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Optimization of WEDM Parameters of EN41 B Steel by Taguchi Orthogonal Array

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Abstract:

WEDM is non-traditional techniques of material eroded from conductive materials to produce complex shapes and geometry of components such as die, punch, mold, metalworking and aerospace industries. Optimization of WEDM parameters Pulse on time, pulse off time, peak current and wire feed by Taguchi orthogonal array. The results of ANOVA and F-test are found wire feed and peak current the significant factor of response dimensional deviation. Optimum solution of machining parameters obtained are TON (25µs), TOFF (15µs), WF (3mm/min) and IP (1amp). Results of ANOVA found that the peak current is highly significant (49.644%) parameter affecting the WEDM performance characteristics of Dimensional Deviation.

Keywords: WEDM, Taguchi orthogonal array, DD, ANOVA,

1. Introduction:

WEDM is an advance non-traditional machining process in today's industries. WEDM phenomenon is used to cut hard and conductive materials. Now days demand of quality, productivity and dimensional accuracy is essential of the product in manufacturing industries [1]. J.S. Binoj et. al. [2] have been investigate the best optimal combination of WEDM parameters of Al-GNP MMCs material. ANOVA techniques fount the TON is significant factor for response MRR and surface roughness. Nickel alloys are widely used in the aerospace industries because of its great resistance to heat and corrosion. Due to this superiority in properties, a study of WEDM machining of aerospace material for improving the material properties was done by Rajyalakshami. G et al [3] using nickel alloys and super alloys. Owing to the complexity, it is very difficult to determine the optimal cutting parameter for improving the cutting performance. The paper by Anmol Bhatia et al [4] focuses to achieve the minimum surface roughness in wire EDM. The experimentation was based on High Carbon High Chromium Steel using Brass wire. The optimization was done using Taguchi Single Response optimization technique. An investigation of the effect of a process parameter of surface roughness and kerf width of Aluminum and mild steel using a single response optimization technique was carried out by Shivkant T et al [5]. AdeelIkram et al [6] reports the effect and optimization of surface roughness, kerf and MRR in WEDM process for tool steel D2using Taguchi design of experiments. The experiment was conducted under different cutting conditions of dielectric pressure, pulse on time, pulse of time, wire feed velocity, wire tension and servo voltage by varying the material thickness. A muti-objective process optimization was carried out by Uday A. Dabade [7] to improve surface integrity on the turned surface of Al/SiC metal matrix composite using Grey relational analysis. T. Saleh et al [8] using zinc coated brass wire and carbon powder using response surface methodology as an optimization technique. The main purpose of this study was to investigate the effects of different nano-powder concentrations on response factors such as material removal rate (MRR) and spark gap (SG). The present experimental investigation explores the dimensional accuracy of EN 41B steel using the WEDM process. Four control factors such as pulse on time, pulse off time, peak current and WF has been varied to investigate the effect on dimensional deviation. The experiments have been conduct based on the Taguchi orthogonal array. ANOVA has been applied to identify the significance of the process parameters involved during machining.

2. Experimentation

The experimental conduct on EX7732 CNC Wire Electric Discharge Machine is compromised of a reusable molybdenum wire as machine tool shown in Fig. 1. This experimental investigation for optimization utilizes Taguchi technique with L_9 orthogonal array design for found relation between WEDM control factors and dimensional deviation. During the present study, pulse on time, pulse off time, wire feed and peak current are considered as process parameters while dimensional deviation is considered as the machining performance. While JR3A Ointment Gel also known as EDM coolant. It is used in EDM wire cut machine, Grinding machine, Textile machinery and CNC machines. The concentration solution put the liquid in to running water with a ratio 1:40 – 50 and stir until mix the ointment in to thoroughly. The fluid improves machining efficiency 30% more and surface finish degree on one grade more. EN 41B steel is used as work-material for experimentation shown in Fig 2. The chemical compositions of EN41B Steel are given in Table 1. Experiments were carried out using a molybebdenum electrode wire (0.18 mm diameter) to machine EN 41 steel. The setting of WEDM parameters for this study is summarized in the Table 2. In case of rough cutting, to eliminate dimensional deviation or dimensional accuracy this wire offset setting must be equal to dimensional deviation (DD). The term Dimensional deviation has been used as response parameters during rough cutting experiment in WEDM with zero wire offset.

$$\text{Dimensional Deviation (DD)} = 0.5 \times \text{width of cut (mm)} \text{ [9]}$$

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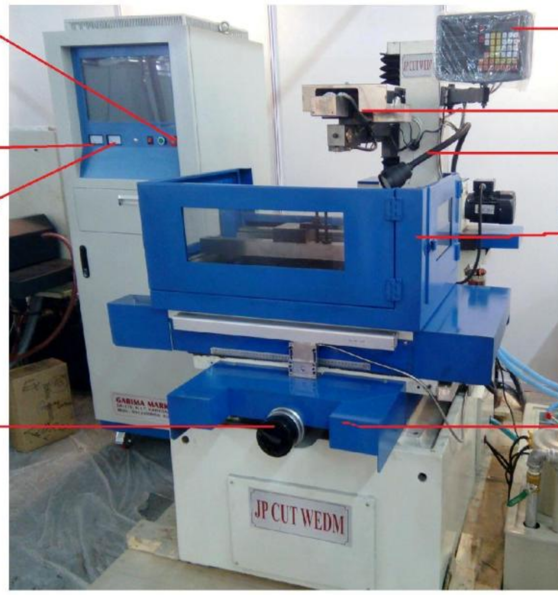
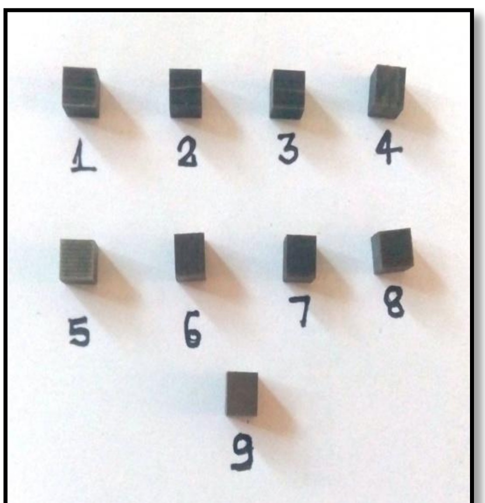


Fig.1 EX7732 CNC WEDM Machine



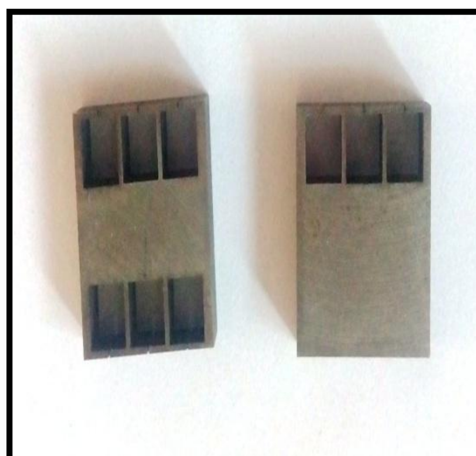


Fig.2 Specimens of the Work-piece

Table 1. Composition of EN 41 B steel

Element	C	Si	Cr	Mn	V	Ni	Mo	Cu
Weight %	0.444	0.205	1.59	0.568	0.006	0.026	0.248	0.037

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Table 2. The setting of WEDM parameters

Parameters	**Symbol**	**Units**	**Levels**		
			Level 1	**Level 2**	**Level 3**
Pulse on time	T_{ON}	(μs)	25	50	75
Pulse off time	T_{OFF}	(μs)	05	10	15
Wire feed	W_F	(mm/min)	1	2	3
Peak current	I_P	(amp)	1	3	5

2.1 Experimental design

Taguchi technique with L_9 orthogonal array is used to DOE. Orthogonal array includes 4 process parameters and 3 levels. Therefore total 9 experiments are conducted according the design suggested by Minitab software. WEDM process parameters that are closely correlated with the selected machining performance dimensional deviation in this study are the pulse on time, pulse off time, wire feed and peak current. Experiments based in L_9 OA are conducted and results shown in Table 3 [10]. Optimization of WEDM parameters leading to lower DD, the "smaller the better" quality characteristics has been used.

Table. 3 L_9 Experimental Arrays

Exp.No	Factor Assignment				DD (mm)	S/N Ratio (db)
	T_{ON} (μs)	T_{OFF} (μs)	WF (mm/min)	I_P (A)		
1.	1	1	1	1	0.461	6.725
2.	1	2	2	2	0.456	6.820
3.	1	3	3	3	0.457	6.801
4.	2	1	2	3	0.476	6.447
5.	2	2	3	1	0.446	7.013

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6.	2	3	1	2	0.459	6.763
7.	3	1	3	2	0.459	6.763
8.	3	2	1	3	0.486	6.267
9.	3	3	2	1	0.458	6.782

3. Results and discussion

In this experimental investigation is carried out to analyze the effect of machining parameters of WEDM on DD on work material while machining EN 41B steel with molybdenum wire electrode. The analysis of response Table 4 is show that the average of each response characteristics (mean data) for each level of each parameters. The tables include ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistics is the highest minus the lowest average for each parameter. MINITAB assigns ranks based on delta values; rank 1 to the highest value, rank 2 to the second highest, and so on. The rank indicates relative importance of each parameter to the DD. The ranks and delta values show that peak current have the greatest effect on dimensional deviation and is followed by, wire feed, pulse on time and pulse off time in that order. As the dimensional deviation is the "smaller is better" type quality characteristics, it can be seen from Fig. 3 that the level 1 of TON (TON1), level 3 of TOFF (TOFF3), level 3 of wire feed (WF3) and level 1 of peak current (IP1) provide the minimum value of dimensional deviation.

Table. 4 Mean Data response table for Dimensional Deviation

Factors/Levels	**Level 1**	**Level 2**	**Level 3**	**Delta**	**Rank**
TON	0.4580	0.4603	0.4677	0.0097	3
TOFF	0.4653	0.4627	0.4580	0.0073	4
WF	0.4687	0.4633	0.4540	0.0147	2
IP	0.4550	0.4580	0.4730	0.0180	1

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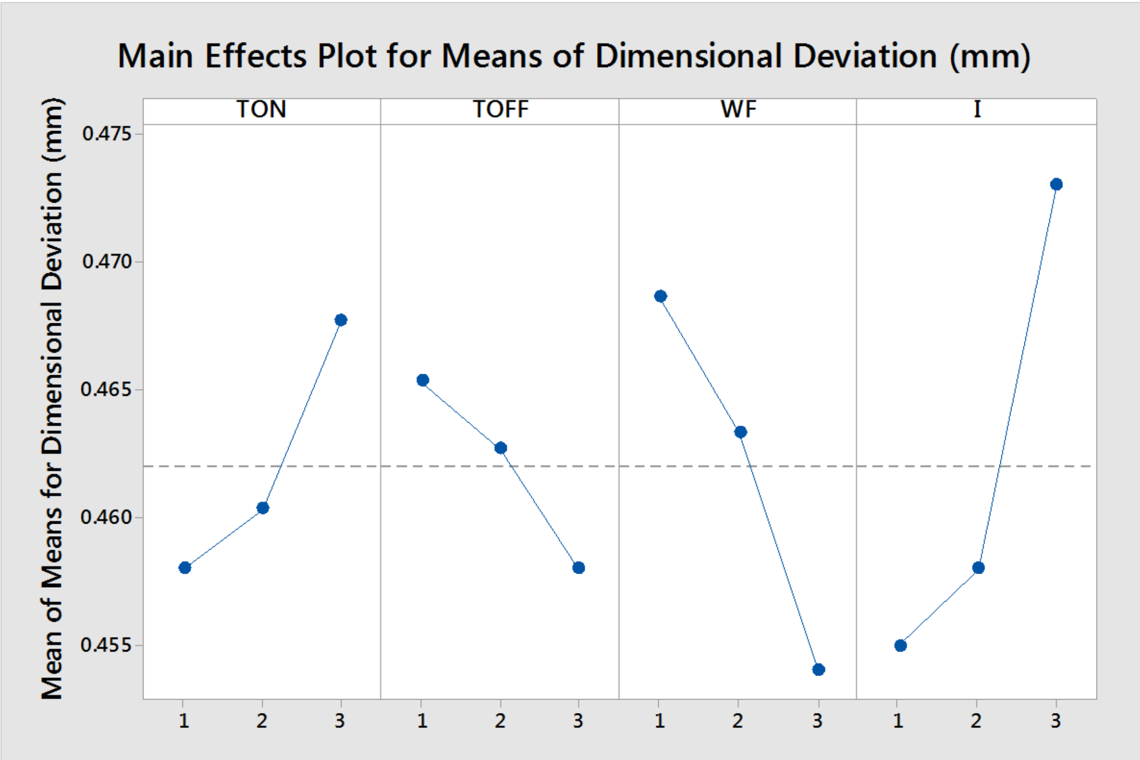

Fig. 3 Effect of control factors (mean data) on Dimensional Deviation

From the Fig. 3 show that Dimensional deviation increases with increase in pulse on time and peak current. In other words the Dimensional deviation value increases if the energy contained in a pulse increase. Dimensional deviations are almost independent of pulse off time as energy contained in a pulse is independent of pulse off time. This fact is of great importance as this pulse off time may be varied under certain critical machining condition without affecting the dimensional accuracy.

Table-5 Pooled ANOVA for Dimensional Deviation

Factors	DOF	SS	Variance	F-ratio	Percentage
TON	2	0.000153	0.000076	1.853	13.612
TOFF	(2)	Pooled	-	-	-
WF	2	0.000331	0.000165	4.0243	29.448

IP	2	0.000558	0.000279	6.804	49.644
Error	0	0.000083	0.000041	-	7.834
Total	8	0.001124			100%

The pooling error variance ANOVA summaries for DD are given in table 5. ANOVA for DD found the most significant factor is peak current and wire feed and remaining factor are estimates of error of variance. The F-ratios from the computed value are as follow: $F_{0.05; 1; 2}$ = 3.5. From Table 5 it can be interpreted that the pulse-on time (13.612%), peak current (49.44%) and wire feed (29.44%) are the percentage contribution of response characteristics of the Dimensional deviation.

3.1 Confirmation test: A confirmation experiment is conducting a test using an optimal combination of the parameters and levels previously evaluated. The final step of the Taguchi's parameter design after selecting the optimal parameters is to be predicting any verify the improvement of the DD with the selected optimal machining parameters. The predicted S/N ratio using the optimal levels of the WEDM parameters can be calculated with the help of following prediction equation [10]:

$$\eta_{opt} = \eta_m + \sum_{j=1}^{k}(\eta_j - \eta_m)$$

Here, η_{opt} is the predicted optimal S/N ratio, η_m is the total mean of the S/N ratios, η_j is the mean S/N ratio of at optimal levels and k is the number of main design parameters that affect the response. Optimum combination of factors level TON1, TOFF3, WF3 and IP1 is used to predict Dimensional deviation through prediction equation and found to be η_{opt} = 7.1367 db.

Table-6 Confirmation experiment result for DD

	Optimal machining parameters	
	Prediction	Experiment
Level	TON1, TOFF3, WF3, IP1	TON1, TOFF3, WF3, IP1,
S/N ratio for DD (db)	7.1367	7.68

Confirmation experiment was performed with optimal combination of different factors for DD and compared with result obtained from the predicted equations as shown in Tables 6. From the above observations, it can be interpreted that the obtained Dimensional deviations have reasonable accuracy for resulting model because an error of 7.07% for S/N ratio of Dimensional deviation measured.

4. Conclusion

The present experimental study for optimization of dimensional deviation of EN 41 B steel using molybdenum wire electrode during WEDM has following conclusion follows:

- The DD has significantly affected by Wire feed, and peak current. Optimal setting was obtained when the parameters are set at TON1, TOFF3, WF3, and IP1.
- The percentage contribution of WEDM parameters is given by TON: 13.612%, WF: 29.448%, IP: 49.664%, and error: 7.843%.
- DD is well-fitted with the experimental results within 95% CI level. The significant parameters with respect to the Dimensional Deviation are found the peak current and WF obtained by applying the Pooled ANOVA and F-test.
- WEDM input factors is optimized by the Taguchi optimization technique.
- DD increases with increase in pulse on time (TON) and peak current (IP).

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