IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

EXPERIMENTAL INVESTIGATION AND OPTIMISATION IN EDM PROCESS OF AISI P20 TOOL STEEL

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Abstract: Among recently developed non-conventional machining techniques, Electro Discharge Machining (EDM) is one of the most widely used methods for "hard to machine" materials such as heat-treated tool steel and other "hard-to-machine" materials, such as ceramics and hastelloy, nitralloy, nemonic alloys, carbides, and heat-resistant steels. To remove electrode material, EDM uses high-frequency sparks between the tool and the workpiece. The EDM process's material removal rate (MRR), tool wear rate (TWR), and surface integrity are three of its most important performance metrics. The goal of EDM is to produce a machined component with an excellent surface quality while also achieving a high MRR. Machining parameter settings that yield the highest MRR are directly related to surface area, which has become an essential problem in the approaching widespread use of AISI P20 in the manufacturing industry. To make injection molding tools, the tooling industry uses AISI P20 steel. Because of their higher strength and hardness, these steels are classified as "difficult to process." materials. Because of this, standard and non-traditional machining of AISI P20 steel is known to provide significant difficulties.

As a result of these considerations, an experiment was conducted to examine the EDM surface's productivity, quality, surface integrity, and accuracy. Working with an AISI P20 steel work-piece and copper electrode, the research was conducted. Discharge current (I_p), time on pulse (T_{on}), time off pulse (T_{off}), time up lift (T_{up}), and time on work (T_w) are just a few of the important machining characteristics that will be examined. MRR, TWR, Surface Roughness (SR), Micro hardness (MH), and the influence of machining settings on these responses were studied.

1. INTRODUCTION

1.1 Overview on EDM

Electrical Discharge Machining (EDM) is a non-traditional machining technique that generates controlled sparks between an electrode and a workpiece using electrically conductive materials and dielectric fluid. Thermoelectric energy sources can be used to manufacture materials with limited machinability and perform extremely challenging intrinsic-extrinsic-shaped operations. EDM can mill any electrically conductive material, regardless of its hardness, which is a major advantage. Since the electrode and the workpiece never make direct contact during machining, EDM reduces or eliminates mechanical stresses, chatter, and vibration (the inter electrode gap is maintained throughout the operation). We will just be discussing die-Sinking (also known as Ram) type EDM machines here, however there are several input parameters that may be varied widely in this process, which affects the EDM performance characteristics. Traditional machining techniques have been replaced by EDM, which is now a well-established machining alternative in a wide range of industrial industries worldwide. EDM, created in the late 1940s, has become a typical industrial method across the world. Sir Joseph Priestley, an English scientist, discovered the origins of EDM techniques. For almost a century, there was no purpose for it. Over the previous half-century, this type of machining has increased in popularity at an exponential rate.

1.2 Types of EDM

Basically, there are three different types of EDM

1. Die Sinking EDM
2. Micro Electro Discharge Machining (MEDM)
3. Wire Electro Discharge Machining (WEDM)

1.3 Equipments of EDM

- Dielectric system:
- Electrode:
- Servo System:
- Power Supply

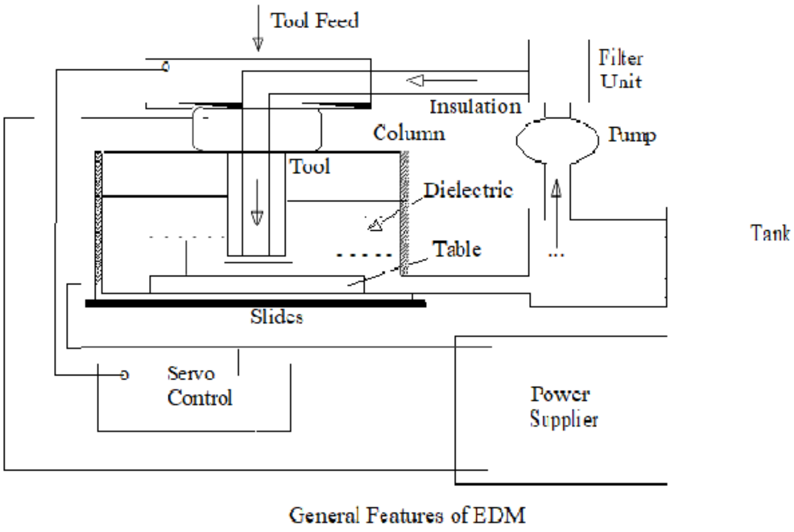


Fig. 1.1: Schematic of an electric discharge machining machine

1.4 Objectives of the Proposed Study

The objectives of the study are as follows:

i. To assess the Electro Discharge Machining (EDM) behaviour of AISI P20 tool steel as work-piece and copper as electrodes.

ii. To analysed against the variation of some of the most important EDM parameters namely, current (Ip), pulse on-time (T_{on}), lift time (T_{up}), flushing pressure (Fp), work time (T_w), Inter Electrode Gap (IEG) that influence the process performance.

iii. To measure the technological outputs such as Material Removal Rate (MRR), Tool Wear Rate (TWR), Surface Roughness (SR), micro-hardness.

2. MICRO-HARDNESS STUDY ON AISI P20 STEEL USING TAGUCHI METHOD

2.1 Introduction

The goal of this research was to improve the process' surface hardness. A substance's micro-hardness is an essential factor in determining its material's strength. The material's crystal structure is primarily responsible for this feature. An Electro Discharge Machining (EDM)-produced steel item is typically hardened to a high degree in a region spanning the recast layer and the martensitic Heat Affective Zone (HAZ). As a result of this hard zone, the base material's hardness may gradually increase until it reaches the same level as that of pre-hardened steel. The higher quantity of dendritic cementite formed as a consequence of carbon absorption from oil dielectric pyrolysis is the main cause of the material's high hardness (Bleysetal.2006).

A variety of businesses have used the Taguchi technique for many years to boost the efficiency of their goods and processes. Using this technology, firms may make high-quality items in a shorter amount of time and at a lesser price. As described by Tong et al. (2007), the Taguchi method is an experimental technique that employs an orthogonal array to conduct experiments and employs the Signal-to-Noise (S/N) ratio as the quality measurement index, to optimise only one response, meaning that parametric settings can be optimised with respect to only one performance characteristic. In order to find the most cost-effective answer to the product design specification, it is preferable to combine or establish quality improvement factor levels that best meet the needs of the client.

A variety of input parameters were tested concurrently on AISI P20 and the hardness values corresponding to those results were recorded. Performance metrics are reported to be strongly influenced by the kind of material used. Taguchi analysis is proposed in this study as a method for determining EDM parameter design for a single quality characteristic, namely micro-hardness.

2.2 Experimental equipment and design

Using an Electronica Electraplus PS 50ZNC die-sinking EDM machine and EDM oil (specific gravity =0.763, flash point =94°C), this experiment was carried out. An example of the experimental setup is shown Fig. 2.1 Semicircular in shape (100 mm in diameter and 10 mm thick), it was made of AISI P20 tool steel, which has "the composition and attributes of AISI P20 work-piece materials Table 2.1 and Table 2.2 respectively."

As indicated in Table 2.3 the micro-hardness of an EDM process may be affected by four process parameters: current (Ip), pulse on time (Ton) lift time (Tup), flushing pressure (Fp), and fixed parameters including duty cycle (τ), voltage (V), and polarity (p).

Fig. 2.1: Die Sinker EDM, Brand : Electronica Elektra Plus; Model : PS 50ZNC

Table 2.1 Chemical Composition of AISI P20

C	Mn	Si	Cr	Mo	Cu	P	S
0.28-0.40	0.60-1.00	0.20-0.80	1.40-2.00	0.30-0.55	0.25	0.03	0.03

Table 2.2 Mechanical Properties of Workpiece Material

Temperature T(˚C)	Density (kg/m^3)	Poison's ratio ν	modulus of elasticity E(GPA)
25	7.85	0.27-0.30	190-210

As indicated in Table 2.3, the micro-hardness of an EDM process may be affected by four process parameters: current (Ip), pulse on time (Ton) lift time (Tup), flushing pressure (Fp), and fixed parameters including duty cycle (τ), voltage (V), and polarity (p).

Table 2.3 Control parameters and their levels

Control Parameter				
Parameter	Level			Unit
	1	2	3	
Discharge current (Ip)	2	5	8	A
Pulse on Time (T_{on})	100	300	500	μs
Lift Time (T_{up})	0	0.7	1.4	s
Flushing Pressure (Fp)	0.2	0.4		kgf/cm^2
Fixed Parameter				
Duty Cycle (τ)		90		%
Voltage (V)		45		V
polarity (p)		+ve		

Micro-hardness was measured in a variety of ways, and the results are shown in Table 2.4. Using a Vickers indenter, a hardness tester was utilised to take micro hardness depth profile measurements. Using 200g and a loading duration of 15s, the indenter was pressed into the work piece under test at an angle of 136 degrees. Because of this, the linear value (d) of the impression illustrated in Fig. 2.2 has been calculated. At a 400X magnification, an optical microscope was used to accurately quantify the indentation diagonals' lengths. Equation 2.1 defines the hardness number (HV) as the load applied to the indenter/sample contact area

$$HV = P/V \qquad 2.1$$

Fig. 2.2: Vickers test scheme

2.3 Results and discussions

The primary effect shows an increase in Vickers hardness with a rise in Ip. More carbon particles were formed on the machined surface when Ip was raised, increasing its hardness as a result of the resolidified layer's fast cooling and subsequent rise in heat production (Krishna Mohana Rao et al., 2008). Whereas, as the pulse on-time and current grow, the dielectric fluid cracks more often, resulting to bigger and deeper craters on the surface of the workpiece, the hardness value decreases as Ton increases. Craters, debris, micro-cracks and arches increased, causing the micro-hardness of the surface to decrease, leading to a decrease in the overall surface rough. Tup and Fp have little impact on the hardness.

Table 2.4 Experimental Layout

Run	Fp	Ip	T_{on}	T_{up}	Micro Hardness (HV)			Avg. (HV)
					1st	2nd	3rd	
1	0.2	2	100	0.0	215	221	212	216
2	0.2	2	300	0.7	221	213	199	211
3	0.2	2	500	1.4	173	160	165	166
4	0.2	5	100	0.0	232	218	228	226
5	0.2	5	300	0.7	216	236	229	227
6	0.2	5	500	1.4	177	186	198	187
7	0.2	8	100	0.7	232	242	252	242
8	0.2	8	300	1.4	240	231	246	239
9	0.2	8	500	0.0	219	232	227	226
10	0.4	2	100	1.4	209	221	227	219
11	0.4	2	300	0.0	196	207	212	205
12	0.4	2	500	0.7	168	175	185	176
13	0.4	5	100	0.7	229	242	234	235
14	0.4	5	300	1.4	227	219	238	228
15	0.4	5	500	0.0	181	207	197	195
16	0.4	8	100	1.4	254	243	262	253
17	0.4	8	300	0.0	232	242	255	243
18	0.4	8	500	0.7	229	218	210	219

2.4 CONCLUSIONS

The following are the results of the impact of EDM parameters on machined surface hardness.

1. The EDM technique in AISI P20 steel results in a ridged surface and surface layer machining damage, which increases the micro-hardness.
2. The Vickers micro-hardness value increased when Ip was raised.
3. Ton enhanced the micro-hardness.
4. The input variables Fp and Tup had no effect on hardness.
5. Fp1, Ip1, Ton3, Tup3 were found to be the ideal conditions.

3. OPTIMIZATION OF MULTIPLE QUALITY CHARACTERISTICS BASED ON FUZZY TOPSIS

3.1 INTRODUCTION

Globalization and rapid technical improvement have heightened the level of competition in today's industry. Product quality and productivity are both critical to any manufacturing or production unit's success in meeting the needs and expectations of its customers in an economically viable manner. In situations when many responses need to be improved concurrently, the use of a single-objective optimization approach might be a problem. A multi-objective optimization strategy should be investigated in order to reduce costs while also increasing output.

The fuzzy-TOPSIS fuzzy multi-criteria decision making approach is utilised in this work to analyse the relative importance of each criterion and the relative weight of alternatives. The Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS) are used to determine the order in which alternatives should be considered (FNIS). This method has been criticized because it fails to take into account uncertainty. Fuzzy logic, on the other hand, is able to represent uncertainty. A highly useful notion for dealing with circumstances that are excessively complicated or poorly defined is the use of linguistic variables instead of typical quantitative expressions.

Flexibility, product quality, increased responsiveness to market demand, and inventory reduction can't be quantified using crisp values or random procedures. Linguistic variables and fuzzy numbers are a good alternative. Fuzzy numbers are used in conjunction with membership functions to convey ambiguous values. Fuzzy-TOPSIS is one of the most widely used techniques for objective and systematic assessment of answers to numerous criteria. Based on distances from the FPIS and FNIS, TOPSIS allocates the best options from a pool of possible alternatives. On one hand, there is FPIS, which is made up of solutions that maximize benefits while minimizing costs, and there is FNIS, which is made up of solutions that maximize both costs and benefits at the expense of one another.

In the last several years, a variety of Fuzzy-TOPSIS based methodologies and applications have emerged. Electro Discharge Machining literature shows that the fuzzy TOPSIS approach has gotten little attention (EDM). In this chapter, we aim to create a mathematical model of the EDM process's Material Removal Rate (MRR), Tool Wear Rate (TWR), and Surface Roughness (SR) using the fuzzy-based Taguchi approach and to simultaneously optimise these multi-response process characteristics

3.2 EQUIPMENT AND EXPERIMENTAL DESIGN

Using a die-sinking EDM machine, an EDM fluid (specific gravity =0.763, freezing point=94(°C)) as dielectrics and copper tool electrode of 12 mm diameter were tested. The AISI P20 tool steel was chosen for the project because of its semicircular shape (100 mm diameter and 10 mm thickness). The machining time for each trial run was 60 minutes. The influence of five process factors on the EDM process's MRR, TWR, and SR performance characteristics were studied using the data in Table 3.1. Specifically, the effects of current (Ip), pulse-on-time, lift time, work time, and inter electrode gap were all evaluated in this experiment. The duty cycle (ʈ), voltage (V), flushing pressure (Fp), and polarity (P) are also constants.

Fig. 3.1: Copper electrode and AISI P20 work-piece

Weight loss technique was used to determine MRR and TWR using Equation 3.1 and 3.2.

Using a precision balance, how the weight of the work piece and tool was determined in Fig.3.2.

$$\mathrm{MRR}= \frac{W_b - W_a}{(t \times \rho_w)} \tag{3.1}$$

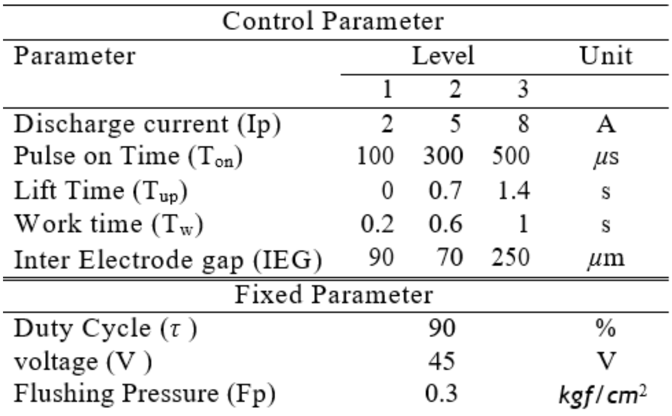
$$\mathrm{TWR} = \frac{T_b - T_a}{(t \times \rho_t)} \tag{3.2}$$

Fig. 3.2: Electronic Balance

Work-piece weights before and after machining, as well as the amount of time it takes to process each component, are shown in Wb, Wa, and tm and ρ_w is the density of work-piece (7.85 g/cm3). Tool Weights before and after machining, as well as the amount of time it takes to process each component T_b and T_a and t_m and ρ_t is the density of tool (8.92 g/cm3). The tool is dense enough that it can be machined in less than a minute. As shown in Fig 3.3 Talysurf (Model: Taylor Hobson, Surtronic 3+) was used to measure SR utilizing a Ln=4mm sample length; Lc=0.8 mm cut-off length; and 2CR ISO filters. MRR, TWR, SR, and three additional performance indicators were studied as a result of four process factors: current (Ip), time to the first pulse (Ton), lift time (Tup), and flushing pressure (Fp).

Fig. 3.3: Talysurf Surface Analyser

Table 3.1: Control Parameters and their levels with unit



Control Parameter				
Parameter	Level			Unit
	1	2	3	
Discharge current (Ip)	2	5	8	A
Pulse on Time (T_{on})	100	300	500	μs
Lift Time (T_{up})	0	0.7	1.4	s
Work time (T_w)	0.2	0.6	1	s
Inter Electrode gap (IEG)	90	70	250	μm
Fixed Parameter				
Duty Cycle (τ)		90		%
voltage (V)		45		V
Flushing Pressure (Fp)		0.3		kgf/cm^2

Table 3.2: Experimental result with final output

Run	Ip	Ton	Tup	Tw	IEG	r_{ij}			CCI
	A	μs	s	s	μm	MRR	TWR	SR	
1	1	1	1	1	1	0.084	0.075	0.137	0.347
2	1	1	1	1	2	0.087	0.131	0.133	0.329
3	1	1	1	1	3	0.083	0.142	0.127	0.323
4	1	2	2	2	1	0.027	0.056	0.096	0.324
5	1	2	2	2	2	0.029	0.093	0.085	0.317
6	1	2	2	2	3	0.028	0.131	0.081	0.304
7	1	3	3	3	1	0.014	0.112	0.060	0.314
8	1	3	3	3	2	0.013	0.020	0.067	0.340
9	1	3	3	3	3	0.015	0.112	0.063	0.313
10	2	1	2	3	1	0.058	0.142	0.165	0.279
11	2	1	2	3	2	0.071	0.206	0.189	0.250
12	2	1	2	3	3	0.067	0.261	0.181	0.224
13	2	2	3	1	1	0.021	0.093	0.168	0.274
14	2	2	3	1	2	0.023	0.085	0.172	0.279
15	2	2	3	1	3	0.019	0.120	0.207	0.245
16	2	3	1	2	1	0.131	0.070	0.075	0.429
17	2	3	1	2	2	0.139	0.122	0.088	0.419
18	2	3	1	2	3	0.115	0.031	0.098	0.413
19	3	1	3	2	1	0.179	0.316	0.253	0.359
20	3	1	3	2	2	0.164	0.393	0.249	0.315
21	3	1	3	2	3	0.167	0.419	0.271	0.310
22	3	2	1	3	1	0.432	0.318	0.306	0.686
23	3	2	1	3	2	0.425	0.261	0.290	0.709
24	3	2	1	3	3	0.442	0.291	0.278	0.714
25	3	3	2	1	1	0.301	0.159	0.268	0.612
26	3	3	2	1	2	0.283	0.056	0.282	0.601
27	3	3	2	1	3	0.302	0.093	0.296	0.616

3.3 RESULTS AND DISCUSSIONS

CCI values are used to identify the most effective set of machining settings.. Ip=8A (level 3), Ton=500 s (3rd level), Tup=0 s (1st level), Tw=1 s (3rd level), and IEG =90 µm are the ideal parameters for EDM machining.

3.4 CONCLUSIONS

a. Ip=8A, Ton=500µs, Tup=0s, Tw=1s, and IEG=90µm were shown to be the best process conditions for increased MRR and lower TWR/SR.

b. IEG is able to endure alterations in the preferences of DMs.

4. CONCLUSION

This study examined the behavior of Electro Discharge Machining using an AISI P20 tool steel work piece and copper electrodes (EDM). Key process factors such as current (Ip), pulse on-time (Ton), lift and flush pressure (Fp), work and the Inter Electrode Gap were examined in the EDM experiment findings. All of these parameters have a substantial influence on the process efficiency. In terms of technical outcomes, MRR, TWR, SR, and micro-hardness were all measured. Specifically, here are some of the most important findings from the research:

4.1 MOST IMPORTANT CONCLUSIONS

4.1.1 Taguchi analysis for Micro hardness

Micro-hardness value rise with increasing Ip and dropped with rising Ton.
- It was discovered that Fp1, Ip1, Ton3, and Tup3 were the most ideal conditions.

4.1.2 Fuzzy TOPSIS modelling for MRR, TWR and SR

- The ideal process conditions for the best MRR and the lowest TWR and SR were Ip= 8A, Ton= 500s, Tup= 0s, Tw= 1μs, and IEG= 90μm.

- In order to determine how the weighing criteria influenced decision-making, it was conducted. The optimal parameter values were chosen by 55.56 % of the people.

4.2 Scope for future work

- It is possible to assess the surface integrity of EDM-cut metal (for example, roughness, micro hardness, residual stress distribution and white layer thickness) in relation to steel type (hardenable or non-hardenable).
- WLT, SCD, MRR and TWR are all feasible to model using the finite element technique (FEM).
- All of these responses may be multi-objective optimized using various types of electrode materials.

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