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Influence of EDM Process Parameters on MRR and TWR on Mild Steel and Cast Iron using Taguchi's Method

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Abstract

An alternative to conventional machining methods, Electrical Discharge Machining (EDM) uses electrical current for generating controlled sparks that erode surface of the material through thermal energy. Unlike traditional cutting processes, hard and electrically conductive materials with high precision can be machines very easily, which make it suitable for applications in tool and die manufacturing, aerospace, and automotive industries. Tool Wear Rate (TWR) and Material Removal Rate (MRR) for mild steel and cast iron are examined in relation to process factors including peak current, cutting speed, pulse-on time, and pulse-off time. Experiments were conducted using the ELEKTRA EMS 5535 die-sinker EDM, and the Taguchi Method (L-9 orthogonal arrays) was employed for the design of experiments. When both Keeping the pulse-off time and current constant, the MRR for cutting mild steel rose as the cutting speed increased. The ratio of TWR to peak current also rose when the former rose. Furthermore, the cutting speed of 3 µm/10 sec, 200 µs for the pulse-on length, 5 µs for the pulse-off time, and 8 A for the current produced the highest metal removal rate (MRR) for cast iron, which was 0.202 g/min. It was also found that TWR exhibited a tendency to rise even when current was constant, highlighting the influence of thermal stress and tool–workpiece interaction.

Keywords: Mild steel, EDM, Taguchi's method, material removal rate, tool wear rate

INTRODUCTION

One non-traditional thermo-electric machining method is known as Electrical Discharge Machining (EDM). In EDM, the tool (cathode) and the workpiece (anode) are subjected to repeated spark discharges, which erode the metal [1–4]. A tiny spark gap, of about 0.01 to 0.05 mm, separates the tool and workpiece [5]. The dielectric fluid eliminates material from both sides as it passes between the electrode (tool) and the work. [6, 7]. Electrical discharge machining (EDM) makes direct use of electrical energy to produce electrical sparks [8, 9]. Spark erosion machining is another name for it. When traditional machining techniques fail, the EDM process steps in to make short work of the material. Graphite, ceramics, metallic alloys, and metals are just a few examples of the conductive materials that may be machined with EDM [10].

P. Kuppan et al. investigated how different EDM input settings affected Inconel 718 deep hole drilling. Output parameters were MRR Depth average surface roughness, with peak current, duty factor, electrode speed serving, and pulse on time as input parameters [11]. They discovered showed MRR was more affected by peak current, duty factor, and pulse on time. Gaikwad et al.'s goal was to maximize the MRR of cryo-treated NiTi alloys

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by utilizing Taguchi's electric discharge machining technique. The gap current, pulse on time, pulse off time, and the workpiece and tool conductivities were among the process parameters that were selected. [4]. During experiments, it was observed that the all selected parameters significantly influence the MRR Aharwal K.R.et. al. carried out the experiment about the enhancement of MRR and surface finish of composite material made of metal matrix in electric discharge machining [12]. They measured MRR duty factor, and surface roughness as outputs, and timely pulse, servo voltage, and peak current as inputs. The findings demonstrated that the ideal circumstances for optimizing the material removal rate were low voltage and high current. Using Die sinker EDM, M.Ravi Kumar et al. examined how output responses like MRR and TWR were affected by input factors including current, pulse on and pulse off timings, and SS304 micromachining, and circularity [8]. The results of the trials demonstrate that the current is the most critical variable in determining the MRR and TWR.

Using Taguchi's approach, Vats et al. optimized the wire EDM settings for HDS H13 [13]. Pulse on time was determined to have a greater impact than other elements include tension, pulse off time, delay time, and wire feed speed. The effects of EDM process variables including voltage, current, and pulse duration on MRR was investigated experimentally by Sahani et. al. [14]. Their research showed that there is a peak at which the MRR drops, following which it continues to rise with a timely increase in pulse. Likewise, initially, MRR increases with current but then falls as current grows.

In the present work, samples of mild steel and cast iron were selected for the comparing the MRR and TWR for both materials. The study carefully investigated how various EDM process factors, including as peak current, cutting speed, and pulse on and off time, affected MRR and TWR. The experiment was designed on the basis of Taguchi’s method. It is a wonderful approach to design any robust experiment. It is very popular in the optimization of process parameters in the area of manufacturing and machining, because of the reduction of number of required experiment which needed. Taguchi’s method contains the number of controlled inputs known as factors and each factor is set at discrete values known as levels. In the present experiment, peak current, pulse on time etc. are the factors which set at the 3 levels each.

There are predefined matrices that ensure the balance and unbiased estimation of effect of factors at minimum run known as orthogonal arrays. The common orthogonal arrays are L4, L8, L9, L16 etc. If there are four factors at three levels, then the total experiments will be 81, while Taguchi’s L9 reduces it to 9. Therefore, Taguchi’s method not only save the time to explore the most important factor which influence the manufacturing, but it also utilize the man and machine minimally [15].

EXPERIMENTAL DETAILS

Experimental setup

The experimental setup is shown in Figure 1, where, A, B, C, D are electrode holder, tool, workpiece,and machining tank, respectively. The values of input process parameters are displayed in Table 1. The testing was done on both mild steel (M.S.) and cast iron (C.I.) as shown in Figure 20, using the ELEKTRA/Ems5535 die-sink electric discharge equipment. The apparatus includes a dielectric supply system, a servo control system, a worktable, and an electrode holder. There is a maximum height of 250 mm for work pieces, and the table size of the machine is 550 × 350 mm. A 300 mm X-axis travel and a 200 mm Y-axis travel.

Workpiece materials and Tool Material

The material for electrode was selected as copper (Figure 20) having of dia 13.4mm length 2.35 cm and weight 30 gram [16]. The EDM 30 oil was used as dielectric fluid. As it has properties of high flash point, low viscosity, transparent, high dielectric strength and negligible aromatics [17, 18]. The specifications of workpiece materials are given in Table 2.

Experimental Procedure

Prior to testing, the workpiece's surfaces were all satisfactorily polished with a grinding machine. Using fine-grade emery paper, the electrode's base was polished. The initial weights of the C.I.

specimens 1 and 2 were measured as 260.045 g, 270.010g respectively .Similarly the initial weights of M.S specimens 1 and 2 were found as 166.975g, 176.925g respectively. For weighing, high precision weighting machine WENSAR with least count 0.001 g was used. Figure 1 shows the process of clamping the workpiece onto the machine table with a fixture that was custom made. The electrode holder was used to mount the electrode. The workpiece was linked to the DC power source's positive terminal, while the negative terminal to the electrode.

Nine experiments were conducted for both material. Weighing of the workpieces was carried out before and after of each experiment as shown in observation tables.

Selection of process parameters

Four input parameters have been selected for conducting experiments on both metals.They are

(a). *Pulse on Time (Ton):* The pulse on time is the amount of time that the current flows throughout a complete cycle.[19]. The tests were conducted at intervals of 50 µs, 100 µs, and 200 µs.

(b). *Pulse off time (Toff):* The time interval between the sparks is known as the pulse off time. [20]. It is also measured in microsecond (µs). The experiments were conducted at 5 µs, 6 µs, and 8 µs.

(c). *Peak current (I):*There is a clear correlation between the amount of power utilized in EDM and the MRR. It is measured in ampere(A) Experiments were conducted at 5 A, 8A, and 10A.

(d). *Cutting speed (µm/s):* It is the speed at which cutting takes place and it is measured in micron per sec. The experiments were conducted at 2 µm,3 µm and 4µm.

Table 1. Input parameters and their levels.

Input Parameters	**Unit**	**Level 1**	**Level2**	**Level3**
Peak Current(I)	Ampere	5	8	10
Cutting Speed(µm)	micron	2	3	4
Pulse on Time(Ton)	µs	50	100	200
Pulse off Time(Toff)	µs	5	6	8

Table 2. Specifications of workpiece material

S.N.	**Material**	**Workpiece**	**Dimensions(cm)**	**Weight(g)**
1	Mild Steel	Specimen1	6.0 × 2.95 × 1.15	166.975
2		Specimen 2	5.9 × 2.95 × 1.20	176.925
3	Cast Iron	Specimen1	6.3 × 2.9 × 1.9	260.045
4		Specimen 2	6.3 × 3.1 × 1.9	270.010

Figure 1. Set up for EDM experiments; (source IGTR Indore M.P.)

Selection of Output Measures

Material Removal Rate (MRR)

MRR is the total amount of material removed from a work piece as a function of machining time [3]. The mass of material removed from the work item (W) in a specific amount of time is known as the mass reduction rate (MRR). There is a linear link between MRR and pulse on time. The formula determines it [1,21].

MRR= (Wi-Wf)/tm (1)

Where, Wi and Wf are the workpiece weights both before to and following machining, tm is the machining time in min.

Tool Wear Rate (TWR)

It is a performance metric for the tool electrode's erosion rate and describes the amount of material extracted in a given amount of machining time (1). TWR can be calculated as from the equation (2).

TWR=(Ti-Tf)/tm (2)

In equation (2), Ti and Tf are tool weights both before to and following cutting.

DESIGN OF EXPERIMENTS (DOE) AND TAGUCHI’S METHOD

Taguchi’s method uses orthogonal arrays for DOE.[22]. This arrays are fractional factorial design of experiments in which only fraction of total possible combinations of input variables are considered. Due to fractional design the number of experiments reduces, but gives the complete information of the useful variables that affect the performance. There are several orthogonal arrays like L-4 (2^3), L-8 (2^7) L-9 (3^4) etc. In this experiment we use L-9 orthogonal arrays where number of experiments are 9, number of variables are 4 and number of the level of input parameters are 3.

RESULTS AND DISCUSSION

To investigate the effects of EDM process parameters on the material removal rate(MRR) and tool wear rate (TWR) of M.S. and C.I., the experiments were built using Taguchi's L9 orthogonal arrays. Peak current, cutting speed, pulse on time, and pulse off time are the input parameters that are used, nine tests were carried out for both MS and CI. The values for the aforementioned input parameters have been determined using the data in table 1.

Results for MRR and TWR were documented in experimental observation Tables 3A, 3B, 4A, and 4B, correspondingly. During observation, it was found that even when the current was constant, the MRR appeared to be increasing, as shown in Figure 2. It was also found that even when the cutting speed is increased, then MRR also increases as shown in Figure 3.

Table 3 A. Observations for Mild steel as workpiece and copper as electrode.

S.No	Peak current	Cutting speed	Pulse on time	Pulse off time	Workpiece (Mild steel)		MRR(g/20min.)
	(in ampere)	*(μm/10sec)*	*(μs)*	*(μs)*	*Initial weight(wi)*	*Final weight(wf)*	*Wi-Wf*
1	5	2	50	5	166.975	166.565	0.410
2	5	3	100	6	166.565	165.905	0.660
3	5	4	200	8	165.905	164.460	1.445
4	8	2	100	8	164.460	162.705	1.755
5	8	3	200	5	162.705	160.010	2.695
6	8	4	50	6	160.010	157.545	2.465
7	10	2	200	6	176.925	173.905	3.020
8	10	3	50	8	173.905	169.985	3.920
9	10	4	100	5	169.985	165.605	4.380

Workpiece Material:Mild Steel

Table 3 B. Observations for tool wear rate.

S. No.	Peak current	Cutting speed	Pulse on time	Pulse off time	Tool wear		TWR(g/20min.)
	(in ampere)	*(μm/10sec)*	*(μs)*	*(μs)*	*Initial weight(Ti)*	*Final weight(Tf)*	*Ti-Tf*
1	5	2	50	5	30.000	30.000	0.000
2	5	3	100	6	30.000	29.999	0.001
3	5	4	200	8	29.999	29.998	0.001
4	8	2	100	8	29.998	29.996	0.002
5	8	3	200	5	29.996	29.993	0.003
6	8	4	50	6	29.993	29.990	0.003
7	10	2	200	6	29.990	29.665	0.410
8	10	3	50	8	29.665	29.255	0.410
9	10	4	100	5	29.255	29.015	0.240

Tool Material: Copper, Diameter = 13mm Initial, weight=30grm

Table 4 A. Observations table for cast iron as workpiece and copper as electrode.

S.No.	Peak current	Cutting speed	Pulse on time	Pulse off time	Workpiece(Mild steel)		MRR(g/20min.)
	(in ampere)	*(μm/10sec)*	*(μs)*	*(μs)*	*Initial weight(wi)*	*Final weight(wf)*	*Wi-Wf*
1	5	2	50	5	260.045	259.995	0.050
2	5	3	100	6	259.995	257.97	2.025
3	5	4	200	8	257.97	254.915	3.055
4	8	2	100	8	254.915	251.29	3.625
5	8	3	200	5	251.29	247.245	4.045
6	8	4	50	6	247.245	243.77	3.475
7	10	2	200	6	270.01	266.115	3.895
8	10	3	50	8	266.115	265.67	0.445
9	10	4	100	5	265.195	263.33	1.865

Table 4 B. Observation table for tool wear rate.

S. No.	Peak current	Cutting speed	Pulse on time	Pulse off time	Tool wear		TWR(g/20min.)
	(in ampere)	*(μm/10sec)*	*μs*	*μs*	*Initial weight(Ti)*	*Final weight(Tf)*	*Ti-Tf*
1	5	2	50	5	29.015	29	0.015
2	5	3	100	6	29	28.955	0.045
3	5	4	200	8	28.955	28.935	0.02
4	8	2	100	8	28.935	28.865	0.07
5	8	3	200	5	28.865	28.85	0.015
6	8	4	50	6	28.85	28.465	0.385
7	10	2	200	6	28.465	28.42	0.045
8	10	3	50	8	28.42	28.325	0.095
9	10	4	100	5	24.8	24.67	0.13

Despite maintaining a steady pulse off time, it seemed like MRR was growing throughout observation. Additionally, it was shown that MRR remains near to constant even when the pulse on time varies, as shown in Figure 4 and 5.

When mild steel was used, it was observed that at current 5 to 8 amp, tool wear rate was negligible and at 10amp. TWR increases, as shown in Figure 6 and 7.

From Figure 8 and 9 it was observed that TWR is minimum upto expriments no. 6.

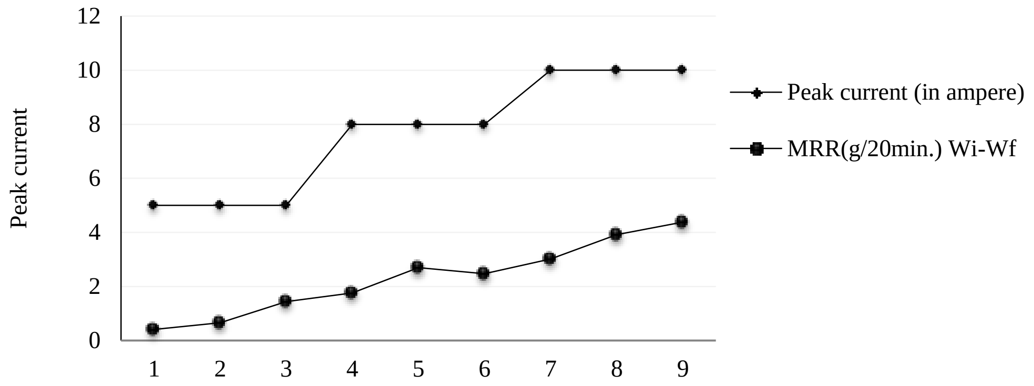

Figure 2. Reaction of peak current to MRR.

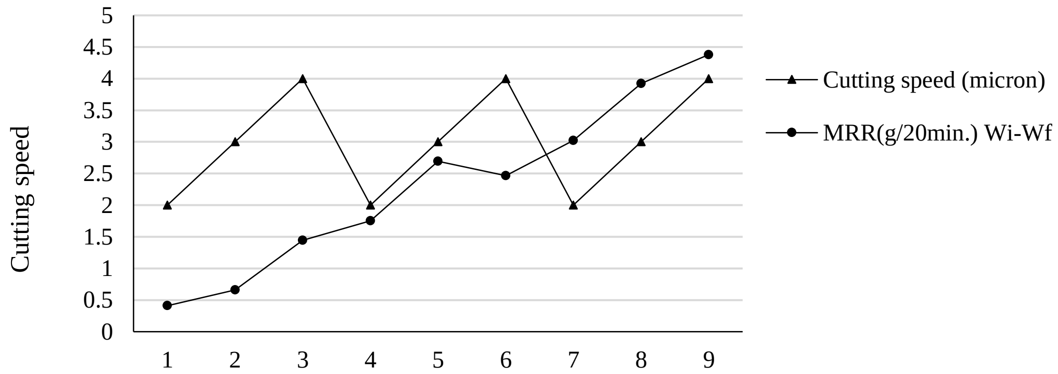

Figure 3. Effect of cutting speed on MRR.

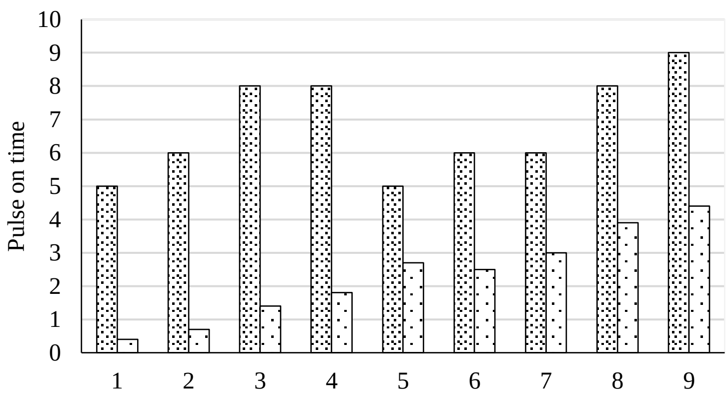

Figure 4. Pulse off time's impact on MRR.

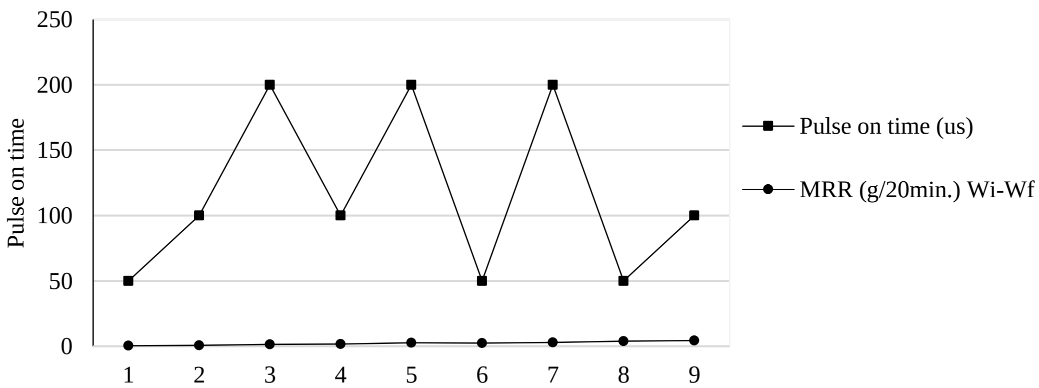

Figure 5. Impact of pulse timing on MRR.

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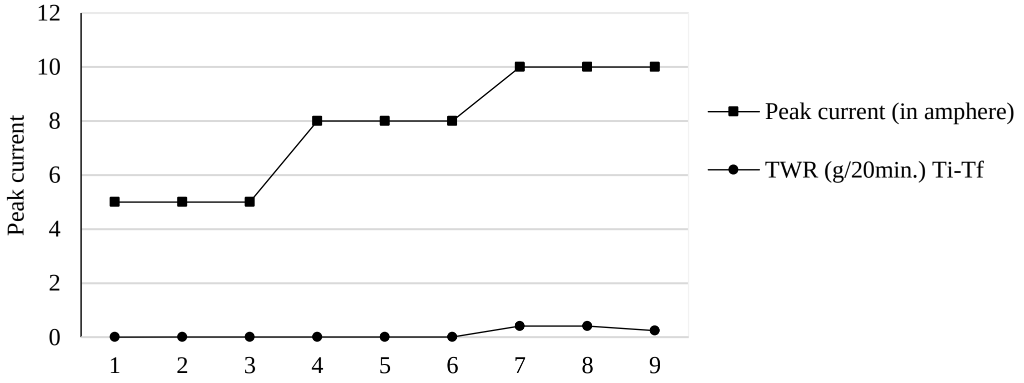

Figure 6. Impact of peak current on TWR..

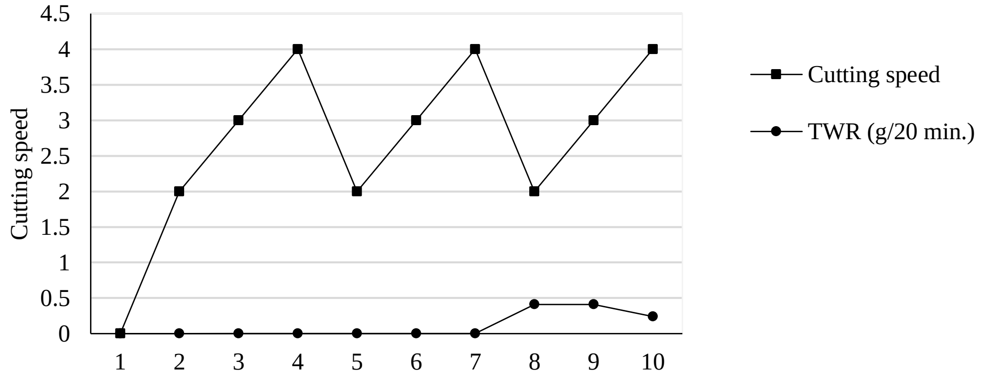

Figure 7. Effect of cutting speed on TWR

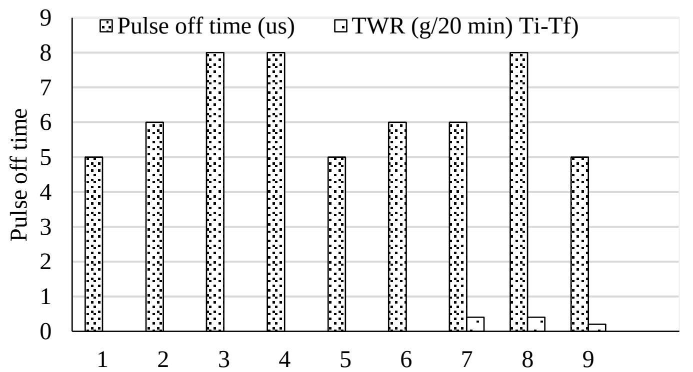

Figure 8. Pulse off time's impact on TWR.

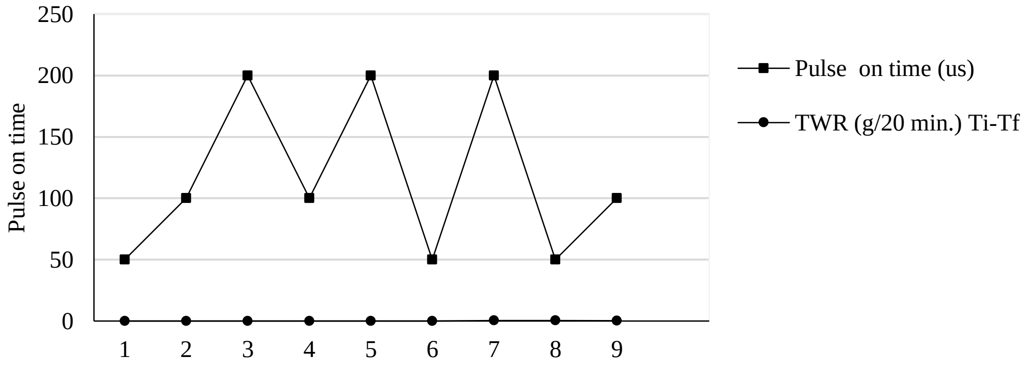

Figure 9. Impact of pulse timing on TWR.

When Cast Iron was used during observation, it was found that even when the current was constant, the MRR appeared to be increasing, as shown in Figure 10.It was observed from Figure 11, that at experiments no.8 MRR decreases. It was also found that even when the cutting speed is increased, then MRR also increases.

While keeping the pulse off time constant as shown in Figure 12, it was discovered that MRR seemed to be growing throughout observation. Results also shown in Figure 13, that MRR is very near to constant, regardless of how the pulse on time changes.

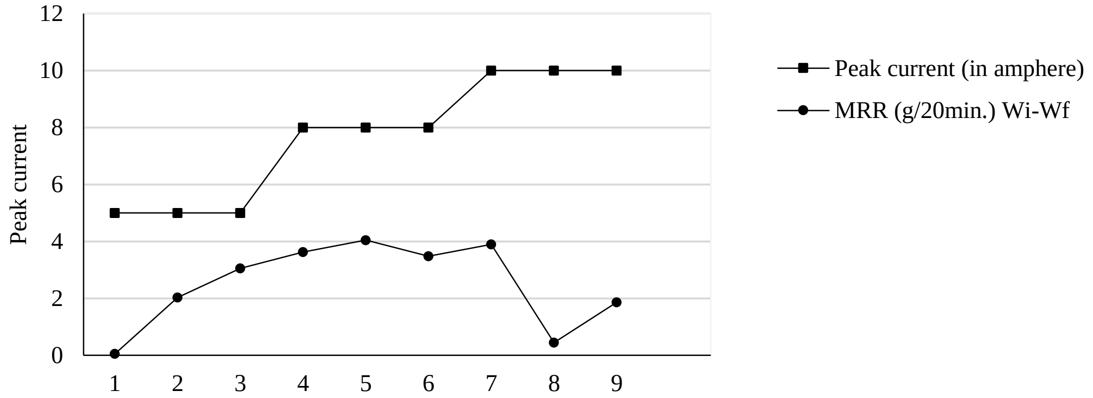

Figure 10. The impact of peak current on MRR

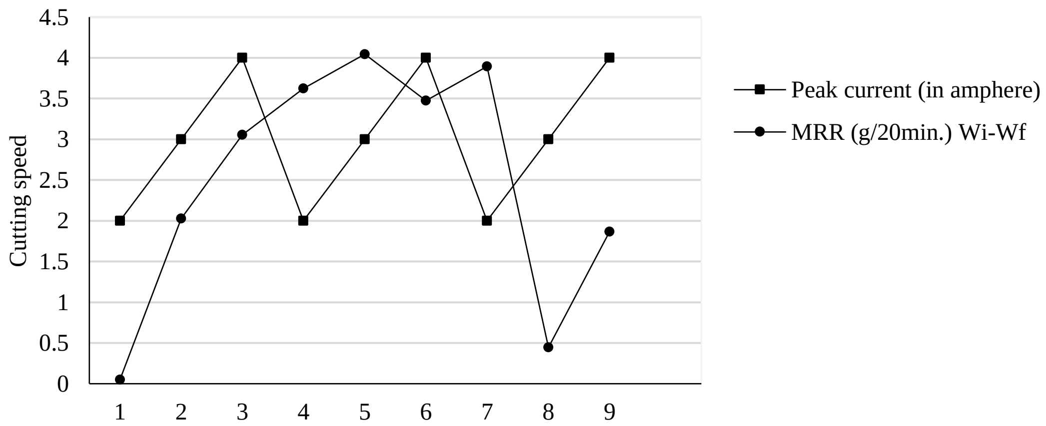

Figure 11. Effect of cutting speed on MRR

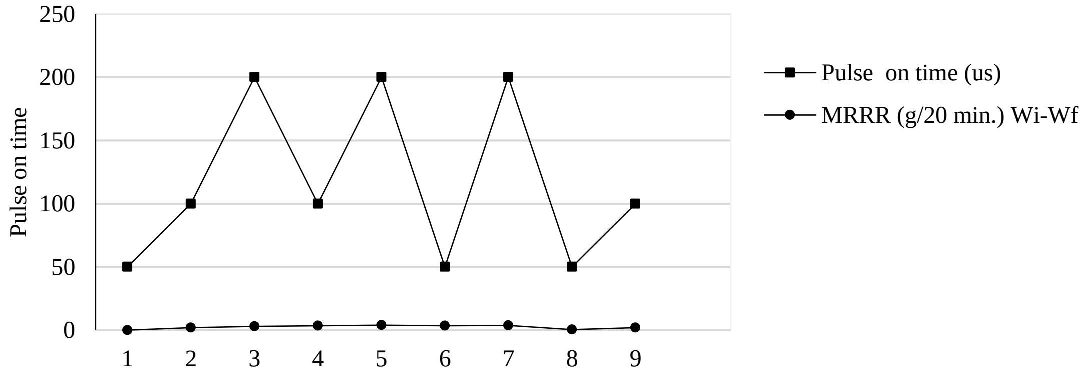

Figure 12. Impact of pulse timing on MRR.

When Cast Iron was used, it was observed that at current 5 to 8 amp, tool wear rate was negligible and at 10amp. TWR starts increasing, as shown in Figure 14 and 15.

From above Figure.16 and 17 it was observed that TWR is minimum at 8 µs Toff and 200µs Ton

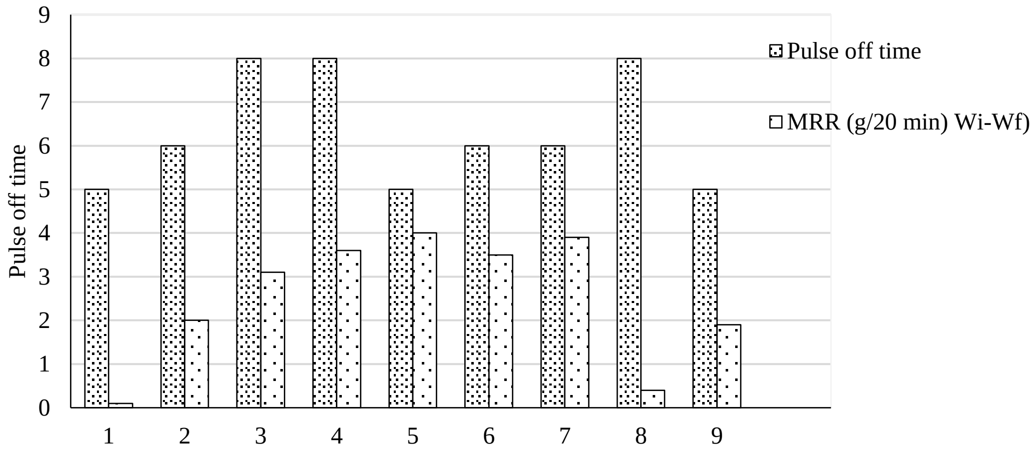

Figure 13: Pulse off time's impact on MRR.

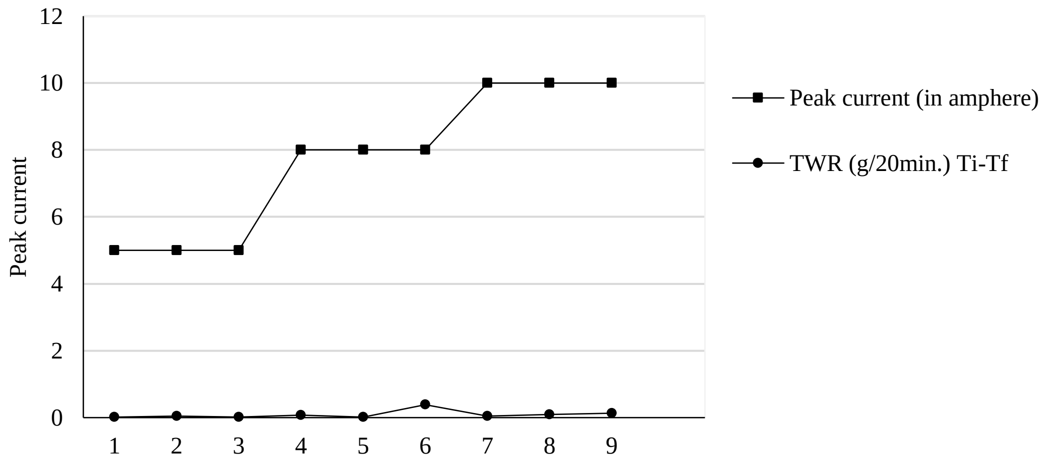

Figure 14. Impact of peak current on TWR.

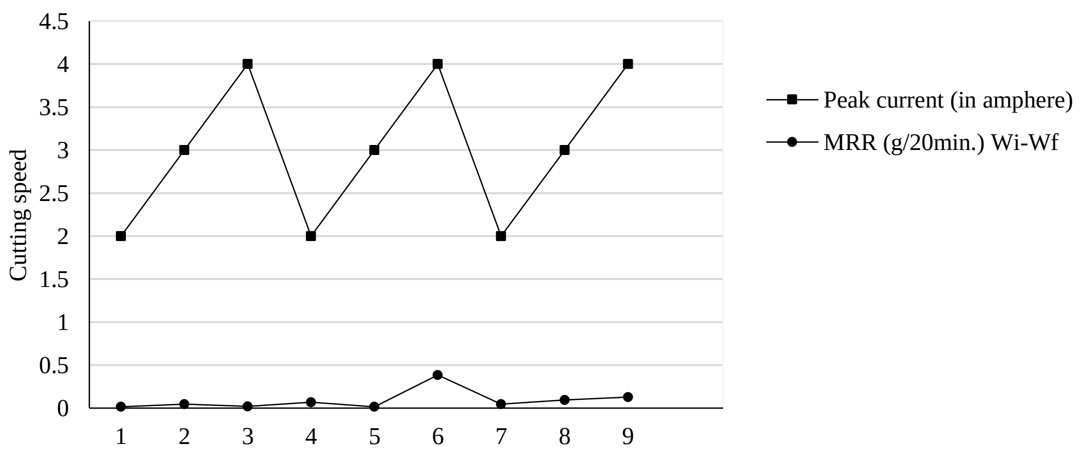

Figure 15. Effect of cutting speed on TWR.

During observation, it was found that from experiments s.n.1 to 6 the tool wear rate is minimum i.e..003 while MRR is increasing as shown in Figure 18. From above Figure.19, it was observed that at experiment no.5 MRR was maximum 4.045g and TWR was minimum0.015g

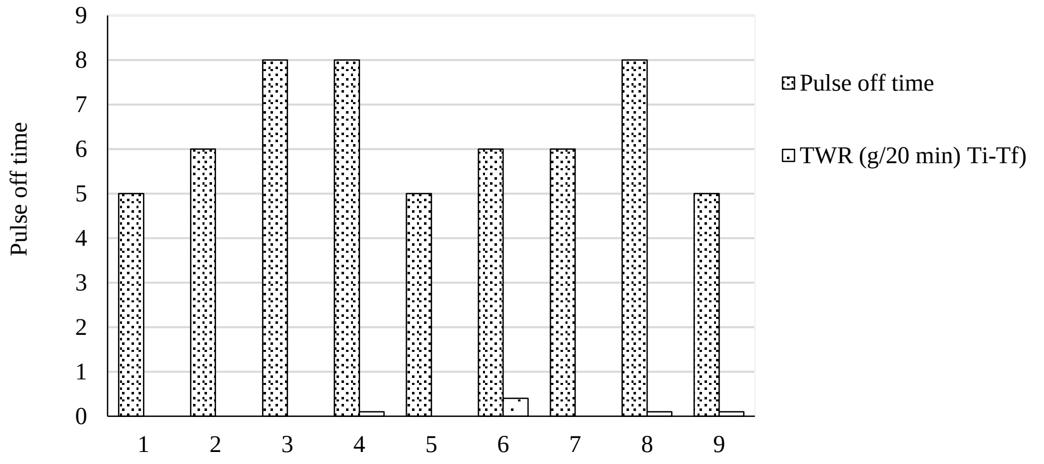

Figure 16. Pulse off time's impact on TWR.

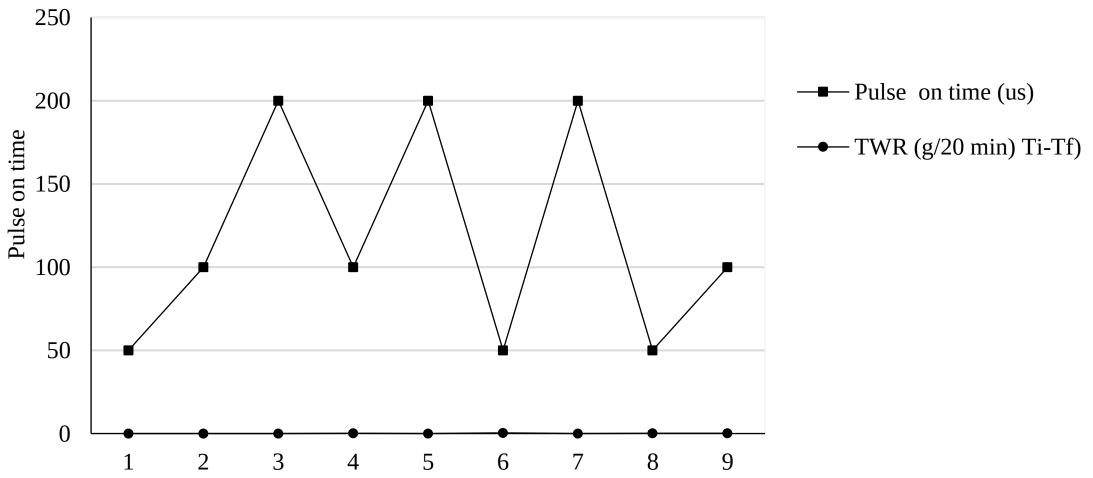

Figure 17. Pulse time effect on TWR.

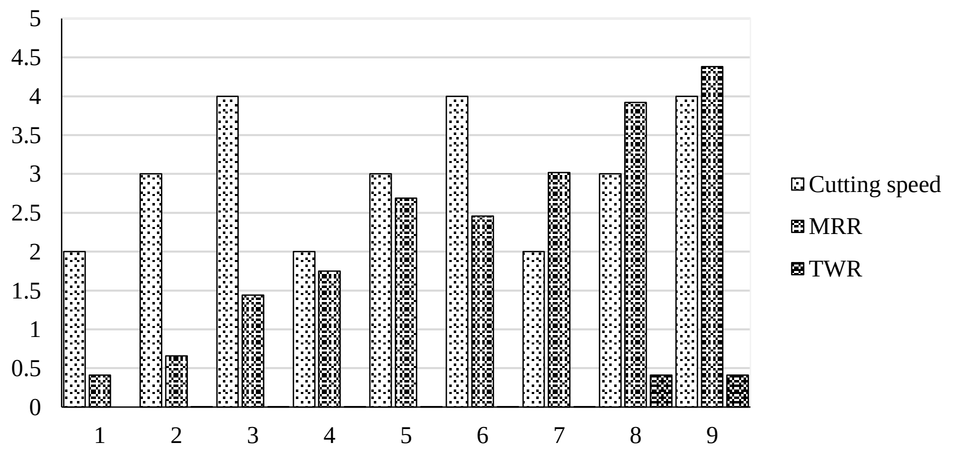

Figure 18. Cutting speed's impact on MRR and TWR for MS.

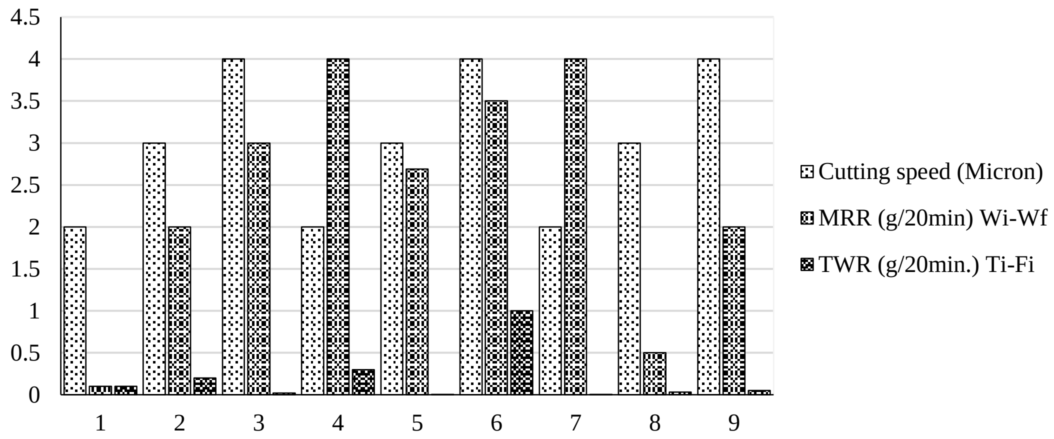

Figure 19. Cutting speed's impact on MRR and TWR for cast iron.

Figure 20. Machined specimens of the MS and cast iron and copper tool.

Scope of the experiment

The dies and molds of various manufacturing processes like injection molding and die casting are made of Mild steel and Cast iron ,having sharp internal corners and complex cavities .Many other parts are made of mild steel used in aerospace and medical fields. Similarly various automotive parts and pump housings are made of cast iron. Machining of above parts is very difficult by conventional machining technique. EDM can machine mild steel and cast iron having complex shapes can drill deep hole etc.

CONCLUSION

The machining of workpieces made of cast iron and mild steel are assessed in this experiment. In this experimental study, peak current, cutting speed, pulse-on time, and pulse-off time were found to have a significant impact on materials removal rate and tool wear rate. These results allow us to derive the following conclusions:

When Material was Mild steel and copper as tool

1. Raising the cutting speed results in a higher material removal rate (MRR). If the peak current stays the same, MRR goes up as well.
2. With a constant pulse-off time, MRR displays a rising tendency. Nevertheless, MRR stays rather consistent even when the pulse-on time changes.
3. As the peak current rises, tool wear also rises.
4. Peak currents of 5A and 8A produced the lowest tool wear rates, ranging from 0.001 to 0.003 g.

For Cast Iron with Copper as the Tool

1. When the current remains constant, MRR increases. Initially, MRR rises with increasing cutting speed but later fluctuates as the cutting speed continues to increase.

2. The highest MRR value of 4.045 g/20 min was recorded at level 2 for current and cutting speed, level 3 for pulse-on time, and level 1 for pulse-off time.
3. Tool wear rate (TWR) initially fluctuates at a constant current and then increases with a further constant current.

The maximum mechanical resistance attained for both Mild Steel and Cast Iron was 2.695 g and 4.045 g, respectively, when the following parameters were used: 8A current, 3 micron cutting speed, 200 µs pulse-on duration, and 5 µs pulse-off time. Simultaneously, TWR was the lowest, measuring 0.003 g for Mild Steel and 0.015 g for Cast Iron.

The present experiment focuses on four factors with three level per factor in L9 array. While it explored the dominant factor which significantly influence the TWR and MRR, the higher level can also be chosen for more accuracy. Optimal settings across additional materials, electrode geometries, and dielectrics to strengthen generality can be optimized in future.

Declaration of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

REFERENCES

1. Choudhary SK, Jadoun R. Current advanced research development of electric discharge machining (EDM): a review IJRAT.2014;2(3):273–97p.
2. Yang RT, Tzeng CJ, Yang YK,et al. Optimization of wire electrical discharge machining process parameters for cutting tungsten. Int.J.Adv.Manuf.Technol.2012;60:135–47p.
3. Jeevamalar J, Ramabalan S, Sivashanmugam N. Influence of EDM process parameters on material removal rate. Int.J.Appl.Eng.Res. 2015;10:14041–51p.
4. Gaikwad V, Jatti VS. Optimization of material removal rate during electrical discharge machining of cryo-treated NiTi alloys using Taguchi's method. J. King Saud Uni.Eng.Sc. 2018;30:266–72p.
5. Kishan B, SudheerPremkumar B, Gajanana S,et al. Development of regression model for Al6061+ SiC tool and optimization of process parameters on electro discharge machining. J. Phys. Conf.Ser.2020;1455(1); 1–10p.
6. Khan MY, Rao PS. Optimization of process parameters of electrical discharge machining process for performance improvement. IJITEE 2019;8(11):3830–36p.
7. Vagile RC,Agarwal P, Singh P et al.A Review on Electrical Discharge Machining Tool. EUSRM .2023 ; 15 (7);1–5p
8. Kumar MR, Krishnaiah A, Kalva RS. Experimental study on micro machining of SS304 by using electric discharge machining. Materials Today: Proceedings. 2018;5:27269–76p.
9. Pandey A, Singh S. Current research trends in variants of Electrical Discharge Machining: A review. Int.J. Eng. Sci.Technol. 2010;2(6):2172–91p.
10. Ho K, Newman S.T.State of the art electrical discharge machining (EDM). Int. J.Mach. Tools Manuf. 2003;43:1287–300p.
11. Kuppan P, Rajadurai A, Narayanan S. Influence of EDM process parameters in deep hole drilling of Inconel 718. Int.J. Adv.Manuf.Technol. 2008;38:74–84p.
12. Aharwal K, Sitaram,Krishna C. Optimization of material removal rate and surface roughness in EDM machining of metal matrix composite using genetic algorithm. Materials Today: Proceedings. 2018;5(2):5391–7p.
13. Vats N, Nandal R, Dhuhan R. Multiple-Performance Optimization of Wire EDM Parameters for HDS H13 BY Using Taguchi Method.IJRASET.2021;9(12);2291–94p.
14. Sahani OP, Kumar R, Vashista M. Effect of electro discharge machining process parameters on material removal rate. JBAER. 2014;1(2):17–20p.
15. Chandramouli S. Shrinivas B U and Eswarraiah K.Optimization of Electrical Discharge Machining Process Parameters Using Taguchi Method .IJAME. 2014 ;4(4);425–34p

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

16. Mahajan R, Krishna,H, Singh AK et al. A Review on Copper and its alloys used as electrode in EDM IOP Conf. Ser. ;Mater. Sci. Eng.2018;377;1–11p.
17. Ndaliman MB, Khan AA, Ali MY. Influence of dielectric fluids on surface properties of electrical discharge machined titanium alloy. Proc I MechE Part B J Engineering Manufacture. 2013;227(9):1310–16p.
18. Kumar S S, Varol T, Canakci A et al. A review on the performance of the materials by surface modification through EDM. Int. J. Lightweight Mater Manuf ,2021;4(1); 127–44p.
19. Dadge M S,Ranganath M S,Vipin A Detailed Review of Input and Output Parameters of EDM. IJNIET.2019;11(1);48–64p.
20. Torres A, Luis C, Puertas I. Analysis of the influence of EDM parameters on surface finish, material removal rate, and electrode wear of an INCONEL 600 alloy. Int. J. Adv. Manuf. Technol. 2015;80:123–40p.
21. Sapkal SU, Jagtap PS. Optimization of micro EDM drilling process parameters for titanium alloy by rotating electrode. Procedia Manufacturing. 2018;20:119–26p.
22. Das MK, Kumar K, Barman TK,et al.Optimization of surface roughness and MRR in EDM using WPCA. Procedia Engineering. 2013;64:446–55p.

