Experimental investigation into portable near dry EDM

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Process Parameter,
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ABSTRACT

The Near Dry Electric Discharge Machining (NDEDM) process is becoming increasingly used now a days due to its suitability to produce complicated geometries and machining of materials with high mechanical properties. Experimental designs were created by using central composite design method & experiments were performed by using a copper (ρ 8.9 gram per cm cube) tool and EN31 Die steel (ρ 7.8 gram per cm cube) workpiece. The influence of gap voltage, discharge current and pulse on time on the material removal rate of EN31 Die steel has been analysed. The tool electrode was designed as a tube to allow high, velocity gas to flow through from it. A tool was used to deliver high pressure air from the air compressor into the discharge gap. This work presents a series of findings that allow optimizing the starting parameters of the process to increase the useful life of the tool, increase the MRR. The result outcome shows that discharge current followed by pulse on current has the major influence on the MRR of EN31 Die steel.

1. Introduction

The electrical discharge machining (EDM) process includes the controlled erosion of electrically conductive materials. A rapid and intermittent spark ignition between the cathode (tool electrode) and the anode (workpiece). They are separated by a small gap of about 0.01 to 0.50 mm, spark flow is created by a controlled DC pulse between electrodes. The dielectric fluid is ionized by a spark and a spark is produced between electrodes. The unique feature of EDM process is that there is no direct contact between the tool and the workpiece. The material is removed by melting and vaporization in a controlled way by a sequence of electric sparks. Fig. 1.1 shows the principle of EDM process.

The dielectric is allowed to flow between the electrodes, to remove material (Pallavi et al., 2021). Researchers have developed various EDM techniques (near-dry and dry EDM) which reduces issues and existing limitations. Near-dry EDM uses a mixture of water and gas as the dielectric medium. Dry EDM uses high-pressure gas as the dielectric processing medium for machining (Dhakar & Dvivedi, 2017). Fig. 1.2. depicts the environmental friendly EDM dielectrics and their properties.

In EDM process, both the work-piece material and a cathode must be connected to straight polarity (Khatri et al., 2016). Recently it has been found that hybrid machining techniques comprising multiple machining techniques are becoming more suitable for the machining of challenging materials (Yadav & Yadav, 2017).

2. Materials & Method

2.1. Experimental setup

The whole experiments were coducted using a Near-dry Electric Discharge Machine. A near dry electrical discharge machining unit attachment was created, this attachment unit is designed. Recently it has been found that hybrid machining techniques comprising multiple machining techniques are becoming more suitable for the machining of such types of challenging materials meets the following dry EDM requirements.

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Following are the components of near dry EDM (Fig. 2.1).

- Dielectric reservoir
- Pump and circulation system
- Power generator and control unit
- Working tank with work holding device
- X-Y table
- Tool holder
- Servo system

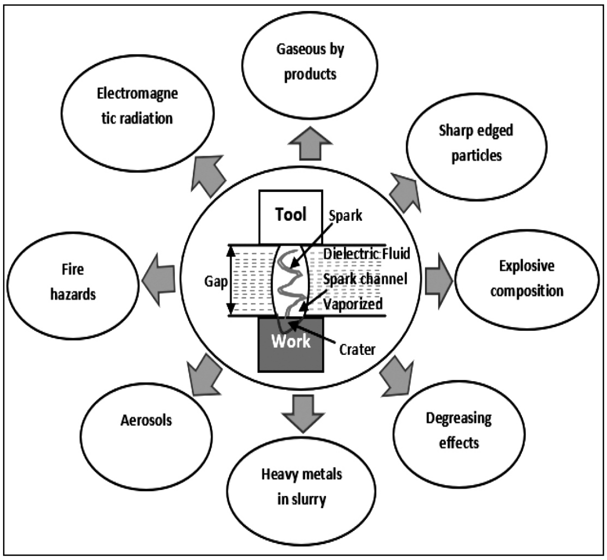

Fig. 1.1. Schematic view of principle of EDM process with hazards potential (Masanori et al., 1997; Kunieda & Furudate, 2001; Yadav et al., 2017a; Yadav et al., 2017b, Yadav et al., 2021; Sing et al., 2022).

2.2. Work material

Experiments were performed by using a copper (ρ= 8.9 gram per cm cube) tool on EN31 Die steel (ρ= 7.8 gram per cm cube) workpiece. The tool electrode was designed as a tube to allow high velocity gas to flow from it. The dielectric medium used in the experiments was air. The tool was used to deliver high pressure air from the air compressor into the discharge gap. EN31 is a very high strength steel alloy. It has high tensile strength, with good ductility and wear resistance. The chemical composition of EN31 Die steel is shown in Table 2.1.

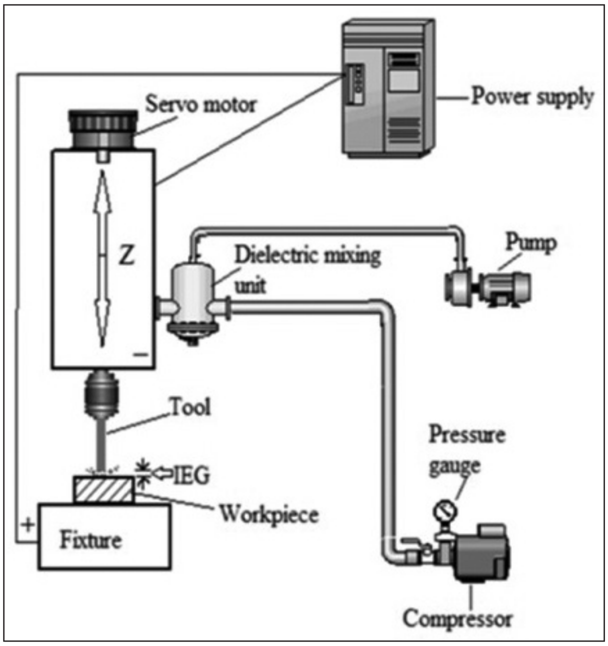

Fig. 2.1. Near-dry EDM NDEDM schematic.

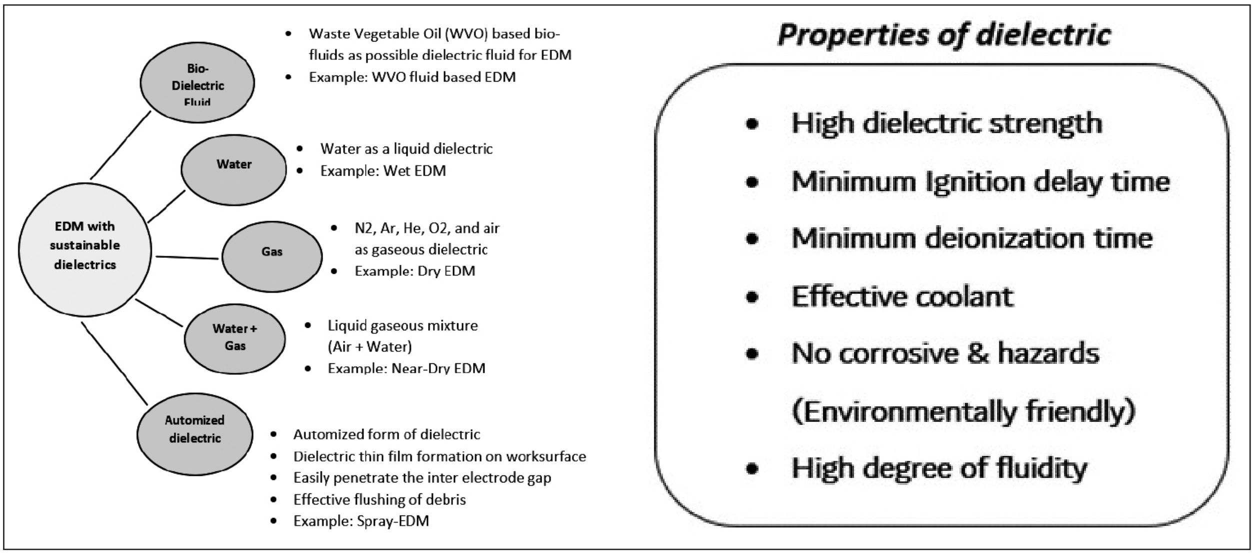

Fig. 1.2. Environment friendly EDM dielectric (Masanori et al., 1997; Kunieda & Furudate, 2001; Kunleda et al., 2003; Valaki et al., 2019, Singaravel et al., 2020; Dhakar et al., 2022).

Table 2.1
Chemical composition of EN-31 die steel.

Elements	C	Si	Mn	Cr	S	P	Fe
Wt %	09-1.2	0.1-0.35	0.3-0.75	1-1.6	0.025	0.025	Balanced

3. Result & Discussion

3.1. Experimental result

Table 3.1
Experimental data obtained from the CCD runs.

Exp. No.	Current	Pulse on	Gap Volt	MRR	SNR
1	4.5	120	40	0.34	-9.37
2	4.5	120	60	0.80	-1.94
3	4.5	150	40	0.84	-1.01
4	4.5	150	60	0.92	-0.72
5	4.5	200	40	1.10	0.83
6	4.5	200	60	1.17	1.36
7	6	120	40	0.65	-3.74
8	6	120	60	0.80	-1.94
9	6	150	40	0.99	-0.09
10	6	150	60	1.24	1.87
11	6	200	40	1.32	2.41
12	6	200	60	2.15	6.65
13	9	120	40	2.52	8.03
14	9	120	60	1.93	5.71
15	9	150	40	3.10	9.83
16	9	150	60	3.30	10.37
17	9	200	40	3.55	11.00
18	9	200	60	3.10	9.83

3.2. Analysis of variance (ANOVA) for MRR

According to ANOVA, discharge current (F value 142.14), pulse on time (F value 34.29), and gap volt (F value 1.32) all have a contribution in maximizing MRR. Table 3.2 shows the rank of each parameter in terms of its contribution to maximizing MRR. With a contribution of 75.71 %, discharge current was found to be the most significant characteristic. In addition, pulse on time (18.26 % contribution) and gap volt (0.70 % contribution) play a significant role.

Regression Equation

MRR = -3.89 - 0.547 Current + 0.0260 Pulse on + 0.106 Gap volt + 0.0736 Current*Current - 0.000096 Pulse on* Pulse on - 0.00072 Gap volt*Gap volt + Current*Pulse on - 0.00625 Current*Gap volt + 0.000078 Pulse on*Gap volt

3.3. Parametric analysis

- Effect of current on MRR

The effect of dis-charge current on MRR is shown in Fig.3.1 & Fig 3.2 MRR was shown to increase as discharge current increased. Spark energy increases as current increases, resulting in larger craters. As a result, MRR increases as current increases. For large current, a crater volume may grow due to gain in depth or diameter of crater, or a combination of both.

Table 3.2
Analysis of variance for S/N ratios for MRR.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P- Value
Current	2	3.0337	75.71%	3.0337	1.51685	142.14	0
Pulse on	2	0.73182	18.26%	0.7318	0.36591	34.29	0
Gap Volt	2	0.02822	0.70%	0.02822	0.01411	1.32	0.289
Error	20	0.21343	5.33%	0.21343	0.01067		
Total	26	4.00718	100.00%				

Table 3.3
Model summary for transformed response.

S	R-sq	R-sq (adj)	PRESS	R-sq (pred)
0.103304	94.67%	93.08%	0.388982	90.29%

Table 3.4
Response for signal to noise ratios larger is better (MRR).

Level	Current	Pulse on	Gap volt
1	-1.6091	-.03162	1.9317
2	1.0778	3.1836	3.2033
3	9.1317	5.733	3.4654
Delta	10.7407	6.0492	1.5337
Rank	1	2	3

Table 3.5
Response table for means.

Level	Current	Pulse on	Gap Volt
1	0.8756	1.1689	1.6011
2	1.2311	1.6922	1.7289
3	2.9356	2.1811	1.7122
Delta	2.06	1.0122	0.1278
Rank	1	2	3

In comparison to the crater diameter, the crater depth affects the MRR value. It can be further explained if studies are conducted on the effects of parameters such as voltage and current on the discharge plasma channel.

- Effect of pulse on time on MRR

Higher discharge currents have been found to result in higher MRR and improved crater volume. This is due to the fact that the diameter of the crater is determined by the current level. Figure 3.1 and 3.2 depicts the effect of T_{on} on MRR. It is clear to observe that as T_{on} rises, MRR values rise as well.

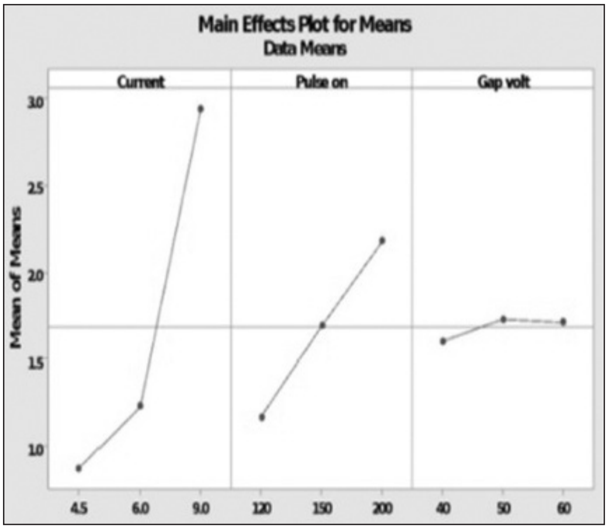

Fig. 3.1. Effect of I, pulse on time and V_g.

Because spark energy is directly related to T_{on}, higher T_{on} results in deeper discharge craters & more material removal per spark. Furthermore, the duty factor alone may not be sufficient to predict the spark frequency of a revolving tool. As a result, even if the duty factor remains constant, the MRR rises with T_{on}. The decrease in MRR can be explained by the large values of pulse off-time for very large values of T_{on}. This is because the duty factor was kept constant throughout the experiment, a greater T_{off} value equating to a higher T_{on} value was attained. During the T_{off}, no material is removed. As a result, a large T_{off} value increases no machining time resulting decreased MRR.

- Effect of V_g on MRR

Figure 3.1 & 3.2 shows the effect of the pulse time on spark energy and discharge gap. The

Table 3.6
Analysis of variance.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	9	27.2223	95.44%	27.2223	3.0247	39.56	0
Linear	3	25.7377	90.24%	24.1756	8.0585	105.39	0
Current	1	21.1911	74.30%	19.4838	19.4838	254.81	0
Pulse on	1	4.491	15.75%	4.9092	4.9092	64.2	0
Gap volt	1	0.0556	0.19%	0.0317	0.0317	0.41	0.528
Square	3	0.7871	2.76%	0.7871	0.2624	3.43	0.041
Current*current	1	0.6343	2.22%	0.6343	0..6343	8.3	0.01
Pulse on*pulse on	1	0.1215	0.43%	0.1215	0.1215	1.59	0.225
Gap volt*Gap volt	1	0.0313	0.11%	0.0313	0.0313	0.41	0.531
2-Way Interaction	3	0.6976	2.45%	0.6976	0.2325	3.04	0.057
Current*Pulse on	1	0.4399	1.54%	0.4399	0.4399	5.75	0.028
Current*Gap volt	1	0.2458	0.86%	0.2458	0.2458	3.21	0.091
Pulse on* Gap volt	1	0.0118	0.04%	0.0118	0.0118	0.15	0.699
Error	17	1.2999	4.56%	1.2999	0.0765		
Total	26	28.5222	100.00%				

Table 3.7
Model summary analysis of variance.

S	R-Sq	R-Sq (adj)	Press	R-sq (pred)
0.276519	95.44%	93.03%	3.95725	86.13%

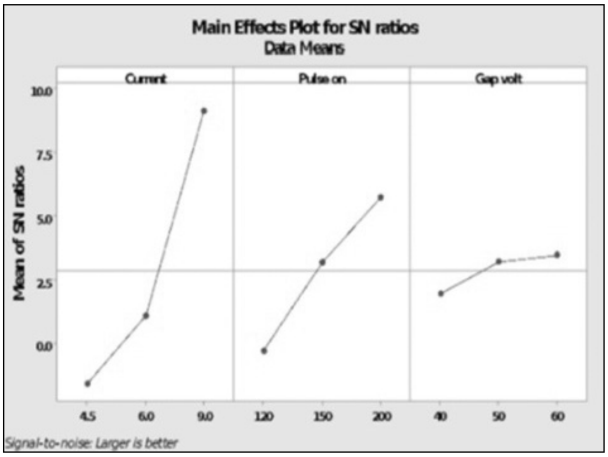

Fig. 3.2. Effect off current, pulse on time and V_g on SN ratios.

deeper discharge craters form with a larger T_{on}, and the more material is removed each spark, Figure 3.1 & 3.2 shows the influence of V_g on MRR, MRR initially increases as voltage is increased, but there is an optimum value at which MRR reduces as voltage is increased more. Because spark energy i's directly proportional

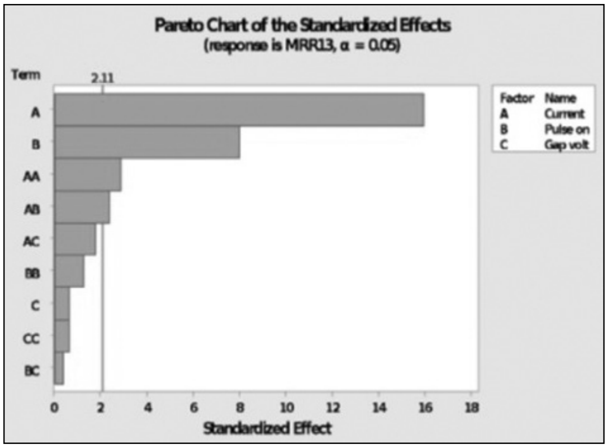

Fig. 3.3. Pareto chart of the standardized effect.

to V_g, a higher MRR would result from a higher voltage. When the effective electric field between the electrodes increases the dielectric strength of medium, discharge occurs. As a result, as the V_g rises, the discharge gap-distance grows, and breakdown of electric domain (field) may now be reached even a great gap distance. When the gap distance is large, the effective gas velocity on the workpiece surface is reduced. As a result of the dirt in the tool-workpiece gap, flushing efficiency decreases and the risk of arcing increases. At very high voltages, low MRR value were attained due to the partial debris removal from discharge gap. As a result, there is an ideal voltage value that yields a high MRR.

4. Conclusions

The di-electric liquid used in the EDM typically repeated without regard for the environmental impact; however, the dielectric's existence cycle should be resolved in order to avoid destructive vaporized and metallic polluted outflows, which legitimately underpins the machining cycle's natural harmony. The following are the findings of the current study:

- In the current study it has been found that current contributes 75.71% while pulse on time contributes 18.26% on MRR
- A requirement for the creation of a standard maintainability list for energy consumption evaluation, with support identified for a continuous fabricating process. Machining can be used to address a variety of drawbacks associated with typical EDM methods.

Remarks

- The post activity measure is avoided by selecting the correct dielectric with earlier assessment of hardware and workpiece materials at the underlying level. After a thorough examination of maintainability difficulties in 50 distributions after 2005, the ongoing years 2016 and 2017 curiously observed a favourable effect in environmentally friendly approaches.
- The design is required by today's generation and development of a versatile and low-cost mechanical manipulator that is analogous to the human hand.

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