Experimental Investigation And Optimization OfProcess Parameters Of WEDM Using Taguchi Method

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***Abstract*— Wire electric discharge machining (WEDM) is a crucial non-traditional method of machining. It is primarily utilized for the machining of hard metals and materials that prove challenging to machine using traditional processes. This makes WEDM a valuable tool in aerospace, automotive and tooling applications. The goal of this research paper is to identify the most suitable set of process parameters, including pulse on time (Ton), voltage, and current in the electric discharge machining (WEDM) process to achieve higher material removal rate, improved surface finish. Taguchi method is used to get the optimized result. The Taguchi Method offers a systematic approach to identify and optimize these parameters to enhance machining efficiency and quality. EN31 alloy steel material is used as a workpiece and the cutting wire is made up of Brass with 0.25 mm diameter.**

Keywords*— Wire Electric discharge machining, EN31 alloy steel, pulse on time (Ton), voltage, current, material removal rate, surface finish, Taguchi method

I. Introduction

Wire Electro Discharge Machining (WEDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. WEDM has ability to machine structurally complex or high strength material, the materials which are difficult to machine like tools of steel which are heat treated with heat, composite materials, super alloys, Ceramics, carbides, Heat resistant steels etc. The only condition for WEDM is the material should be electrically conductive.

There is no direct contact of the electrode and work piece in the WEDM. So, the machining problems like the stresses and the vibrations does not arise during the machining processes. The process of wire WEDM machining includes immersing the workpiece in a dielectric fluid, clamping it with a machinist vice, and passing a wire through it to generate sparks by applying an electric current. The wire acts as one side of the charge, while the workpiece, made of conductive material, serves as the other side.

When they come into close proximity, a high electric charge bridges the gap, causing small bits of metal to melt away. The electric spark functions as the cutting tool to shape the material as needed.

Moreover, the wire WEDM process utilizes dielectric fluid to manage the operation and eliminate the tiny particles that are removed. Mostly dielectric fluid used are Kerosene/WEDM oil/Deionized water but in some special cases Gaseous dielectric fluids are also used.

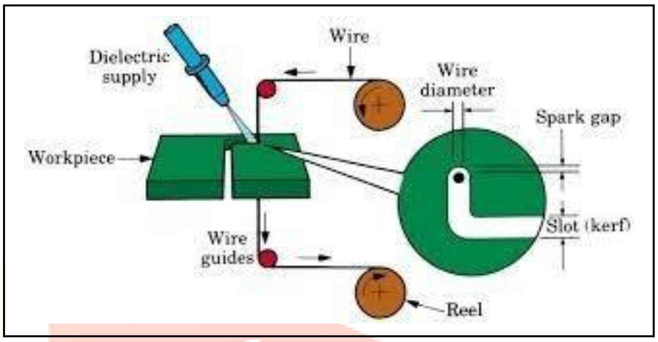

Fig. 1. Working of Wire WEDM.

II. Literature Review

Aishwarya Payla, Kunal Chopra et.al. study published in October 2019 was dedicated to calculate the power consumption in WEDM for machining of EN31 steel for sustainable production. The study gives useful insights for sustainable manufacturing methods by examining the impact of critical factors such as servo voltage and pulse on-time on material removal rate and power usage. Through real-time monitoring and experimental investigations, the study provides light on the complex link between WEDM parameters and energy consumption, with practical implications for reducing the environmental effect and economic sustainability of machining operations.[1]

Anil Kumawat et.al. had published a paper titled 'Development and optimization of triangular profile by using WEDM machining process' in January 2020. The study discusses the creation and optimization of a triangle profile utilizing the wire WEDM machining method. It explores the impact of process factors such as pulse on/off time, peak current, and wire feed on material removal rate. To reach ideal results, the study uses Composite Desirability function-based optimization and the surface response Design of Experiments approach. The study approach involves pilot experiments, Taguchi's design of experiment methodology, and material removal rate computation. The findings emphasize the need of selecting appropriate process parameters for WEDM machining in order to improve machining efficiency and precision.[2]

Rahul V. M et.al. had published a paper titled 'Optimization of wire-WEDM process parameters for Ni–Ti-Hf shape memory alloy through particle swarm optimization and CNN-based SEM-image classification' in March 2023. This paper focuses on optimizing the wire-WEDM process parameters for Ni-Ti-Hf shape memory alloy using particle swarm optimization and CNN-based SEM-image classification. The study analyses the surface morphology of Ni-Ti-Hf-based alloys using scanning electron microscopy (SEM) images. A convolutional neural network (CNN) model is used to classify SEM images based on the material removal rate (MRR). The study finds that increasing discharge energy leads to material remelting and the formation of lumps and globules on the surface. The size of debris lumps, pores, and globules increases with increasing Ra values. The study uses the TOPSIS method for particle swarm optimization to find optimal solutions for the WEDM process parameters. The optimized parameters are validated through experimentation, with minimal error percentages for MRR and Ra. [3]

Abdul Faheem et.al. had published a paper titled 'Parametric optimization of electric discharge machining of Ni55.65Ti based shape memory alloy using NSGA II with TOPSIS' in June 2023. The research focuses on the parametric optimization of electric discharge machining (EDM) of Ni55.65Ti-based shape memory alloys (SMA) utilizing NSGA II and TOPSIS. The study looks at the impact of input process parameters on surface roughness (SR) and material removal rate (MRR) in Ni55.65Ti-SMAs during EDM. The authors employed the non-dominated sorting genetic algorithm II (NSGA II) for multi-objective process optimization and rated the results using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The study also provides empirical modelling, ANOVA analysis, and a complete factorial design analysis to better understand the impact of machining settings on output characteristics. The data reveal that the minimum SR was 6.828 mm, while the maximum MRR was 4.552 mm3/sec. The work gives useful insights on the machinability of Ni55.65Ti-SMAs using EDM, as well as a full grasp of the solution space for getting the best possible outcomes.[4]

Rakesh Chaudhari, Sakshum Khanna et.al. had published a paper titled 'Experimental investigations and optimization of MWCNTs-mixed WWEDM process parameters of nitinol shape memory alloy' in July 2021. In wire electrical discharge machining (WWEDM) of nickel shape memory alloy (SMA) utilizing a mixed dielectric fluid containing multi-walled carbon nanotubes (MWCNTs), the research concentrates on the experimental studies and process parameter optimization. In order to investigate how different process parameters affected the material removal rate (MRR) and surface roughness of the machined nitinol SMA, the authors conducted tests. To find the important elements influencing the machining performance and improve the process parameters, they employed the Taguchi technique and analysis of variance (ANOVA). The results demonstrated that the machined nitinol SMA's MRR and surface roughness were both enhanced and decreased by the addition of MWCNTs to the dielectric fluid. The work offers insightful information about how to best optimize the WEDM process parameters for nitinol SMA machining, which can help design productive and successful machining methods for shape memory alloys.[5]

The work piece material used for current work is EN31 alloy steel. The material was purchased from 'Rajasthan Steel Shop'. The faces of the workpiece were ground with the help of a surface grinder to remove uneven surfaces and make the workpiece ready for machining. The actual size of raw material was 200mmx40mmx20mm. With the help of cutting machine the workpiece was cut into two pieces of size 200mmx20mmx20mm, one for hardness and chemical composition testing and other for machining on WEDM.

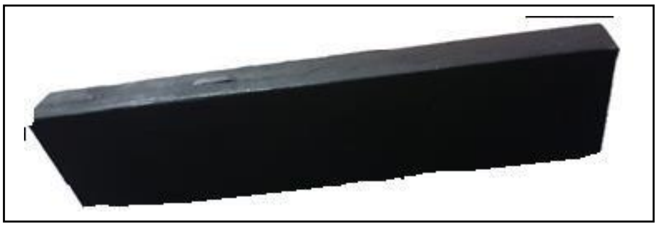

Fig. 2. Raw material

The chemical composition of EN31 alloy steel is also tested at 'Neo Phoenix Testing & Consultancy Services LLP'. The results are shown in Table I below.

TABLE I. CHEMICAL COMPOSITION OF EN31

Chemical Name	Required %	Result %
Carbon	0.90-1.20%	0.9008
Manganese	0.30-0.75%	0.5302
Chromium	1.00-1.60%	1.5492
Sulphur	0.050% max	0.0281
Silicon	0.10-0.35%	0.3209
Phosphorous	0.050% max	0.0292

B. Experimental setup

In the current study, Electronica make Hi-Tech Wire WEDM (Job Master D-zire) machine is used to conduct the overall trials. Brass wire with 0.25 mm diameter is used as a tool to cut the workpiece into pieces. Fig 3 shows the experimental setup used in the current study.

Fig. 3. Electronica Wire WEDM.

III. Experimental Details

A. Material Preparation

Below fig 4 shows the workpiece after cutting on wire WEDM.

Fig. 4. Workpiece after cutting.

C. Measurement of surface roughness

Size of the surface texture equals surface roughness. Denoted by Ra, it is expressed in µm. The surface is smooth at lower values and rough at higher values. A surface roughness tester measures this number. To measure the surface roughness of the workpiece 'MITUTOYO SURFTEST SJ-210 portable surface roughness tester' is used. Fig 5 shows the setup during measuring the surface roughness.

Fig. 5. Mitutoyo Roughness Tester.

D. Machining parameters

Based on the literature review Ton, Toff, Sv and Wt were selected as input parameters. The effective output parameter selected is surface roughness (SR). Four levels are selected for Ton. For remaining input parameters two levels are selected. Table II shows the input parameters and their levels.

TABLE II. INPUT PARAMETERS LEVELS

Parameter	Parameter Levels			
	Level 1	*Level 2*	*Level 3*	*Level 4*
Ton	10	12	14	20
Toff	56	58		
Sv	18	20		
Wt	8	10		

E. Taguchi method

We are using Taguchi method to perform analysis. Taguchi method involves reducing the variation in a process through robust design of experiments. The relative "quality" of a particular parameter design is evaluated using a generic signal-to-noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including "lower is better" (LB), "nominal is best" (NB), or "higher is better" (HB). As the objective is to obtain low surface finish, it is concerned with obtaining smaller value of surface roughness.

Hence, the required quality characteristic for surface roughness is smaller the better, which states that the output must be as low as possible.

F. Software used

For the calculations of response table and plotting the graphs we used MINITAB statistical software.

IV. Results And Discussion

In this investigation total 16 experiments are carried out by using orthogonal array method. For the 16 cuts we made 16 different combinations of the input parameters. With the use of Minitab software, the data are examined using S/N ratios, Response tables, and Response graphs. L16 orthogonal array is created for the calculations.

A. Main Effect Plot for input parameters

Below figures shows the effect of cutting parameters on the surface roughness.

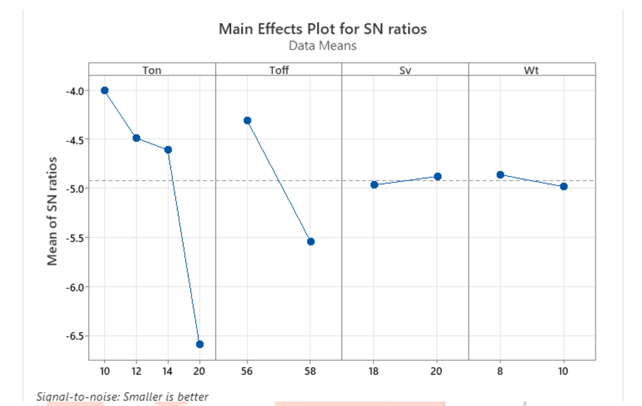

Fig. 6. Effect of cutting parameters (S/N data)

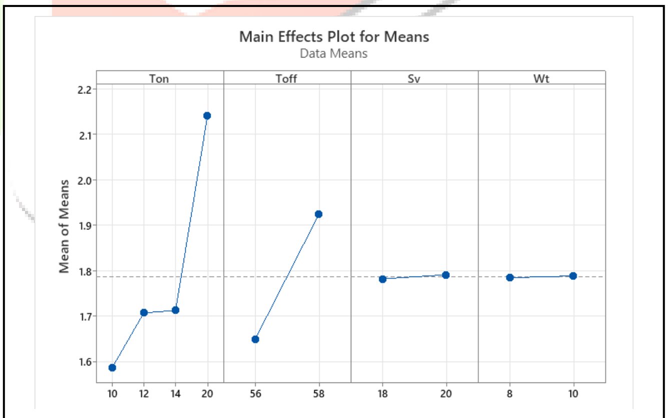

Fig. 7. Effect of cutting parameters (S/N data)

B. Response Table for Signal to Noise Ratios

TABLE III. RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

Level	Ton	Toff	Sv	Wt
1	-4.004	-4.308	-4.969	-4.864
2	-4.489	-5.541	-4.880	-4.985
3	-4.611			
4	-6.593			
Delta	2.588	1.234	0.088	0.121
Rank	1	2	4	3

C. Response Table for means

TABLE IV. RESPONSE TABLE FOR MEANS

Level	Ton	Toff	Sv	Wt
1	1.586	1.650	1.782	1.785
2	1.708	1.924	1.791	1.789
3	1.713			
4	2.141			
Delta	0.555	0.275	0.009	0.004
Rank	1	2	3	4

V. CONCLUSION

The Taguchi approach is used in this study to optimize the following process parameters: wire tension, servo voltage, pulse on and off durations, and surface roughness in WEDM of EN 31 tool steel.

From the response table, we can see that Ton is ranked 1^{st}, Toff is ranked 2^{nd}, Wt is ranked 3^{rd} and Sv is ranked 4^{th}. Therefore, it is concluded that Ton is the most effective input parameter affecting the surface roughness. We can achieve the lowest value of surface roughness by varying the Ton.

VI. NOMENCLATURE

EDM-Electric Discharge Machining
MRR-Material Removal Rate
SR-Surface Roughness
SEM-Scanning Electron Microscopy
CNN-Convolutional Neural Network
SMA-Shape Memory Alloys
mm- millimetre
TOPSIS-Technique for Order Preference by Similarity to Ideal Solution
NSGA-Non-dominated Sorting Genetic Algorithm
MWCNTs-Multi-Walled Carbon Nano Tubes
T_{on} -Pulse on Time
T_{off} -Pulse off Time
S_v -Servo Voltage
W_t -Wire Tension

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