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Study of Wire EDM with Low Frequency Vibration in AISI D2 Steel

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Abstract

In this paper, we will study about the machining performance of Electrical Discharge Machining process with low frequency vibration. In this we will analyze the effect of low frequency vibration provided to the work piece which is taken as a main input factor with the parameters cutting speed and surface roughness of machine. This happened with the help of fixture and vibration actuator unit. By the help of this vibration unit vibration produced to the work piece, this vibration removed the debris fast and our cutting speed increased with increasing speed the surface roughness is minimized. The working range and levels for the WEDM parameters are studied by this survey. The Taguchi technique is used here to study the effects of the WEDM..

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

Introduction

Wire Electrical Discharge Machining (WEDM) is capable of machining geometrically complex or hard material components in which we have difficulties in machining such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. The cutting rate or 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. Most of the problem is solved out by the invention of unconventional machine. There are number of machines which can machined these type of hard 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 is to study the effect of low frequency vibration given to work piece which is taken as an input factor of WEDM on the cutting speed and surface roughness of machining process. This happened with the help of fixture and vibration actuator unit[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. With increasing speed the surface roughness is minimized. This survey helps in finding the parameters of working ranges and level of the WEDM. Taguchi method helps us in study of the changes and the effects on the WEDM[2].

The low frequency vibration given to work piece with the help of vibration unit[3]. When the work piece came in to contact with wire of WEDM it eroded the work piece because the spark struck between the moving electrode wire and the work piece, Which helps in removing the material but the vibration helped to remove the debris fast from the cutting zone and helps us to optimize the cutting speed and surface roughness[5]. Confirmation experiments are further conducted to validate the results.

Figure-1
Shows the EDM used for the experiment

Ultrasonic Vibration in Micro EDM: Ultrasonic vibration helps us in two ways. These are given below as: i. Removing material directly. ii. Best condition to machine. iii. Two effect can be observe, iv. Hammering effect. v. Pumping effect.

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. 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].

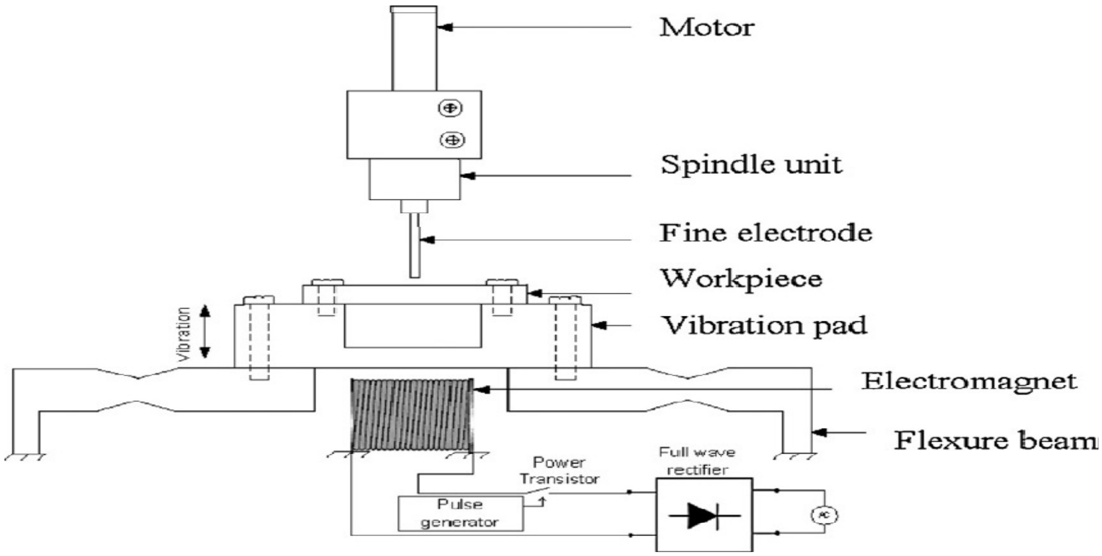

Figure-2
Shows the Schematic diagram of low frequency work piece vibration unit

Parameters Used

Design Parameters: Cutting Rate, Surface Roughness.

Machining Parameter: Pulse on time (Ip), Pulse off time (Toff), Servo voltage (Vg).

Constant Parameter: Duty cycle, Flushing pressure, Polarity, Wire feed, Wire tension, Servo Feed.

Work Piece Material

The AISI D2 steel square keys of 24mm x 10mm x 10 mm size has been used as a work piece material for the present experimental work. D2steesl have good hardness and toughness properties.D2 steel is most commonly uses for extreme load conditions such as hot working like forging, extrusion etc. It has practical applications such as in manufacturing of punching tools, mandrels, mechanical press forging die, plastic mould and die-casting dies, aircraft landing gears, and shafts. The working life and dimensional accuracy for D2 steel dies and tools can also be improved by suitable heat treatments. The chemical composition of this material is given in Table-1.

Methodology

Taguchi Method: This method helps us to deal with response influenced by multi-variables and focuses on minimizing the effect of causes of variation[1]. 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 provides a significant reduction in the size of experiments, experimental process becomes fast. Orthogonal arrays and signal-to-noise (S/N) ratios are two important tools in Taguchi approach. To control experimental error orthogonal arrays are 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 are conducted to study the effect for output response characteristics accordingly from E1 to E9 shown in Table-3. The experimental results for cutting rate and surface roughness shown in the Table-4. Nine experiments were conducted and each experiment was simply repeated three times.

Table-1
Chemical Composition of the work piece material

Total Constituents	Carbon (C)	Molybdenum (Mo)	Silicon (Si)	Vanadium (V)	Chromium (Cr)
%	1.50	0.80	0.30	0.90	12

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

Table-3
L_9 Design Matrix

Exp. No	Frequency (Hz)	Ton (µs)	T off (µs)	SV (volt)
E1	0	105	40	20
E2	0	114	50	35
E3	0	123	60	50
E4	150	105	50	50
E5	150	114	60	20
E6	150	123	40	35
E7	300	105	60	35
E8	300	114	40	50
E9	300	123	50	20

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	0.97	0.96	0.94	2.38	2.24	2.35
E2	2.49	2.39	2.45	2.66	2.70	2.74
E3	0.84	0.82	0.80	2.74	2.60	2.64
E4	1.26	1.28	1.22	1.93	2.04	2.21
E5	0.91	0.94	1.33	2.25	2.16	2.28
E6	2.51	2.56	2.54	3.01	3.13	3.20
E7	0.64	0.69	0.65	1.78	1.69	2.02
E8	2.4	2.48	2.44	1.84	1.96	1.92
E9	6.41	6.35	6.31	2.03	2.16	2.20

Table-5
Signal to noise ratio and cutting speed for number of Test

Ex. No.	Frequency	Ton (µs)	T off (µs)	SV (volt)	CS	SN Ratio
1	0	105	40	20	0.95667	-0.3870
2	0	114	50	35	2.44333	7.7559
3	0	123	60	50	0.82000	-1.7289
4	150	105	50	50	1.25333	1.9561
5	150	114	60	20	1.06000	0.1403
6	150	123	40	35	2.53667	8.0844
7	300	105	60	35	0.66000	-3.6227
8	300	114	40	50	2.44000	7.7455
9	300	123	50	20	6.35333	16.0640

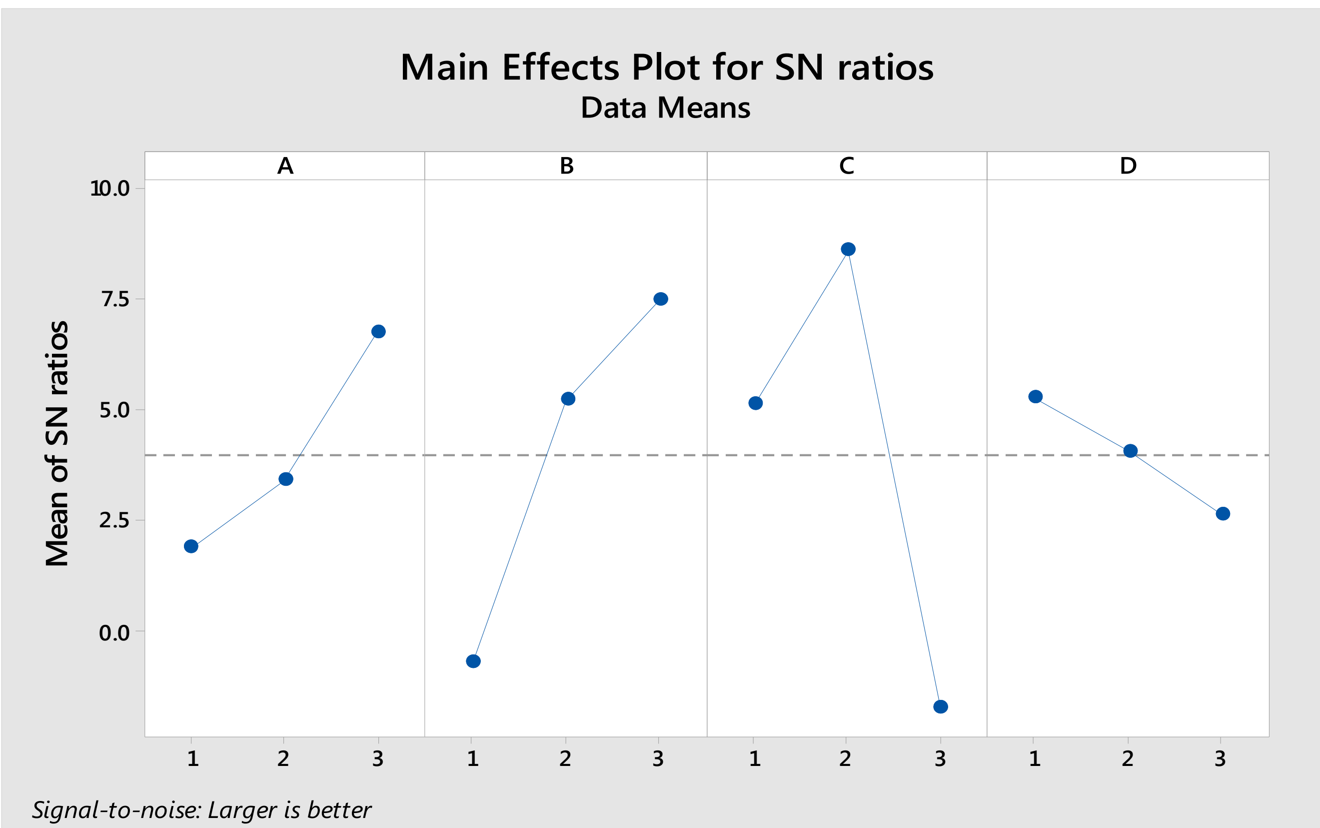

Figure-3
Shows the S/N ratio in this study is calculated by the MINITAB 17 Software for C.S.

Response Table for Signal to Noise Ratios for C.S: The response table for signal to noise ratio for C.S is shown in Table 6 for C.S, the calculation of S/N ratio for the "larger the better" model.

Table-6
Response table for signal to noise ratios for C.S

Level	**Frequency**	**Ton (µs)**	**T off (µs)**	**SV (volt)**
1	1.8800	-0.6845	5.1476	5.2724
2	3.3936	5.2139	8.5920	4.0725
3	6.7289	7.4732	-1.7371	2.6576
Delta	4.8489	8.1577	10.3291	2.6149
Rank	3	2	1	4

Table-7
Signal to noise ratio and surface roughness for number of condition

Sr. No	**Frequency**	**Ton (µs)**	**T off (µs)**	**SV (volt)**	**SR**	**S/NRATIO**
1	0	105	40	20	2.32333	-7.32514
2	0	114	50	35	2.70000	-8.62791
3	0	123	60	50	2.66000	-8.49976
4	150	105	50	50	2.06000	-6.29090
5	150	114	60	20	2.23000	-6.96837
6	150	123	40	35	3.11333	-9.86727
7	300	105	60	35	1.83000	-5.27411
8	300	114	40	50	1.90667	-5.60847
9	300	123	50	20	2.13000	-6.57263

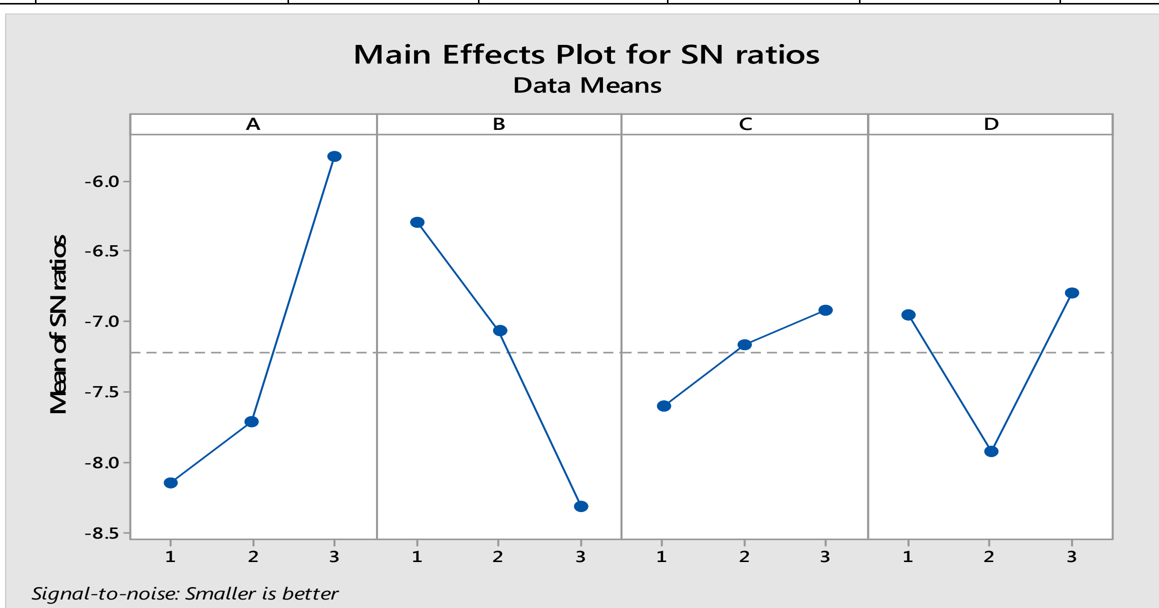

Figure-4
Shows the S/N ratio in this study is calculated by the MINITAB 17 Software for S.R.

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

Level	**Frequency**	**Ton (µs)**	**T off (µs)**	**SV (volt)**
1	-8.151	-6.297	-7.600	-6.955
2	-7.709	-7.068	-7.167	-7.923
3	-5.818	-8.313	-6.914	-6.800
Delta	2.333	2.017	0.686	1.123
Rank	1	2	4	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 for the “Smaller is better” model.

Conclusion

For Cutting Speed: In the above given table response’s for the signal to noise ratio as shown. This analysis of Taguchi is done by MINITAB 17. This is software for design of experiment. 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 affecting factor in cutting speed of D2 steel.

For Surface Roughness: In the above given table response’s for the signal to noise ratio as shown. From table it is clear that the most significant factor among all the factors is the frequency which is followed by pulse on and then gap voltage while the factor pulse off is the least affecting factor in surface roughness of D2 steel.

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