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An Experimental Study of Low Frequency Vibration Assisted EDM in AISI 1045 Steel

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Abstract

This experimental study helps to analyze the performance characteristics of ultrasonic vibration assisted EDM process. The objective of the present work was to investigate the effect low frequency vibration given to workpiece which taken as an input factor with other parameters of WEDM on the cutting speed and surface roughness of machining process. This happened with the help of fixture and vibration actuator. By the help of this vibration unit vibration produced to the workpiece, this vibration removed the debris fast and our cutting speed increased. And with increasing speed the surface roughness minimized. The working ranges and levels of the WEDM process parameters are found from literature survey to investigate the effects of wire WEDM we use Taguchi Method.

Keywords: Electrical Discharge Machining (EDM), Wire EDM, Taguchi Method, Cutting Speed (C.S), Surface Roughness (S.R)

Introduction

WEDM is used to machine geometrically complex material, hard components. It is used to machine that material which are not easy to machine. The cutting rate/speed of conventional machining process is low and it become very low when machining the materials which are high strength-to-weight ratio, heat resistance and hardness, such as alloy with alloying elements such as tungsten, molybdenum.

Most of the problem is solved out by the invention of unconventional machine. There are number of machines which machines these hard type of materials in which some of them have good machining rate. But various researches are going on to optimize the cutting rate and surface roughness of these machines.

The objective of the present work was to investigate the effect low frequency vibration given to work piece which taken as an input factor with other parameters of WEDM on the cutting speed and surface roughness of machining process. This happened with the help of fixture and vibration actuator[1]. By the help of this vibration unit vibration produced to the work piece, this vibration removed the debris fast and our cutting speed increased. And with increasing speed the surface roughness minimized.

The literary survey helps in finding the parameters of working ranges and levels of the WEDM. The Taguchi method helps in investigation of the changes and the effects of the WEDM[2].

The low frequency vibration given to work piece with the help of vibration unit[3].

When work piece come to contact with wire of machine it eroded the work piece because the spark struck between the moving electrode wire and the work piece, thereby removing the material but the vibration helped to remove the debris fast from the cutting zone and helped to optimize the cutting speed and surface roughness[5]. Confirmation experiments are further conducted to validate the results.

Figure-1
Experimental set for USEDM workpiece Vibration

Ultrasonic Vibration in Micro EDM: Ultrasonic vibration helps in to two ways. These are given as below: i. Removing material directly. ii. Best condition to machine. Two effects can be observed: i. Hammering effect. ii. Pumping effect.

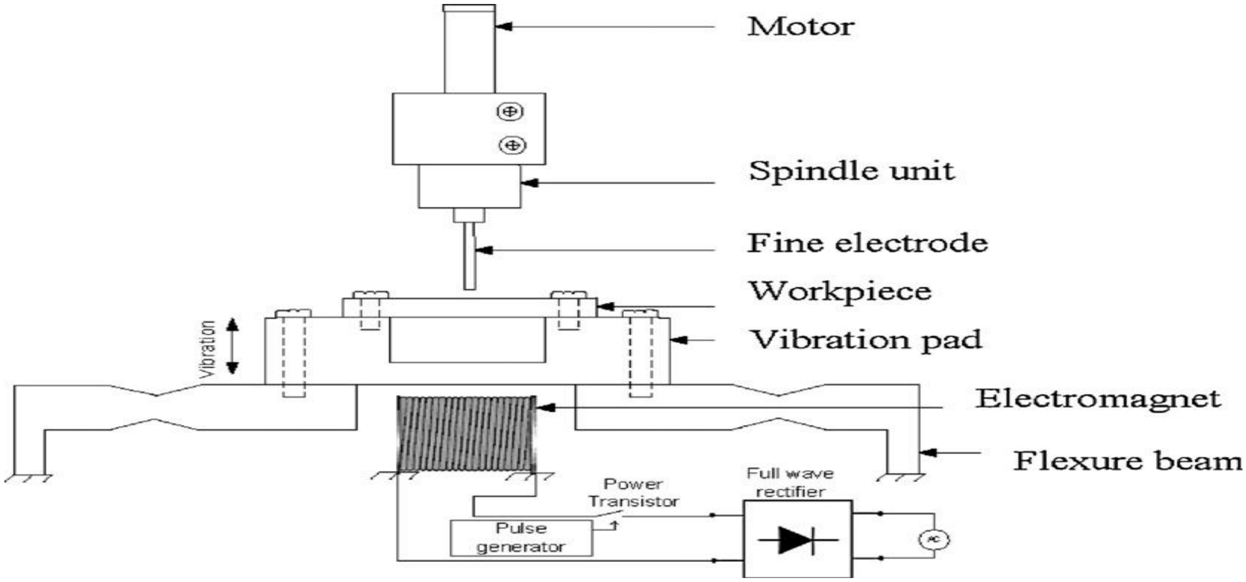

Figure-2
Schematic diagram of low frequency work piece vibration unit

Due to vibration, inertial force set up in work piece which helps in expelling debris and molten metal from the machined surface. Under predetermined machining conditions efficiency of the ultrasonically aided micro-EDM is much better than that of micro-EDM with an improved dielectric circulation[4]. Vibration increases the flushing effect, when high frequency and high amplitude increases the Metal removal rate .Vibration also effects the dimensions of a hole due to high frequency[6].

Parameters Used

Design Parameters: Cutting Rate, Surface Roughness.

Machining Parameter: Wire feed, Wire tension, peak current, frequency of vibration.

Constant Parameter: Pulse on time (Ip), Pulse off time (Toff), peak voltage (Vg), Flushing pressure, Polarity, Servo Feed

Work Piece Material

The AISI 1045 steel square keys of 30mm x 5mm x 5mm size has been used as a work piece material for the present experiment. D2 steel has toughness properties and also good toughness property. It is used for good, good mach inability, good weldablity and high strength and high impact properties in either the normalized or hot rolled condition. It has varied practical applications such as Based on the recommendations given by the machine manufacturers, operations like, milling, tapping, drilling, broacing, sawing and turning etc[5] can be carried out on AISI 1045 steel using suitable feeds, tool type and speeds. Heat treatment is used is used to improve the working life and dimensional accuracy of 1045 steel dies and tools. EDAX (Electro Dispersive X-ray Spectroscopy) test gives its chemical composition as shown in Table-1.

Methodology

Taguchi Method: This method helps to deal with response influenced by multi-variables and focuses on minimizing the effect of causes of variation1. The process performs consistently on target and is relatively insensitive to uncontrollable factors. Traditional full factorial design of experiments is time consuming but Taguchi's approach in provide a significant reduction in the size of experiments, experimental process becomes fast[2]. Orthogonal arrays and signal-to-noise (S/N) ratios are two important tools in Taguchi approach. To control experimental error orthogonal arrays developed by Taguchi. Orthogonal array are developed in such a way that, for each level of any one factor, all levels of other factors occur an equal number of times thereby giving a balanced design. Orthogonal arrays allow researchers or designers to study many design parameters simultaneously and can be used to estimate the effects of each factor independent of the other factors. Quality is indicated by signal-to-noise ratio by which observer can examine the effect of changing a particular design parameter on the performance of the process. MINITAB 17 is used for full factorial result.

Experimental Results

The WEDM experiments were conducted to study the effect of output response characteristics according to E1- E9 shown in Table-3. The experimental results for cutting rate and surface roughness shown in Table-4. Nine experiments were conducted using Taguchi methodology and each experiment was simply repeated three times.

Table-1
Chemical Composition of the work piece material

Constituents	Carbon (C)	Manganese (Mn)	Sulphur (S)	Phosphrous (p)	Iron (Fe)
%	0.50	0.80	0.05	0.04	Balance

Table-2
Taguchi L_9 Orthogonal array Design Matrix

Exp. No	Factor 1	Factor 2	Factor 3	Factor 4
E1	1	1	1	1
E2	1	2	2	2
E3	1	3	3	3
E4	2	1	2	3
E5	2	2	3	1
E6	2	3	1	2
E7	3	1	3	2
E8	3	2	1	3
E9	3	3	2	1

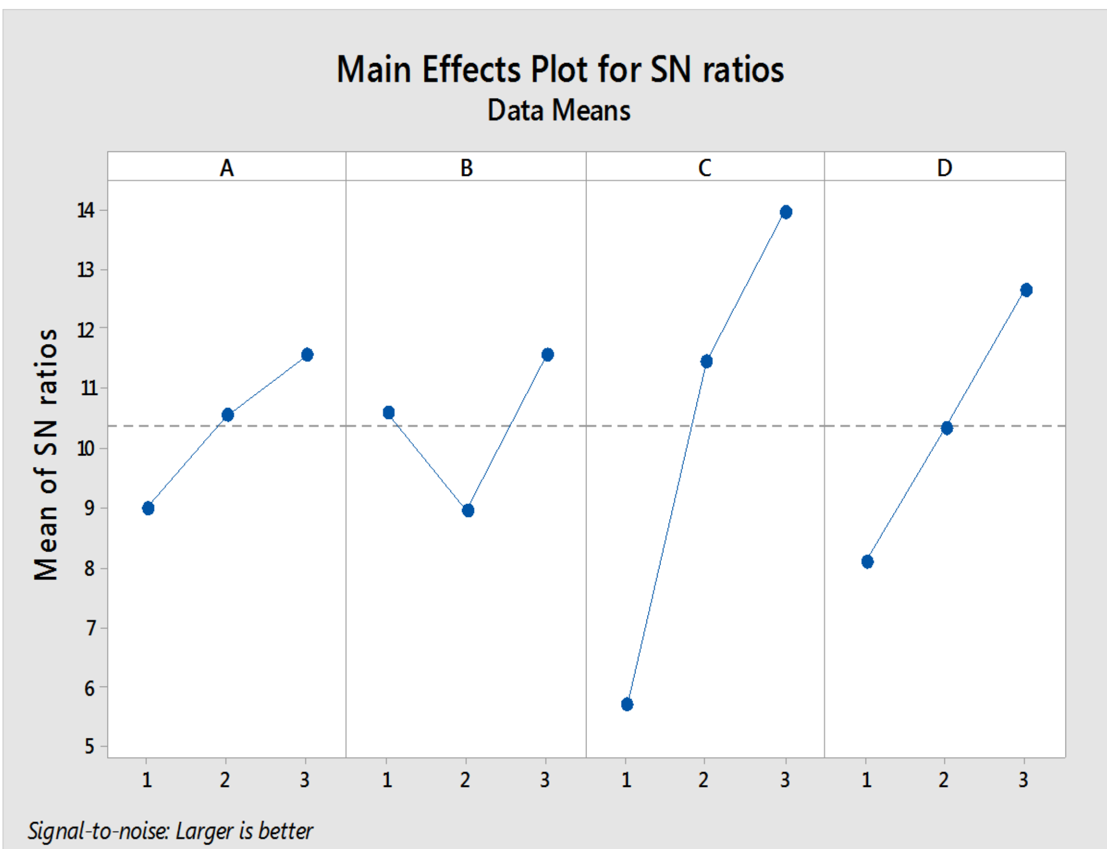

Figure-3
Shows the S/N ratio in this study is calculated by the MINITAB 17 Software for C.S.

Table-3
L_9 Design Matrix

Exp. No	Frequency (Hz)	Ton (µs)	T off (µs)	SV (volt)
E1	100	100	4	4
E2	200	150	4	8
E3	300	200	4	12
E4	300	150	8	4
E5	100	200	8	8
E6	200	100	8	12
E7	200	200	12	4
E8	300	100	12	8
E9	100	150	12	12

Table-4
Experimental results for cutting speed and surface roughness

Exp. No	Cutting Speed (mm/min)			Surface Roughness (Ra)		
	CS 1	CS 2	CS 3	SR 1	SR 2	SR3
E1	1.31	1.32	1.27	3.85	3.24	2.35
E2	2.79	2.69	2.65	4.66	3.70	2.74
E3	6.12	6.14	6.92	5.74	6.60	6.64
E4	5.36	4.98	4.99	4.93	5.04	5.21
E5	3.51	3.20	3.33	3.25	5.16	4.28
E6	1.51	3.56	3.54	3.01	5.13	5.20
E7	5.84	5.89	5.85	4.78	4.69	4.38
E8	2.4	2.48	2.44	3.84	2.96	2.92
E9	2.41	7.35	7.31	3.03	5.16	5.20

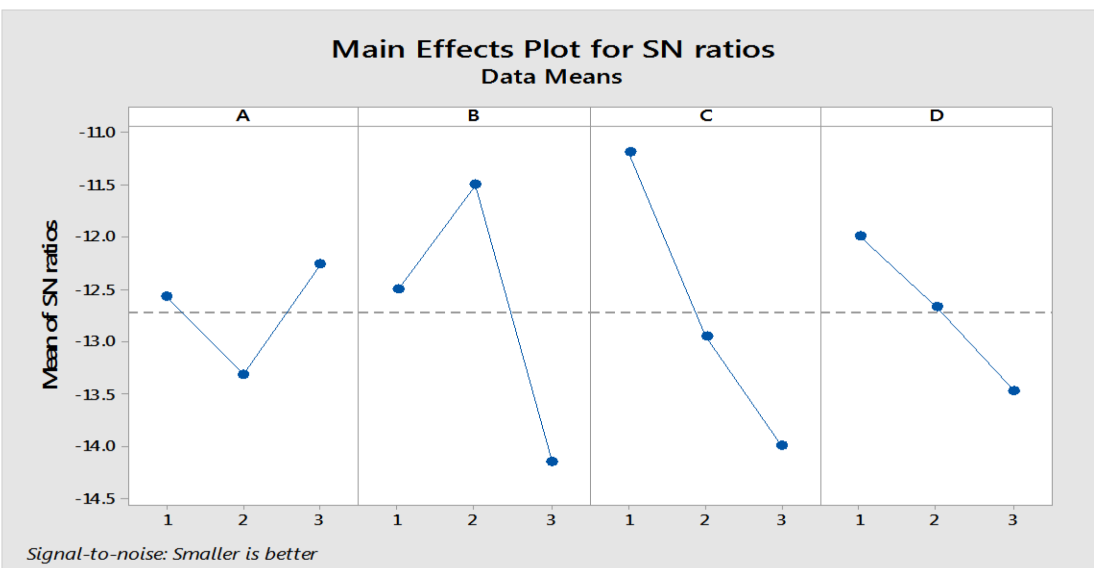

Figure-4
Shows the S/N ratio in this study is calculated by the MINITAB 17 Software for S.R.

Table-5
S/N ratio and Cutting speed for Different Test conditions

Sr. No.	A	B	C	D	CS	SN Ratio
1	100	100	4	4	1.30000	2.2752
2	200	150	4	8	2.71000	8.6533
3	300	200	4	12	6.39333	16.0726
4	300	150	8	4	5.11000	14.1533
5	100	200	8	8	3.34667	10.4736
6	200	100	8	12	2.87000	7.0094
7	200	200	12	4	5.86000	15.3578
8	300	100	12	8	2.44000	7.7455
9	100	150	12	12	5.69000	11.5615

Table-6
Response table for Signal to Noise Ratios (smaller is better)

Level	A	B	C	D
1	9.000	10.595	5.677	8.103
2	10.545	8.957	11.456	10.340
3	11.555	11.548	13.968	12.657
Delta	2.555	2.590	8.291	4.554
Rank	4	3	1	2

Table-7
S/N ratio and surface roughness for Different Test condition

Sr. No	Frequency	Ton (μs)	T off (μs)	SV (volt)	SR	S/NRATIO
1	100	100	4	4	3.14667	-10.1203
2	200	150	4	8	3.70000	-11.5547
3	300	200	4	12	6.32667	-16.0422
4	300	150	8	4	5.06000	-14.0853
5	100	200	8	8	4.23000	-12.6722
6	200	100	8	12	4.44667	-13.1818
7	200	200	12	4	4.61667	-13.2925
8	300	100	12	8	3.24000	-10.2848
9	100	150	12	12	4.46333	-13.2116

Table-8
Response Table for Signal to Noise Ratios (smaller is better)

Level	A	B	C	D
1	-12.57	-12.50	-11.20	-12.00
2	-13.31	-11.50	-12.95	-12.68
3	-12.26	-14.15	-14.00	-13.47
Delta	1.05	2.64	2.81	1.47
Rank	4	2	1	3

Response Table for Signal to Noise Ratios for S.R.: The response table for signal to noise ratio for S.R is shown in Table-8 for S.R, the calculation of S/N ratio follows “Smaller is better” model.

Conclusion

For Cutting Speed: The analysis of Taguchi is done by MINITAB 17. This is software of design of experiment. Signal to noise ratio response table is shown in the table. From table it is clear that the most significant factor among all the factors is the pulse off which is followed by pulse on and then frequency while the factor gap voltage is the least significant factor in cutting speed of 1045 steel.

For Surface Roughness: The signal to noise ratio response table is shown in the table. From table it is clear that the most significant factor among all the factors is the wire tension which is followed by wire feed and then peak current while the factor frequency is the least significant factor in cutting speed of D2 steel.

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