Machining Parameter Effects on MRR and SR for Monel 400 Material: A Taguchi Method Investigation

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Abstract

EDM (electro diffraction machining) is a standard procedure for producing finished products (EDM). When utilizing EDM, high-frequency sparks are used to remove electrode material from a work piece submerged in dielectric. the MRR is a critical indicator for the effectiveness of the EDM process (MRR). Work piece electrode surface size affects the machining settings that generate the optimum MRR the most. Monel 400's potential uses need a thorough investigation of the machining process. An overview of Taguchi optimization for EDM & SR on Monel 400 is provided in this study in order to enhance the process parameters. Work piece thickness has been established as the controlling element. During the machining process, surface roughness and material removal rate are crucial. The Design of Experiment (DOE) is made easier with the aid of Taguchi's L9 Orthogonal Array (OA). MRR and SR analyses used input characteristics such as pulse-on (T-ON), pulse-off (T-OFF), and current (I) to analyze process performance. Achieving maximum Material Removal Rate and minimum Surface Roughness is the ultimate goal of optimizing (SR).

Keywords - Taguchi method, EDM, Monel 400, MRR, SR,
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INTRODUCTION

This study uses process parameter optimization to perform a variety of mechanical tasks using EDM. High-performance alloy materials are in greater demand as the mechanical sector grows. An electrical charge is used to create a spark, and this thermal energy is the major source of material removal in electro discharge machining (EDM). EDM is primarily used to manufacture alloys with high strength and temperature resistance as well as difficult-to-process materials. EDM can be utilised for job-shop machining of complex geometries in small batches. The work piece material for EDM machining must be electrically conductive. The Taguchi approach is utilised to create the best output possible.

Working Principle of EDM

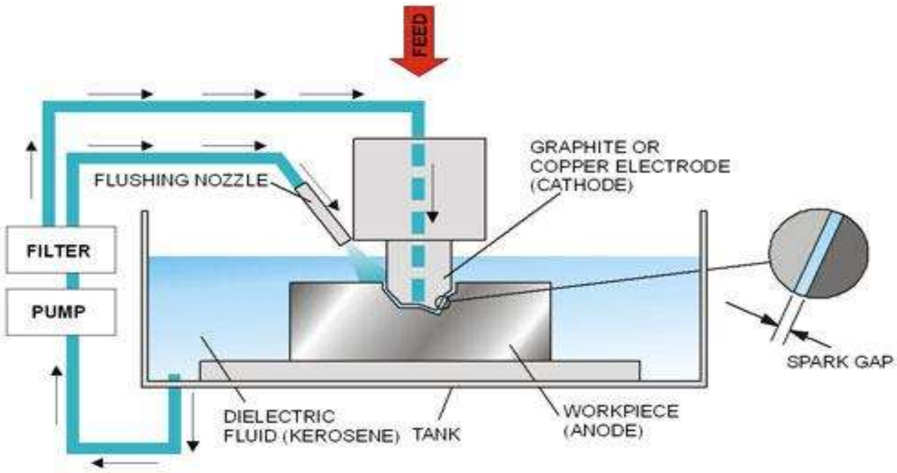

Fig 1: Working principle of EDM

When the anode and cathode have a voltage differential, cold electron emission begins. When a dielectric fluid particle comes into contact with one of these liberated electrons, it breaks down. These released electrons, after being further divided into electrons and ions, create a plasma channel In the vicinity of a sparking zone, objects are quickly melted and evaporated by intense heat. Work pieces and tools may be submerged in dielectric fluid to increase efficiency. When both electrodes are composed of the same material, deterioration of the positive electrode occurs more rapidly, according to a new research Typically, anodes are included within the work item itself to prevent this issue. To avoid sparking, a "spark gap" must be left between the tool and the work piece.Continual removal of material by the traveling spark causes the tool and its form to change with each new spark.

LITERATURE REVIEW

[1] Engineering design projects have required a lot of time and effort to discover the best parametric parameters. Effectiveness in EDM operations depends on a variety of factors such as metal removal rate and surface roughness, kerf size, and degree of dimensional error.

[2] WEDM (spark erosion) is a new machining technology for cutting hard and conductive materials using a wire electrode that optimizes process parameters as the machining progresses. Fastness and roughness of metal removal will be discussed in this section. Using an ANOVA table to show how to optimize a process parameter may improve surface roughness. [3] Increases in discharge energy and impulse lead to a rougher surface and thicker layer. This has been shown time and time again by many studies. Even when plasma arc growth is taken into account, pulse length and current have an effect on MRR and surface roughness. [5] Research has been done on the concept of least squares to predict the peak current level, pulse-on time, and pulse-off time for EDM input parameters such that material removal rate and surface roughness may be fulfilled simultaneously (SR). [6] It has been investigated how important MRR is in determining the efficiency and cost-effectiveness of EDM machining performances. [7] None of the EDM process parameters had a monotonic influence on MRR. The most beneficial process parameters must be chosen in order to achieve the best machining performance. [8]Analysis of variance (ANOVA) is a key component of the Taguchi method-based approach. [9] Investigations were done on how the machining parameters affected responses like MRR. Regression analysis was utilised

in this study to determine the parameters' ideal values.Typically, the experiences gained from experimental studies on EDM are used to identify these required process parameters. In this study, studies based on Taguchi method-based machining parameter optimization of EDM process are listed. Rough machining in the EDM process results in lower precision, and finish machining results in a finer surface finish but lower machining speed. As a result, the goal must be to raise the MRR and lower Ra, which is accomplished via the Taguchi approach.

EXPERIMENTATION

Selection of material

Stronger than pure nickel, the Monel-400 family of nickel alloys is largely made of nickel (up to 67%) and copper. Solid solution binary alloys like Monel are frequently employed in applications with harsh corrosive environments. Some alloys can endure a fire in pure oxygen, and it is resistant to acids and corrosion. Even if the alloy is cold to the temperature of liquid hydrogen, it remains ductile and does not harden. Metal 400, a Monel alloy, performs well mechanically even at minus 40 degrees Fahrenheit. Strength and hardness gains largely cancel out gains in ductility or impact resistance. Monel-400 is often used in marine engineering, chemical and hydrocarbon processing, heat exchangers, valves and pumps, and aerospace applications.

S. No	COMPOSITION	PERCENTAGE (%)
1	Ni	Remainder
2	C	0.23
3	Si	0.04
4	S	0.03
5	Cu	29.69
6	Mg	1.168
7	Fe	2.234

Table 1 : Monel 400's Chemical Composition.

About Orthogonal Array

Before beginning machining, it is a good idea to talk about a previous exploratory project that was created. Material removal rate (MRR) and surface roughness are calculated using experimental data from the Taguchi approach and an orthogonal array using a L9 orthogonal array (SR). Since its introduction, it has been used to improve processes in a broad variety of technological fields. Pulse-on and Pulse-off are two of the most common elements in the study of currents. There will be three tiers of each factor. L9 Orthogonal array was chosen based on the quantity and the levels of the various components. Table-3 shows experimental plans with assigned values, while Table 2 shows varied amounts of machining factors.

To perform an experiment, you'll need:Pulse-on time

Pulse-off time

Current

The variables to be assessed

Material Removal Rate (MRR).

Surface Roughness (SR).

S. No	Parameter	Unit	Level 1	Level 2	Level 3
1	Pulse-ON(A)	µs	29.3804	58.7804	88.23332

2	Pulse-OFF(B)	µs	0.98196	4.9196	8.8641
3	Current(C)	Amps	4.87844	14.7392	24.5294

Table 2: The Level of Machining Parameters

S. No	Current (C)	Pulse ON (A)	Pulse OFF (B)
1	10	25	5
2	20	25	10
3	30	25	15
4	20	50	5
5	30	50	10
6	10	50	15
7	30	75	5
8	10	75	10
9	20	75	15

Table 3: Design of Experiment (DOE)

EXPERIMENTAL SETUP

A&D Sparks in Coimbatore has an EDM equipment from ELECTRONICA that was used for the trials. With measurements of 150 mm in length, 20 mm in breadth and 2 mm in thickness, the specimen is a rectangular blank of Monel 400. There are nine 10 mm long copper electrodes used in this experiment, which were cut from the work piece.

Fig 2: Electric Discharge Machining Shop

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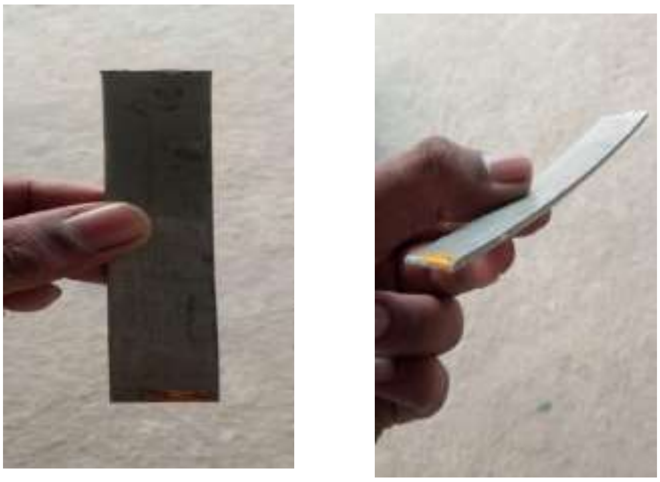

Fig 3: Monel 400 before Machining

Fig 4: Monel 400 after Machining

S. No	A	B	C	MRR (gm./min)	SR (µm)
1	25	5	10	0.5488	0.4998
2	25	10	20	2.5088	0.97314
3	25	15	30	3.528	0.56448
4	50	5	20	1.8816	0.6762
5	50	10	30	2.7636	1.12406
6	50	15	10	0.5488	0.66052
7	75	5	30	1.7444	0.62818
8	75	10	10	0.5096	0.53116
9	75	15	20	1.2544	0.51842

Table 4: Result observed on EDM Process

Pulse On/Off/Current are the machining process's controllable parameters It is possible to gauge the success or failure of an EDM strategy by looking at its MRR and SR values. Table 4 summarizes the findings in this study.

RESULTS AND DISCUSSION

In order to attain the aim of increasing material removal rate while decreasing SR, the Taguchi method is utilized

Taguchi Method

According to Jameson (2001) and Montgomery (2001), the Taguchi technique of optimization entails three steps, the first of which is the selection of raw materials based on their engineering features. At the second phase, the design of the experiment table is used to carry out the optimization procedure. Validation of the results is done in the third step by comparing the experimental and predicted data sets.

The corresponding S/N ratio for each material was produced using Mini tab software based on the various combinations of inputs collected by the Taguchi method (Mini tab Manual 2010).

Taguchi Analysis

The signal-to-noise ratio (SNR) measures how loud a signal is compared to the background noise. It is necessary to first decide whether the quality attribute has a lower, a higher, or a nominally best value in order to calculate the S/N ratio. A combination of "bigger is better" and "smaller is better" paradigms is used in this investigation. This response's S/N ratio is provided.

MRR - Higher is better.

SR - Lower is better.

S/N and mean response graphs for MRR and SR vs pulse on, off, and current are shown in figs. 5, 6, 7, 8, 9.

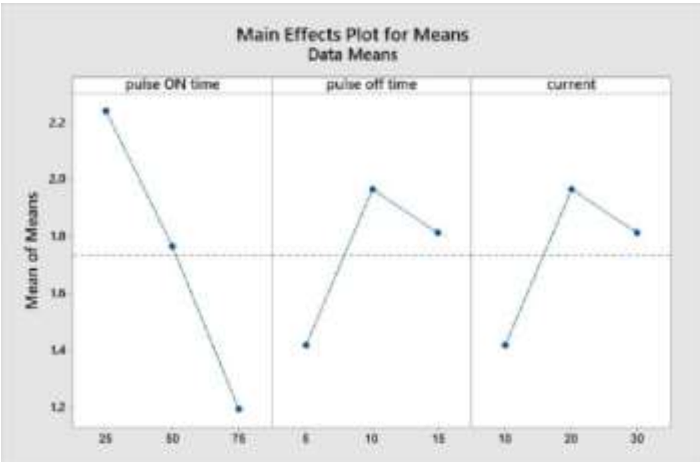

Fig 5: Effects of control factor on MRR (means)

LEVEL	A	B	C
1	2.1952	1.3916	1.3916
2	1.73166	1.92766	1.92766
3	1.16914	1.77674	1.77674
DELTA	1.02606	0.53606	0.53606
RANK	1	2.5	2.5

Table-5: Response Table for Means

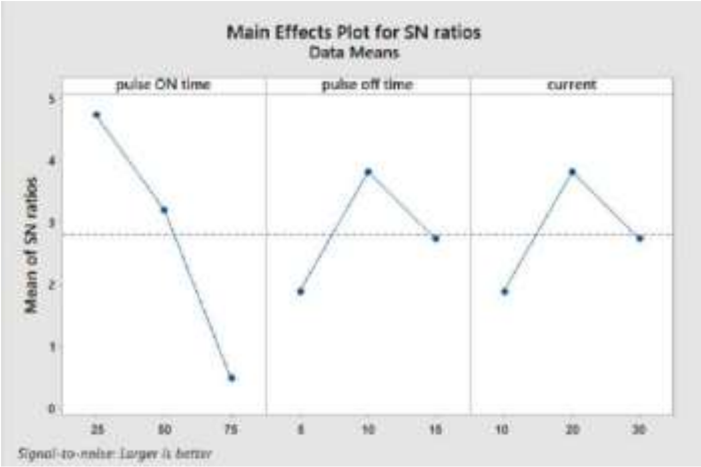

Fig 6: Effects of control factor on MRR

LEVEL	A	B	C
1	4.65647	1.841812	1.841812
2	3.147368	3.746442	3.746442
3	0.471082	2.689806	2.689806
DELTA	4.175388	1.911588	1.911588
RANK	1.01	2.51	2.509

Table-6: Response Table for S/N ratio (MRR)

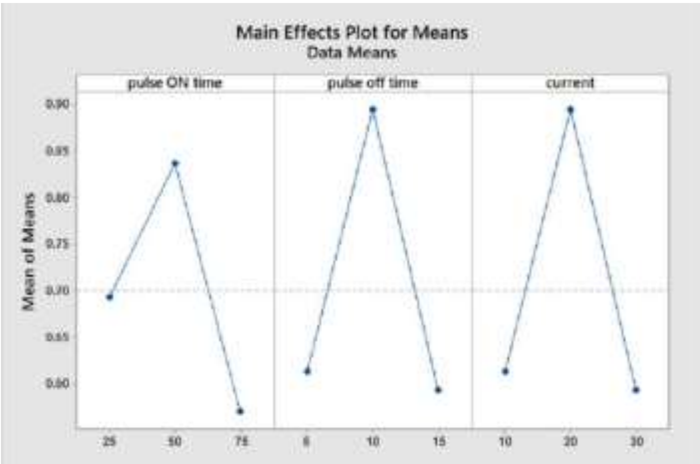

Fig7: Effects of control factor on SR (means)

LEVEL	A	B	C
1	0.67914	0.601426	0.601426
2	0.82026	0.87612	0.87612
3	0.559286	0.58114	0.58114
DELTA	0.260974	0.29498	0.29498
RANK	3	1.5	1.5

Table-7: Response Table for Means

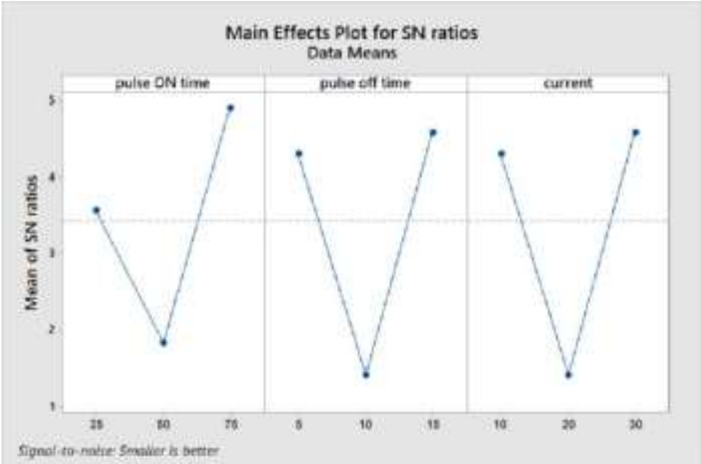

Fig 8: Effects of control factor on SR

Table-8: Response Table for S/N ratio (SR)

LEVEL	A	B	C
1	3.49566	4.22478	4.22478
2	1.7836	1.36906	1.36906
3	4.8069	4.49134	4.49134
DELTA	3.0233	3.12228	3.12228
RANK	3	1.5	1.5

CONCLUSION

For MRR and SR, Taguchi's optimization approach yields the best combination of parameters in table 9.

S. NO	CONTROL FACTORS	MRR		SR	
		BEST LEVEL	VALUE	BEST LEVEL	VALUE
1	PULSE-ON	1	25	2	50
2	PULSE-OFF	2	10	2	10
3	VOLTAGE	2	20	2	20

Table-9: Optimum Conditions using Taguchi Method

It has been shown that the Taguchi's L9 Orthogonal Array (OA) may be used to maximize the objectives such as MRR and SR. As a result of the preceding analysis into Monel 400 optimization, the following is the most important finding:

Following are the best conditions for maximum MRR:

Pulse-ON - 25µs,
Pulse-OFF - 10µs,
Voltage - 20 V

The following are the ideal conditions for obtaining the SR with the lowest possible error rate:

Pulse-ON - 50µs,
Pulse-OFF - 10µs,
voltage – 20V

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