Head and Associate Professor Industrial & Production Engineering Department,
PDA College of Engineering, Kalaburgi, 585102.
*gavali.pb@sginstitute.in
**chandan_w@rediffmail.com
***sonu1196@rediffmail.com

Abstract - It is the common practice in EDM to make tool positive and work piece negative (Normal polarity) , but researches shows that reverse of it is also possible in which tool is negative and work piece is positive (Reverse polarity). Paper discusses the effect of polarity on the machining characteristics with chromium powder suspended dielectric in electric discharge machining. High metal removal rate, low tool wear rate and surface roughness are conflicting goals, which cannot be achieved simultaneously with a particular combination of control settings. To achieve the best machining results, the goal has to betaken separately in different phases of work with different emphasis. A L9 orthogonal array is designed for both polarities. Copper is used as tool material and EN-19 alloy steel is selected as work piece material with normal and reverse polarities.

The study reveals that Normal polarity is suitable for higher metal removal rate and lower tool wear but reverse polarity gives minimum surface roughness as compared to normal polarity. Normal polarity gives 10-21 times more MRR and 4 times less tool wear rate as compared to reverse polarity, and reverse polarity gives 1.5-2 times better surface finish as compared to Normal polarity.

Keywords: - Polarity, PMEDM, MRR, TWR, EDM.

I. INTRODUCTION

In 1770, the English scientist, Priestley, first detected the erosive effect of electrical discharges on metals. During research (to eliminate erosive effects on electrical contacts) the soviet scientists, Lazarenko and Lazarenko (1940), decided to exploit the destructive effect of an electrical discharge and developed a controlled method of metal machining. In 1943, they announced the construction of the first Spark Erosion machine. The spark generator used in 1943, known as the Lazarenko circuit, has been employed over many years in powder supplies for EDM machines and an improved version is being used in many current applications.

Electrical discharge machining (EDM) is non-traditional manufacturing process where material is removed by a succession of electrical discharges. Pulsed arc discharges occur in the gap filled with an insulating medium between tool electrode and work piece. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage. However, it suffers from few limitations such as low machining efficiency and poor surface finish. To overcome these limitations the electrically conductive powder particles are mixed in the dielectric fluid, which reduces its insulating strength and increases the spark gap distance between the tool and workpiece. This new hybrid material removal process is called Powder mixed EDM (PM-EDM) Figure 1. In PM-EDM a suitable metal powder is mixed into the dielectric used in EDM.The additive particles suspended in the dielectric has important influence on the discharge process; increase both the gap distance & the discharging rate. The high electric field energises the conductive powder particles. These conductive particles form chains at different places under sparking area, which bridges the gap between tool electrode & work piece material. Due to this bridging effect, the gap voltage & insulting strength of the dielectric decreases, this causes easy short circuiting and hence early explosion in the gap between the electrode and the work piece. At the same time the suspended particles in the dielectric enlarged the plasma channel, because of which electric density decreases and hence uniform distribution of the sparking takes place.

B. B. Pradhan et al.presented the changing polarity for microelectric discharge machining (micro-EDM) in a systematically designed time domain while machining titanium alloy (Ti–6Al–4V) for the fabrication of straight-through microholes. Experimental investigations were made to study precisely the effects of changing polarity in micromachining of Ti–6Al–4V.

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S.S.Chatha et al. presented the work with an objective to modify the surface characteristics like surface roughness, material removal rate, and hardness by adding different concentrations of TiO2 into the dielectric fluid of EDM. X-Ray Diffraction (XRD) and MAPING analysis has been carried out to find the migration of powder from the dielectric to the machined surface. SEM of the surface and the cross-section was also done to analyze the surface texture and recast layer. The results achieved showed that minor amount of powder was migrated to machined surface, which resulted in surface improvement. The dielectric with added powder also shows significant improvement in material removal rate.

Wei Zhao et al. studied the problem of polarity effect in EDM. In order to find out the deterioration of the anode and the cathode, the experiment with single pulse was taken in kerosene oil. They found the deterioration of the anode was larger than that of the cathode even in the condition of large pulse width. But this result was contradictory with that gotten in electric discharge machining with continue pulses.

Naveen Beri et al. studied the effect of graphite powder on the machining performance of conventional EDM. The machining performance was evaluated in terms of tool wear rate. Concentration of graphite powder, polarity, electrode type, peak current, pulse on time, duty cycle gap voltage and retract distance was taken as the input parameters and their effect were presented on machining performance.

M. S. Reza et al studied the effect of polarity on the material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR) of the tool steel work piece machining using EDM. Wrong polarity can have significant implications on speed, wear, and stability and to investigate this phenomenon using L18 orthogonal arrays design of experiment. They concluded that the positive polarity (tool -, workpiece +) is found optimum for the all analysis on the Material Removal Rate (MRR), Electrode Wear Ratio (EWR) and Surface Roughness (SR)

Kuldeep Ojha et al. studied the parametric optimization for material removal rate (MRR) and tool wear rate (TWR) on the powder mixed electrical discharge machining (PMEDM) of EN-8 steel has been carried out. Response surface methodology (RSM) has been used to plan and analyze the experiments.

PMEDM performance in terms of MRR and TWR. Experiments have been performed on newly designed experimental setup developed in laboratory. Most important parameters affecting selected performance measures have been identified and effects of their variations have been observed.

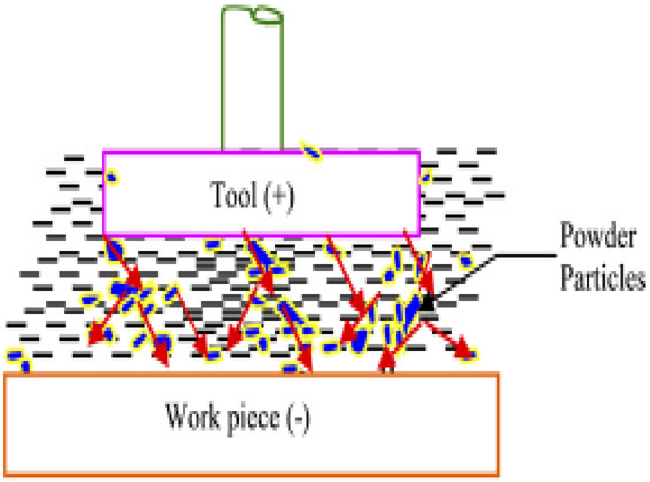

Figure1: Powder mixed EDM (PM-EDM)

A large number of input process parameters can be varied in the PMEDM process, eachhaving its own impact on output parameters such as Material Removal Rate (MRR), ToolWear Rate (TWR), and hardness of machined surface, surface finish, dimensionalaccuracy and overall surface integrity. Various input parameters are:

1. Discharge Voltage
2. Peak Current
3. Pulse Waveform
4. Pulse on-time
5. Pulse off-time
6. Pulse Frequency
7. Polarity
8. Electrode Gap

9. Concentration of powder

It is known from the research works that out of the above listed parameters, four parameters directly affect the MRR, TWR and surface roughness in PMEDM. These four parameters are peak current, pulse on-time, concentration of powder and polarity. These parameters have been investigated thoroughly in this paper.

II. EXPERIMENTAL DESIGN

In the present paper, an effort has been made to study the effect of powder suspended in the dielectric fluid of EDM on process performance on MRR, TWR, and Surface roughness, the design variables can besummarized as follows:

- Chromium powderis to be suspended in the dielectric fluid in three levels. Specification of Chromium powder used shown in table 3.
- Three levels of peak current to be used; because the non-linear behavior of process parameters can only be studied if more than two levels of a parameter are used.
- Experimentation is carried out in Kerosene oil. Specification of Kerosene oil is shown in table 2.
- Three levels of pulse on-time to be used.

Figure 2: EN-19 alloy steel Workpiece

And the whole experimentation is to be done in L9orthogonal array with positive (straight) polarity and Negative polarity (Reverse Polarity) shown in table 6. And find out the optimum parametric combination for powder mixed EDM.

The effect of the variation ininput process parameter will be studied on these three response parameters and theexperimental data will be analyzed as per Taguchi method to find out the optimummachining condition. The machining parameters that have been kept fixed throughout the experimentation shown in table1.

Table 1: Fixed Input Process Parameters

Sr. No.	Machining Parameter	Fixed Value
1	Type of Dielectric	Kerosene
2	Voltage(vg)	70 V
3	Machining time	20 min.
4	Duty Cycle (t)	9
5	Flushing	Straight
6	SEN	10
7	TW	0.5
8	Rd	0.5

Table 2: Specification of Kerosene oil used

Dielectric Constant	Electric Conductivity	Density	Dynamic Viscosity
1.8	1.6 * 10-4 s/m	730	0.94m

Table 3: Specification of Chromium powder used

Cr %	C%	S%	P%	Si%	Al%	Fe%
99	0.01	0.015	0.015	0.090	0.08	0.01

Sieve Analysis: - 325

Mesh Particle Size : - 45-55µm

Machining was performed using copper electrode of 25mm diameter having properties as shown in Table 4 and figure 3.

Table 4: Chemical Composition and mechanical properties of EN-19 alloy steel.

Density	**Electrical resistivity**	**Purity**	**Melting point**
8.9kg/ m^3	0.0167 Ω m m^2/m	99.8%	10830C

Table 5: Properties of Copper electrode

Chemical composition											
Fe	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu
96.8	0.41	0.26	0.79	0.02	0.026	1.01	0.162	0.144	0.07	0.004	0.19
Mechanical properties of EN-19 alloy steel.											
Tensile strength	1150N/mm2										
Yield stress	850N/mm2										
Elongation	14-17%										
Modulus of elasticity	210000N/mm2										
Density	7.8Kg/m3										
Hardness	55 HRC										

Figure 3: Copper Tool

Table 6: Experimental plan, output responses and S/N ratio values

Sr. No.	Polarity	Ip	Ton	C	MRR (mm3/min)	SNR for MRR	TWR (mm3/min)	SNR for TWR	Surface Roughness (Ra)	SNR for SR
1	+	6	100	0	2.500	7.9588	0.056	25.0474	5.845	-15.335
2	+	6	200	1	2.365	7.4766	0.078	22.1248	5.664	-15.062
3	+	6	300	2	3.532	10.9604	0.073	22.7685	4.818	-13.657
4	+	12	100	1	7.458	17.4524	0.185	14.6771	7.548	-17.556
5	+	12	200	2	7.975	18.0346	0.112	19.0268	6.545	-16.318
6	+	12	300	0	6.320	16.0143	0.173	15.2201	10.862	-20.718
7	+	18	100	2	12.452	21.9048	0.459	6.7711	7.689	-17.717
8	+	18	200	0	10.371	20.3164	0.106	19.4723	11.105	-20.910
9	+	18	300	1	11.474	21.1943	0.095	20.4384	9.857	-19.874
10	-	6	100	0	0.186	-14.6097	0.084	21.5255	3.155	-9.9800
11	-	6	200	1	0.295	-10.6036	0.185	14.6771	1.655	-4.3760
12	-	6	300	2	0.289	-10.7820	0.157	16.1042	2.077	-6.3487
13	-	12	100	1	0.395	-8.0681	0.190	14.4249	4.734	-13.5046
14	-	12	200	2	0.315	-10.0338	0.151	16.4201	3.746	-11.4714
15	-	12	300	0	0.389	-8.2003	0.180	14.8945	5.170	-14.2698
16	-	18	100	2	0.340	-9.3704	0.278	11.1191	6.677	-16.4916
17	-	18	200	0	0.383	-8.3439	0.150	16.4782	7.650	-17.6732
18	-	18	300	1	0.450	-6.9357	0.134	17.4431	6.881	-16.7530

I: - Current, Ton: - Cycle on Time C: - Concentration of Powder

III. RESULT ANALYSIS

Effect of parameters on process performance in Normal Polarity

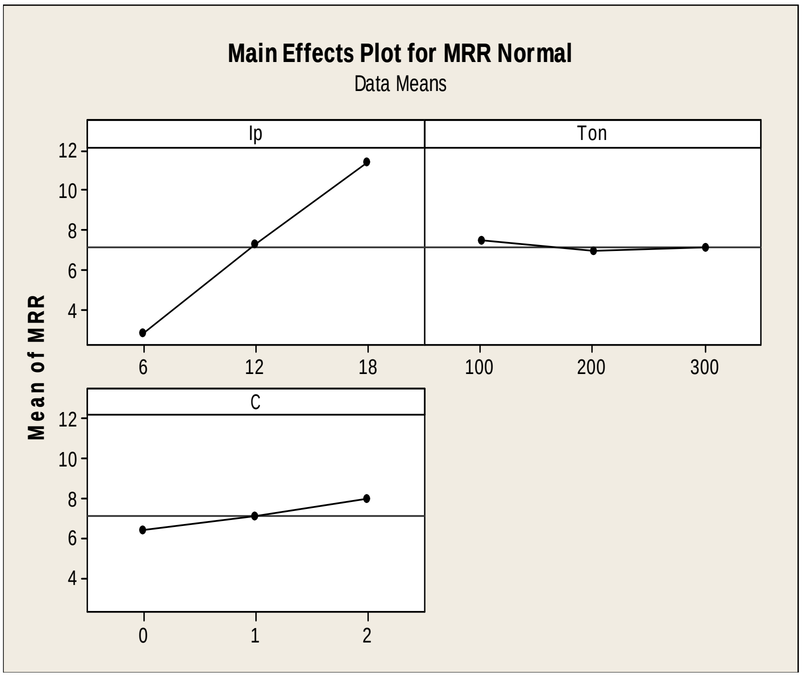

Figure: 4 Response Graph for MRR

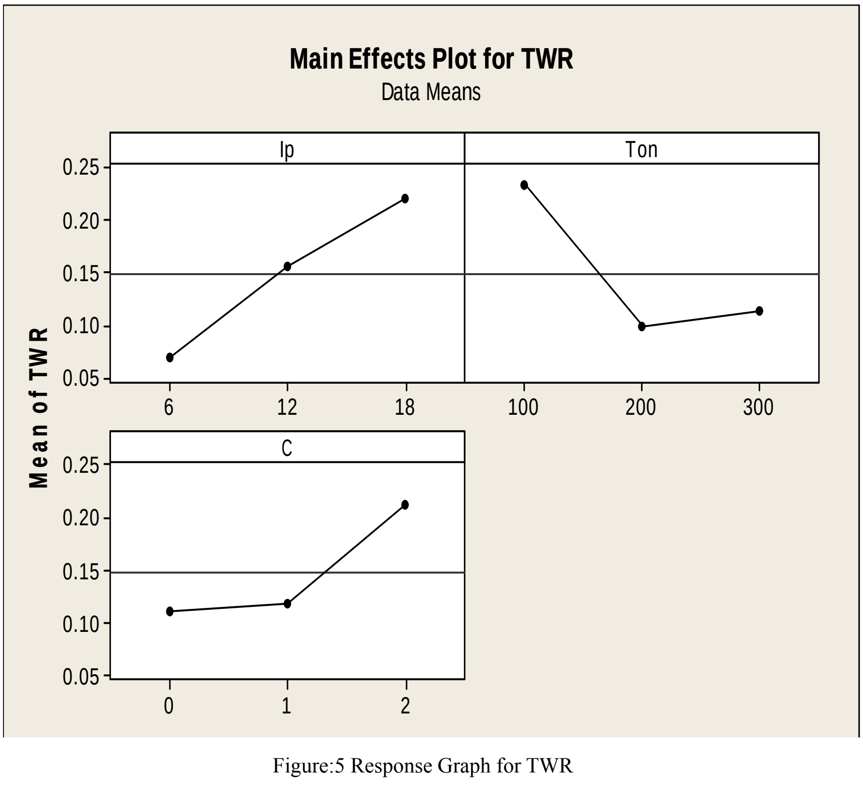

Figure:5 Response Graph for TWR

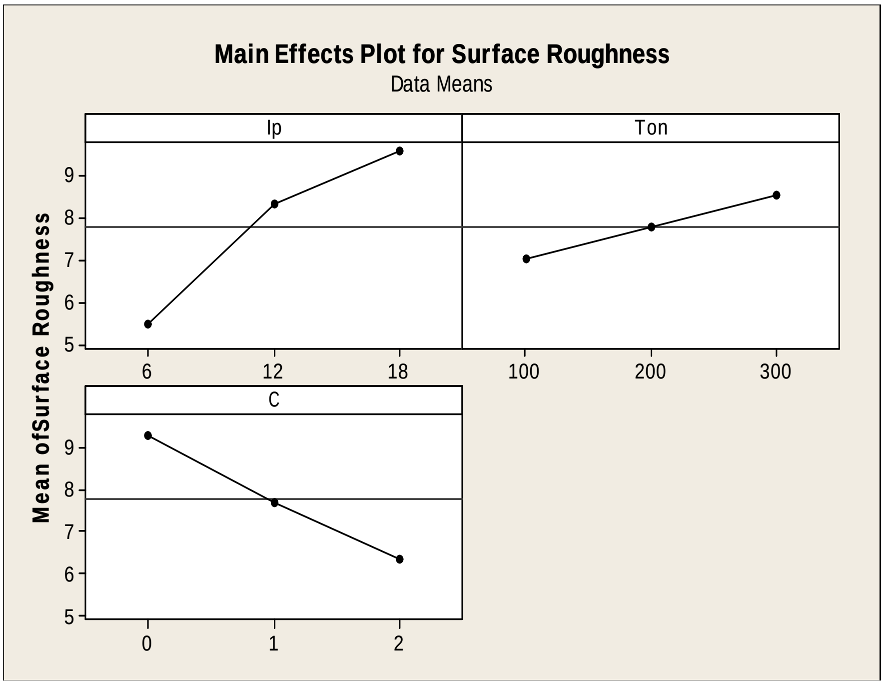

Figure: 6 Response Graph for Surface Roughness

Effect of parameters on process performance in Reverse Polarity

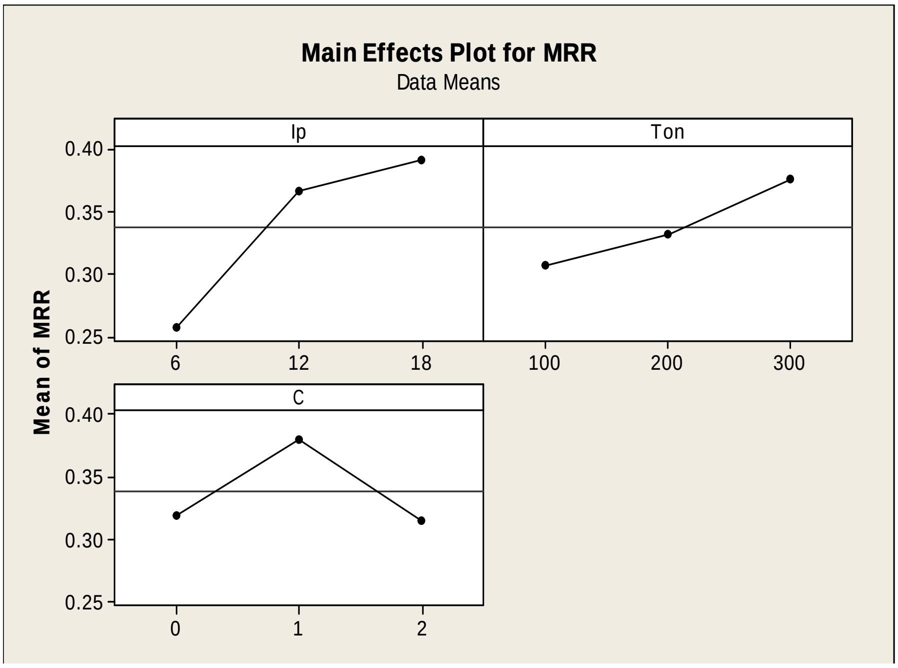

Figure: 7 Response Graph for MRR

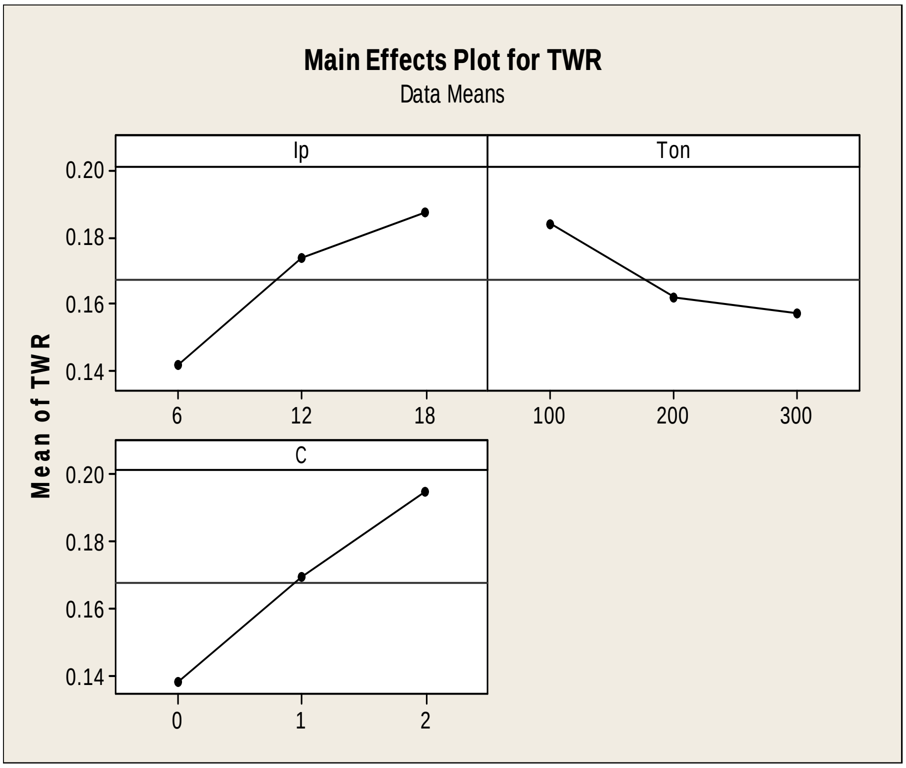

Figure:8 Response Graph for TWR

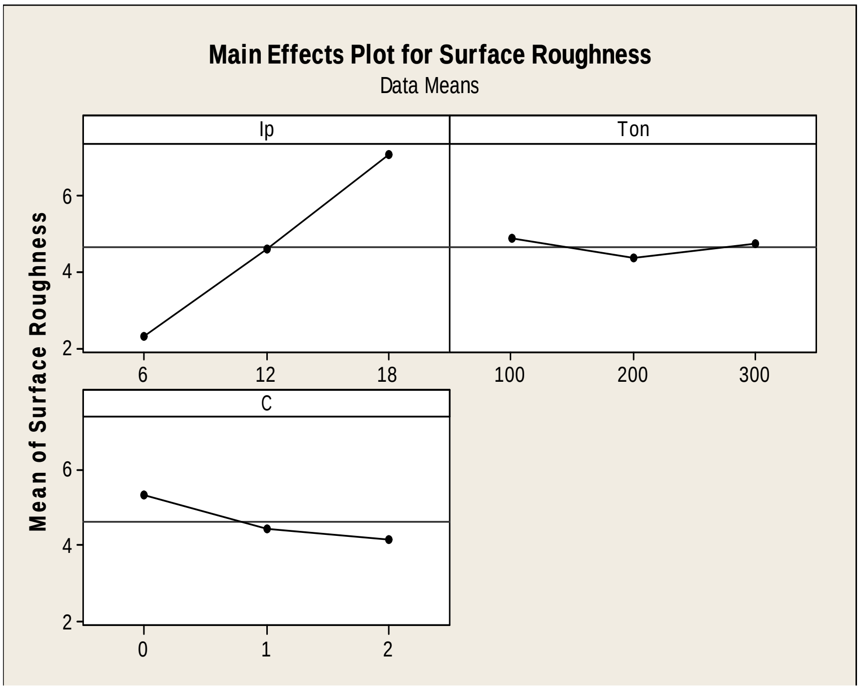

Figure:9 Response Graph for Surface Roughness

The present work on addition of chromium metalpowder in kerosene with changing polarity resulted in high MRR, minimum TWR and Surface Roughness (SR). The results are obtained from the present investigation for selecting the optimum machining conditions for EN-19 work material shown in figure 2, which is extensively used in tool and die industries. Within the range of parameters selected the following specific conclusions are drawn from the experimental results.

1. Maximum MRR is obtained at a high peak current of 18 A, a moderate Ton of 200µs, and a low concentration of powder in Normal polarity shown in figure 4.
2. Low TWR is achieved in Normal polarity with low values of peak current of 6 A, minimum values of Ton of 100 µs, and low concentration of powder as shown in figure 5.

3. To get better surface roughness values, a low peak current of 6 A, a moderate Ton of 200 µs, a low concentration of powder of 1 g/L, and reverse polarity is preferred.
4. Polarity plays an important role in PMEDM. Higher productivity, i.e. high MRR, is obtained in Normal polarity, whereas better surface quality (surface roughness) is achieved in Reverse polarity. Hence for rough machining Normal polarity can be selected to achieve higher MRR and during finishing a better surface is achieved by changing the polarity i.e. Reverse polarity.
5. The optimal parametric combination for both Normal & Reverse polarity is shown in table 7 & 8.

Table 7: Optimum parametric combination in Normal polarity

Requirements	**Optimal Combination (I / Ton / C)**	**Confirmation of results**		
		MRR (mm3/min)	**TWR (mm3/min)**	**Ra(µm)**
Higher MRR	18 A/ 100 µs/ 2gm/lit	**12.452**	0.159	11.105
Lower TWR	6A/ 100 µs/ without powder	2.500	**0.056**	5.845
Lower Ra	6A/ 300µs/ 2 gm/lit	2.070	0.072	**4.818**

Table 8: Optimum parametric combination in Reverse polarity

Requirements	**Optimal Combination (I / Ton / C)**	**Confirmation of results**		
		MRR (mm3/min)	**TWR (mm3/min)**	**Ra(µm)**
Higher MRR	18 A/ 300 µs/ 1gm/lit	**0.450**	0.134	6.881
Lower TWR	6A/ 100 µs/ without powder	0.186	**0.084**	3.155
Lower Ra	6A/ 200µs/ 1 gm/lit	0.295	0.185	**1.655**

IV. CONCLUSION

From the experimental results it is observed that, the higher metal removal rate and lower tool wear is achieved with the Normal polarity but better surface finish is achieved with the reverse polarity. It is seen that Normal polarity gives 10-21 times more MRR and 4 times less tool wear rate as compared to reverse polarity in PMEDM. Reverse polarity gives 1.5-2 times better surface finish as compared to Normal polarity, so for the better surface finish reverse polarity is desirable.

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