Near Dry and Powder Mixed Near Dry Electric Discharge Machining

Sanjay Sundriyal, Vipin, Ravinder Singh Walia

Abstract**:** ***Electric discharge machining (EDM) is a non conventional machining method to fabricate very tough and hard materials. Although EDM has played a vital role in machining industry but with advancement of technology, alternative advanced methods of machining have been evolved such as near dry EDM (ND-EDM) and powder mixed near dry EDM (PMND-EDM). These technologies have been proven more efficient than traditional EDM in terms of machining performance characteristics such as higher material removal rate (MRR), better surface finish (Ra) and low tool wear rate (TWR) with high tolerance quality products. In this study an approach has been made to draw experimental comparison between ND-EDM and PMND-EDM in terms of MRR, SR and TWR. The experimental result and analysis revealed that PMND-EDM was better machining method than ND-EDM as in the former technique, the M RR increased by 45.04 % while SR and TWR reduced by 45.33 % and 60.60% respectively.***

Keywords **:** ***About four key words or phrases in alphabetical order, separated by commas.***

I. INTRODUCTION

Electric discharge machining is widely used in machining hard temperature resistant materials. The erosion of material takes place by conversion of electric energy to thermal energy. Hydrocarbon oil is generally used as dielectric oil in EDM. This EDM oil is a main source of aerosols, toxic fumes which can cause fire hazards [1]. The erosion rate, tool wear rate (TWR) and surface finish (Ra) is quite low in traditional EDM process. The other variant of EDM is dry EDM (D-EDM) which utilizes gas instead of dielectric oil for machining purpose. Although D-EDM eliminates requirement of bulk quantity of oil and toxic fumes but debris deposition becomes a main concern which consequently leads to lower MRR and also deteriorates the accuracy of the machined surfaces [2]. Therefore another variant came into existence in which the dielectric was a combination of dielectric gas and minute quantity of dielectric oil [3]. ND-EDM overcomes limitations of D-EDM, as the liquid phase in the dielectric enhances debris flushing which eliminates debris deposition and at the same time MRR gets increased with quality machined products with higher accuracy. ND-EDM was also eco-friendly as it utilizes very minute amount of oil therefore the fumes produced are lesser toxic in nature [4]. Mirror like finish was achieved on machined surface by ND-EDM and the taper in the holes was considerably lower [5]. The discharges in ND-EDM were easier to initiate and stable machining was achieved due to liquid phase presence in gaseous environment. This phase changes the electric field and also creates a large gap distance between the workpiece and tool electrodes. Other several advantages of ND-EDM were that a broad variety of liquids and gases could be used in order to change the liquid concentration in gas. Therefore dielectric properties could be tailored to meet different machining needs such as higher MRR or enhanced surface finish [6]. Another advanced technique, powder mixed EDM came into existence in which metallic powder was added along with the dielectric oil. Powder additives reduces the insulating strength of the dielectric fluid as a result short circuit at the inter electrode gap (IEG) takes place due to which series discharge occurs and results in faster erosion. Metallic powder modifies the plasma channel between the electrodes and the sparking gets uniformly distributed [7]. Consequently shallow craters are formed over the machined surface which produces machined parts with higher surface finish. Powder mixed near dry EDM was another proposed hybrid technique which combined the advantages of ND-EDM and PMND-EDM in order enhances the machining performance characteristics [8]. Research was performed on different combination of tool and workpiece electrodes in PMND-EDM to study effects of different process parameters on MRR [9]. Gas –liquid-powder mixture of three phases was used in PMND-EDM for material removal process and it was revealed that MRR was much higher as compared to other EDM methods of machining [10]. Comparative study was performed between wet EDM, ND-EDM and PMND-EDM for machining performance characterstics in terms of Ra and TWR. Their study revealed that TWR and surface roughness of machined product was lowest in PMND-EDM as compared to wet EDM and ND-EDM [11].

In this study a comparative experimental analysis has been performed for ND-EDM and PMND-EDM for mainly three output responses which were MRR, SR and TWR.

II. EXPERIMENTAL SETUP AND PROCEDURE.

The experiments were performed on Sparkonix-35A series EDM (Pune, India) while the hybrid setup of PMND-EDM for experimentation was developed indigenously in Delhi Technological University (D.T.U Delhi) as shown in Fig.1. The setup comprises of mixing chamber made of stainless steel (1 litre), 1.H.P compressor, air-mist pressure regulators and dielectric oil flow meter along with dial indicators. The range of dielectric mist pressure was between 0.1 MPa to 0.5 MPa while the flow rate of dielectric medium can be varied from 0ml/min to

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20ml/min. The experiments were performed by two set of experiments. One set of experiment was performed by using two phase dielectric medium (compressed air + dielectric oil) while another set of experiment was performed by using three phase dielectric medium (compressed air + dielectric oil + metallic powder). The machining process parameters were identified by extensive literature review as shown in Table 1. The Physical and chemical properties of the workpiece are shown in Table 2 and Table 3 while Table 4 shows the properties of the metallic powder used for experimentation. The mixing chamber produces the required dielectric medium and then this medium was supplied to the inter electrode gap (IEG) through the flexible plastic tubes connected from outlet of mixing chamber to the hollow tool electrode. Afterwards, the required working pressure and dielectric oil flow rate was set with regulators mounted over the setup. Once the experimental conditions are achieved, the power was supplied from the EDM machine to the electrodes and the erosion starts taking place.

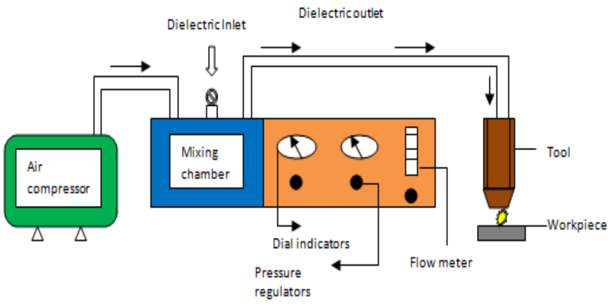

Fig.1 PMND-EDM setup developed indigenously for experimentation.

Table 1. Process parameters for experimentation for ND-EDM and PMND-EDM.

Process parameter	Unit	ND-EDM	PMND-EDM
Dielectric medium		Pressurized air + Dielectric oil	Pressurized air + Dielectric oil + powder
Machining time	Mins	10	10
Discharge current	A	8	8
Pulse on	µs	60	60
Gap voltage	V	30	30
Working pressure	MPa	0.5	0.5
Metallic powder concentration	g/l	10	10
Type of powder		-	Al, Gr, Si
Dielectric oil flow rate	ml/min	10	10
• Workpiece electrode – EN-31, Tool electrode – Copper			

Table 2. Physical properties of workpiece EN -31.

Properties	Values
Thermal conductivity (W/m*K)	44.5
Hardness(HRC)	63
Yield stress (MPa)	450
Tensile strength (MPa)	750
Density (kg/m^3)	7850
Melting point (ºC)	1540

Table 3. Chemical composition of workpiece EN-31

Element	C	Si	Mn	S	P	Cr
%	0.90-1.2	0.10-0.35	0.30-0.75	0.05	0.050	1-1.6

Table 4. Properties of metallic powders [12] .

Property (Units)	Gr	Al	Si
Electrical resistivity (µΩ-cm)	30	5	10000
Thermal conductivity (W/m-K)	25	238	163
Heat of fusion (kJ/mol)	117	10.79	50.21
Specific heat (J/kg-K)	710	910	710
Melting temperature (ºC)	3550	660	1414
Density (g/cm^3)	1.26	2.7	2.33
Mohs hardness (HV)	1.5	3	6.5

The MRR and TWR were calculated by the expressions given in Eq. (1) and Eq. (2).

$$MRR = \frac{W_i - W_f}{\rho_w x t} \times 1000\ mm^3/min \qquad (1)$$

$$TWR = \frac{W_i - W_f}{\rho_t x t} \times 1000\ mm^3/min \qquad (2)$$

Where ρ_w = Density of workpiece (g/cm^3);
ρ_t= Density of tool (g/cm^3);
The SR was measured with the 3-D optical profilometer. The density of EN -31 and copper tool is7.8 g/cm^3 and 8.9 g/cm^3 respectively. Fig. 2 shows the machined EN-31 samples along with the tool electrode.

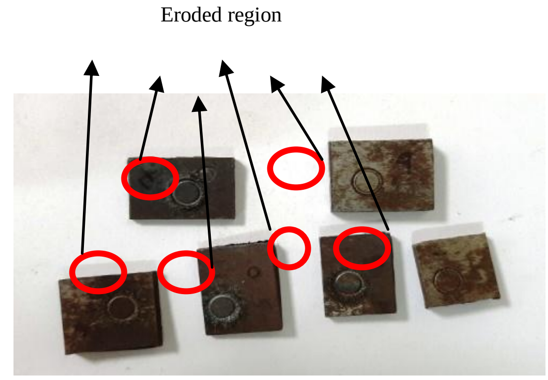

Fig.2 (a) Machined EN-31 samples

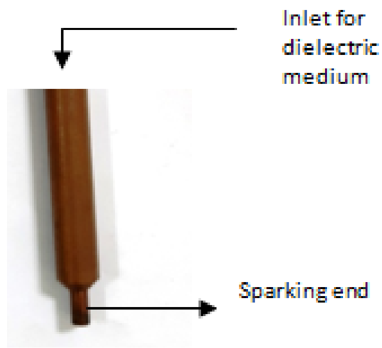

Fig.2 (b) hollow tool electrode.

III. RESULT AND DISCUSSION

A. Comparison of MRR for ND-EDM and PMND-EDM

As compared to ND-EDM, MRR with metallic powder additives in ND-EDM was found to be more due to reduction of breakdown dielectric strength as shown in Fig.3. This uniform dispersion of conductive powders causes increase in inter electrode gap which leads to large discharges [12]. Another contribution is that these metallic additives also help in creating a bridge phenomenon between the electrodes which results in increased thermal conductivity. All these factors are responsible for increasing the frequency of discharges due to which more erosion from the workpiece takes place as compared to conventional EDM [13].

The highest MRR in PMND-EDM was found by using aluminium powder followed by graphite and silicon. The reason attributed was that the Al powder has lowest resistivity (5 µΩ-cm) amongst other metallic powders Gr (30 µΩ-cm) and Si (10000 µΩ-cm). This lowest electrical resisitivity of Al causes sparking to take place from a larger distance at the inter electrode gap (IEG) unlike Gr and Si which has comparatively smaller discharges. This results in increase in sparking frequency and at the same time this increased working gap facilitates easy removal of debris and also improves the flushing conditions.

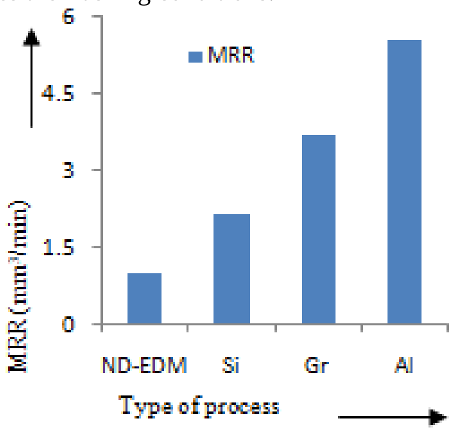

Fig. 3 MRR Vs different types of machining method.

B. Comparison of SR and topography for ND-EDM and PMND-EDM

The optical microscopy images of the machined samples by using different powders are shown in Figs. 4 - 6. The addition of metallic powders in the dielectric has reduced the SR considerably over the machined surface of the workpiece as shown in Fig.9. Powder particles enlarge the plasma generated between the electrodes. The discharge energy of the multiple sparks is distributed evenly over a larger area [14]. This leads to formation of shallow and large craters over the machined workpiece as shown in Figs.4 (a-b). Additionaly the molten metal at the machining gap is not compressed heavily by the gas bubbles and plasma channel which makes the surface less concave and uniformly smooth [15]. The SR was maximum for ND-EDM due to improper discharges while the SR was considerably better with powder additives. The minimum SR was observed with Si followed by Al and Gr due to its low thermal and electrical conductivity. Si powder particles being smaller in size enter the machining gap in more quantity which results in even distribution of discharges over a large area. Therefore the surface finish achieved was higher in quality as compared to surface machined by other powder additives due to their large particle size [16]. Even though the electrical conductivity of Al is higher than Gr powder but still the SR produced by Al powder was higher as shown in Figs.6 (a-b). The reason behind this phenomenon is that the density of Al is higher than Gr powder, which doesn't allow particles to mix thoroughly with the dielectric in a uniform manner. Secondly, powder particles of Al powder agglomerates due to Van der Walls forces or electrostatic force when added to the dielectric. Therefore excessive powder particles concentration causes short circuiting and improper discharges which eventually deteriorates the surface finish of the machined samples.

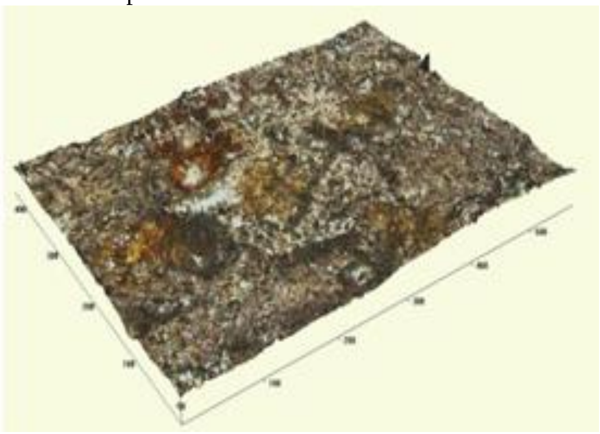

Fig. 4(a) 3-D profile of machined EN-31 sample by Si powder

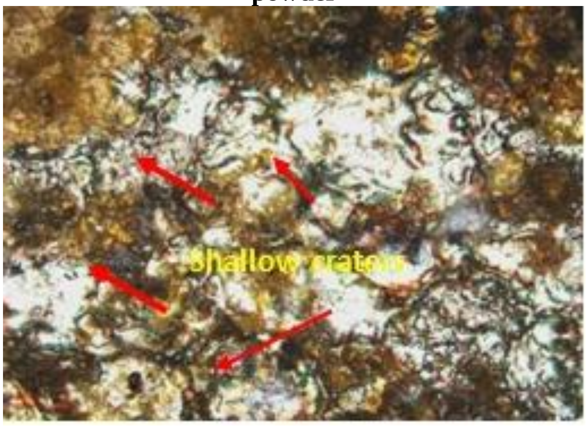

Fig. 4(b) 3-D profile of machined sample with shallow craters by Si powder.

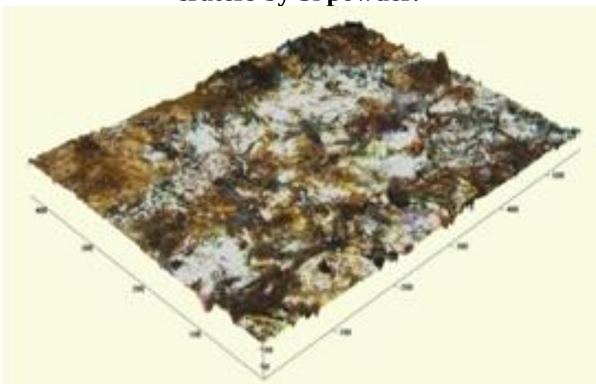

Fig. 5(a) 3-D image of surface profile by Gr powder

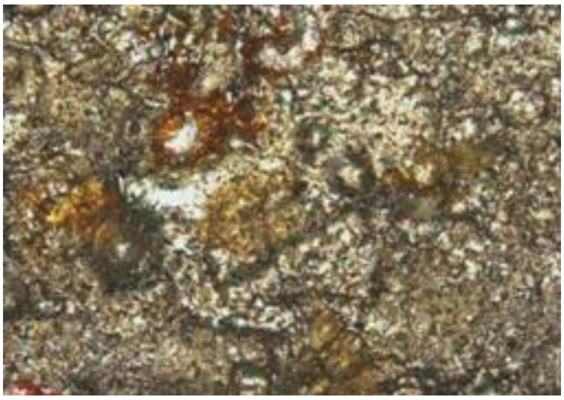

Fig. 5(b) 2-D profile of surface craters of machined sample by Gr powder

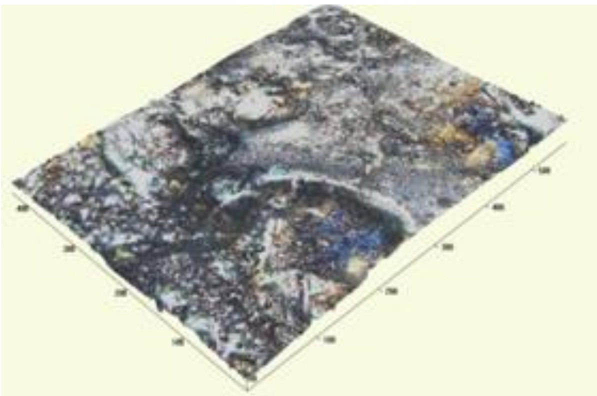

Fig. 6(a) 3-D profile of machined EN-31 sample by Al powder

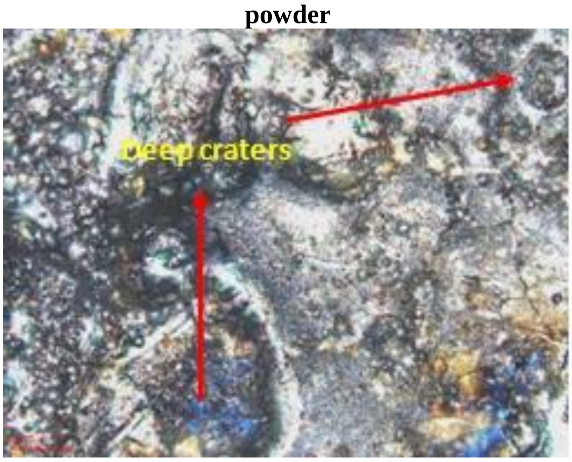

Fig. 6(b) 2-D image of machined surface with deep craters by Al powder

The surface obtained by ND-EDM has large cracks (Fig.7) and these cracks are responsible for corrosion and fatigue failure under tensile loading while the surface defects such as cracks were minimized by powder additives in PMND-EDM. The metallic powders high thermal conductivity was responsible for taking up some part of the residual heat at the sparking zone. Another reason attributed was that the pressure of the plasma channel was considerably lower due to slow cooling rate of the molten material at IEG which leads to formation of micro cracks as shown in Fig.8 unlike large defective cracks [17].

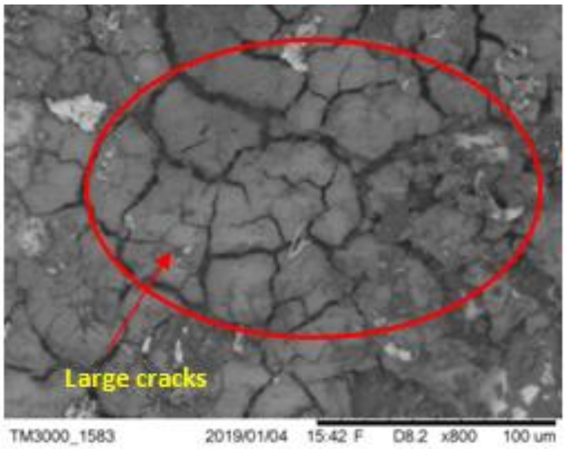

Fig.7 Surface cracks over the machined surface by ND-EDM.

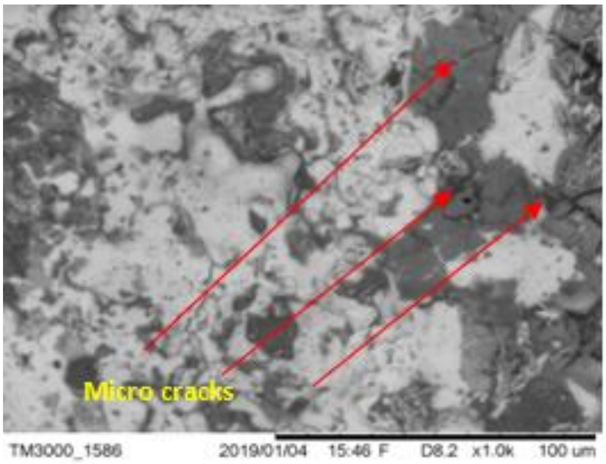

Fig.8 Micro cracks over the machined surface by PMND-EDM.

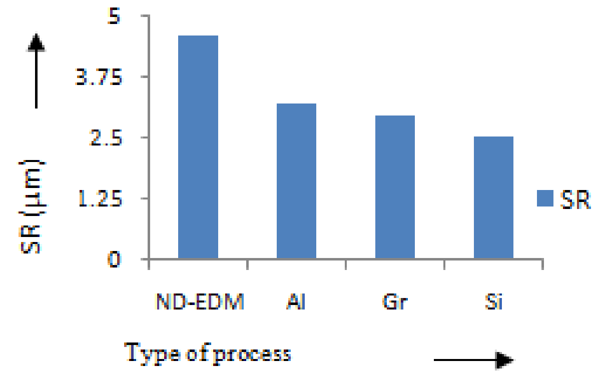

Fig. 9 SR Vs different types of machining method.

C. Comparison of TWR for ND-EDM and PMND-EDM

The TWR in PMND-EDM was much lower as compared to TWR in ND-EDM as shown in Fig.10. The TWR in PMND-EDM reduced by 60.60 % as compared to ND-EDM. The metallic powder particles form a bridge like structure at the IEG due to which the machining gap gets enlarged. This enlarged IEG was responsible for increasing the plasma channel which helps in diminishing the short circuiting between the tool and workpiece electrodes.

This absence of abnormal discharges or reduced short circuiting improves the heat dissipation and the amount of heat transferred to the too electrode gets reduced to a lower level.

This phenomenon of reduced heat transfer brings down the temperature of the materials below melting point and therefore the TWR gets diminished. Additionally, the breakdown voltage gets reduced by metallic powder additives and interspace between electrodes gets enlarged which improves the machining process overall stability which further reduced the TWR.

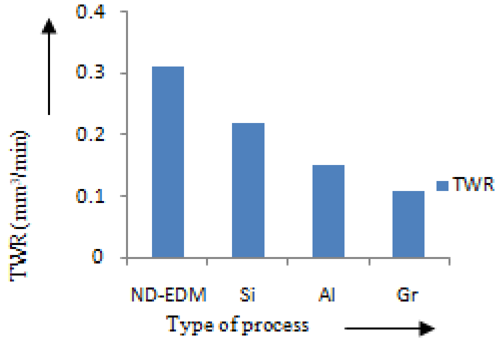

Fig.10 TWR Vs Type of machining process.

IV. CONCLUSION

A comparative experimental study for machining performance characterstics was performed for ND-EDM and PMND-EDM. It was observed that that hybrid PMND-EDM was beneficial in terms of improving machining efficiency and the products obtained were having good quality characterstics.

The following results were found and listed below:

1. ND-EDM and PMND-EDM both are environmentally friendly technologies because unlike traditional EDM, the dielectric oil quantity required was very minute. Therefore less harmful fumes were produced.
2. The MRR in PMND-EDM increased by 45.04 % due to better thermal conductivity between the electrodes.
3. The SR in PMND-EDM reduced by 45.33 % because of better heat dissipation and more uniformly enlarged plasma generated at the machining gap.
4. The stable working condition by addition of metallic powder resulted in stabilization of arc discharges, therefore the TWR in PMND-EDM reduced by 60.60 % as compared to ND-EDM.

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