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OPTIMIZATION OF WIRE-CUT EDM MACHINING PARAMETERS USING TAGUCHI'S TECHNIQUE DURING MACINING Al7075 ALLOY

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ABSTRACT

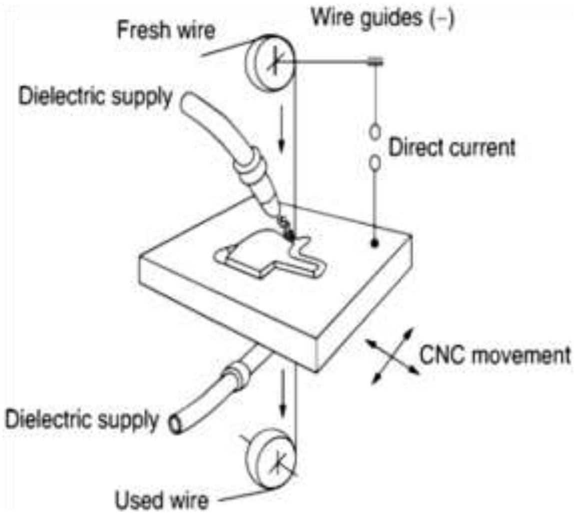
Now a days the manufacturing industries planning to improve the productivity with minimum amount of investment, so that optimization parameters plays major role in manufacturing industries. The optimization parameters such as (speed, feed, depth of cut, pulse on time and off time, gap voltage etc….)

By endured various journals about optimization of WEDM process and their optimization methods we choose Taguchi's Design of experiments and Taguchi's signal to noise ratio is used to estimate the optimum machining condition to produce the best possible response within the experimental constraints. The results from this study will be useful for manufacturing engineers to select appropriate set of process parameters to machine.

Keywords: gap voltage, pulse on and off time, surface roughness, kerf width

INTRODUCTION

Optimization of cutting parameters is valuable in terms of providing high precision and efficient machining. Wire-cut Electrical Discharge Machining (WEDM), a kind of non-traditional precision machining process, has been found to be an extremely potential electro-thermal process in the field of conductive material machining. In this process, the material removal occurs from an electrically conductive material by initiation of rapid and repetitive spark discharges between the gap of the work piece and tool electrode connected in an electrical circuit, and since there is no relative contact between the tool and the work piece, the work material hardness is not a limiting factor for machining of materials by this process. Because of its higher process capability, nowadays, the WEDM process is an important machining aid to produce complex and intricate shapes of components in areas, such as tool and die making, automobile, aerospace, nuclear, computer, and electronics industries. Some of the most important performance characteristics for the WEDM process are Material Removal Rate (MRR), Surface Roughness (SR), Wire Wear Rate (WWR), and Cutting Width (kerf), which are affected by numerous operating parameters, e.g., discharge current, discharge capacitance, pulse duration, pulse frequency, wire speed, wire tension, average working voltage, and dielectric flushing condition etc. Improved performance of the WEDM process can only be achieved by setting the optimal levels for those operating parameters.



Taguchi method of experimental design is a widely used technique for accomplishing the task for optimization of process parameters. This is because (a) it requires lesser number of experimental runs/trials, and (b) since it exploits the inherent non-linearity of relationship among the process parameters, noise factors, and quality characteristics, the performance of a process can be made insensitive to noise factors. It has been extensively verified that using

Taguchi's experimental design, the optimal parametric settings can be effectively determined. However, using Taguchi method, each performance characteristic is separately analyzed and, therefore, the parametric settings can be optimized with respect to one performance characteristic at a time.

But, for WEDM processes, the engineers are required to determine the parametric settings that can simultaneously optimize the multiple performance characteristics (responses). Many researchers have attempted several approaches for establishing an objective procedure for determining the optimal parametric settings that can optimize the multiple responses of WEDM processes. There are some other procedures which may also be useful for optimizing the multiple responses of WEDM processes. However, most of these approaches use complex mathematical/statistical tools and are, therefore, impractical for application by the engineers who may not have a strong background in mathematics/statistics.

The only approaches that require simpler computational procedures. For example combined signal-to-noise (CSN) ratio and the domain of advanced manufacturing technology, the main aim of the engineers is to obtain the best process/product performance. For a given WEDM process, it is not known which method can lead to the best results. Selection of the appropriate method for optimization of WEDM processes, therefore, remains an important issue to the engineers .

2.LITERATURE REVIEW

(1) Kapilkumar is studied the effect of various parameters, viz. pulse peak current, pulse-on time, pulse-off time, wire feed, wire tension and flushing pressure, on the material removal rate and surface finish. It has been observed that a combination of factors for optimization of each performance measure is different.

(2) P. K. Brahmankar is studied the effect of combination of reinforcement, current, pulse on-time, off time, servo reference voltage, maximum feed speed, wire speed, flushing pressure and wire tension on cutting speed, surface finish, and kerf width. Reinforcement percentage, current, and on-time was found to have significant effect on cutting rate, surface

finish, and kerf width. The optimum machining parameter combinations were obtained for surface finish, cutting speed, and kerf width separately.

(3) P.Sivaprakasam is investigated the influence of three different input parameters such as voltage. capacitance and feed rate of micro-wire electrical discharge machining (micro-WEDM) performances of material removal rate (MRR), Kerf width (KW) and surface roughness (SR) using response surface methodology with central composite design (CED) The experiments are carried out on titanium alloy (Ti-6Al-4V).

(4) Reza kashiryFard done the Experiments were designed and conducted based on L27 Taguchi's orthogonal array to study the effect of pulse on time, pulse off time, Gap voltage, discharge current, wire tension and wire feed on cutting velocity CV) and surface roughness (SR). Analysis of variances (ANOVA has been performed to identify significant factors.

(5) Amiteshgoswami investigated on surface integrity. material removal rate and wire wear ratio of Nimonic 80A using WEDM process. Taguchi's design of experiments methodology has been used for planning and designing the experiments. All of the input parameters and two factors interactions have been found to be statically significant for their effects on the response of interest. SEM was performed on the machined samples to investigate the effect and microstructure of the samples after machining. A higher pulse-on time setting leads to thicker recast layer. At lower value of pulse-on time and higher value of pulse off time, the wire deposition on the machined surface is low.

(6) R.Ramakrishnan predict the performance characteristics namely material removal rate and surface roughness, artificial neural network models were developed using back-propagation algorithms. Inconel 718 was selected as work material to conduct experiments. Experiments were planned as per Taguchi's L9 orthogonal array. Experiments were performed under different cutting conditions of pulse on time, delay time, wire feed speed, and ignition current. The responses were optimized concurrently using multi response signal-to-noise (MRSN) ratio in addition to Taguchi's parametric design approach. Analysis of

variance (ANOVA) was employed to identify the level of importance of the machining parameters on the multiple performance characteristics.

(7) N.Rajaneesh investigated on behavior of zinc-aluminium alloy reinforced with silicon carbide particles when machined with wire electric discharge machining process (WEDM). Machining is carried-out by varying applied current of (2, 4 and 6amp.), pulse on time (4, 8 and 16) and pulse off time (5, 7 and 9) while Other parameters such as voltage, dielectric flushing pressure, wire tension etc. are maintained constant. It is observed that reduction in the material removal rate and increase in surface roughness for increasing reinforcement percentage in the composite. It is also observed that applied current and pulse on time increases the material removal rate whereas pulse off time has less effect on it.

(8) Anish Kumar has investigation on WEDM of pure titanium (grade-2). An attempt has been made to model the four response variables, i.e., machining rate, surface roughness, dimensional deviation and wire wear ratio in WEDM process using response surface methodology. The six parameters, i.e., pulse on time, pulse off time, peak current, spark gap voltage, wire feed and wire tension have been varied to investigate their effect on output responses. These responses have been optimized using multi response optimization through desirability. The ANOVA has been applied to identify the significance of developed model.

(9) B. Bhattacharyya is studied wire electrical discharge machining (WEDM) of γ titanium aluminide. A feedforward back-propagation neural network is developed to model the machining process. The three most important parameters – cutting speed, surface roughness and wire offset – have been considered as measures of the process performance. The model is capable of predicting the response parameters as a function of six different control parameters, i.e. pulse on time, pulse off time, peak current, wire tension, dielectric flow rate and servo reference voltage.

(10) Rajesh Khanna investigated the effect of parameters on cutting speed and dimensional deviation for WEDM using HSLA as work piece. It is seen that the most prominent factor for cutting speed and dimensional deviation is pulse-on time, while two-factor interactions play

an important role in this analysis. Response surface methodology was used to optimize the process parameter for cutting speed and dimensional deviation. The results indicate that no method can lead to better optimization than the CSN method.

3. MATERIAL SELECTION.

In this work, the optimization of machining parameters are experimented on AL7075 alloy where AL7075 alloy is a chemical composition of 9 metals such as Aluminium (Al), chromium (Cr), copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn),
Silicon (Si), Tin (Ti), Zinc (Zn). In this zinc is the primary element next to the aluminium, remaining elements are secondary only because of their percentage of composition. 7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651. 7000 series alloys such as 7075 are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mold tool manufacture. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020. The chemical composition of the alloy is given in Table 1.

Table 1 Chemical composition of Al 7075 alloy

Sl. No	Component	Wt. %
1	Al	87.1 - 91.4
2	Cr	0.18 - 0.28
3	Cu	1.2 – 2
4	Fe	Max 0.5
5	Mg	2.1 - 2.9
6	Mn	Max 0.3
7	Si	Max 0.4

8	Ti	Max 0.2
9	Zn	5.1 - 6.1

4.METHODALOGY

The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. The Taguchi method tests pairs of combinations instead of testing all possible combinations. This allows determining the major factors affecting the output, with a minimum amount of experimentation. Analysis of variance on the collected data from the experiments can be used to select new parameter values to optimize the performance characteristic. Taguchi's design of experiments is used to design the orthogonal array for 3 parameters gap voltage, pulse on time and pulse off time and for each parameter 4 level values that were chosen is shown in Table 2.

Table 2 Input control parameters for WEDM

Parameter	Level 1	Level 2	Level 3	Level 4
Gap Voltage (volts)	60	70	80	90
Pulse ON-Time (ms)	5	6	7	8
Pulse OFF-Time (ms)	20	25	30	35

5. EXPERIMENTATION

In this work, two performance parameters kerf width and surface roughness are investigated by varying the three machining parameters on Al7075 alloy with brass wire as electrode in wire-cut electric discharge machine. Experiments are designed using Taguchi's design of experiment (DoE) and analyzed using signal-to noise (S/N) ratio. With the evolved optimum condition, a confirmation experiment is conducted. Experiments were performed on CNC wire-cut electrical discharge machine to study the material removal rate and wire wear ratio affected by machining process variable at different setting of pulse-on time (T_{on}), pulse-off time (T_{off}), gap voltage (GV). L_{16} orthogonal array (fourlevels) with six input variables was selected for experimentation sown in Table 3. The machining tests are carried out on the specimen material of AL7075alloy in rectangular block which as dimension of specimen are 96mm length, 80mm breath, 7.5mm width (96x80x7.5) were prepared from the block using brass wire electrode of diameter 0.25 mm). De-ionized water was used as the dielectric fluid.

Table 3 L_{16} Orthogonal Array

Exp. No	Gap Voltage (volts)	Pulse ON-Time (ms)	Pulse OFF-Time (ms)
1	60	5	20
2	60	6	25
3	60	7	30
4	60	8	35
5	70	5	25
6	70	6	20
7	70	7	35
8	70	8	30
9	80	5	30
10	80	6	35
11	80	7	20
12	80	8	25
13	90	5	35
14	90	6	30
15	90	7	25
16	90	8	20

For analysis, there are three categories of performance characteristics, (i.e.) Smaller-is-the-better, Larger-is-the-better and Nominal-is-the-better to determine the S/N ratio in Taguchi's

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technique. The impact of noise factors on performance is measured by means of S/N ratio. If the S/N ratio is larger, the product will be more robust against noise. For Smaller-the-better category, the quality characteristics are usually an undesired output and for Larger-the-better category, the quality characteristics are usually a desired output and for Nominal-the-best category, the quality characteristics are usually a nominal output.

Smaller-is-the-better (Minimize):

$$S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \tag{1}$$

Larger-is-the-better (Maximize):

$$S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}\right) \tag{2}$$

Nominal-is-the-best:

$$S/N = 10\log\left(\frac{\bar{y}}{s_y^2}\right) \tag{3}$$

6.PERFORMANCE PARAMETERS

In this work, three performance parameters kerf width and surface roughness are investigated by varying the three machining parameters on Al7075 alloy with brass wire as electrode in wire electric discharge machine. The performance parameters included are gap voltage, pulse on time (Ton) and Pulse off time (Toff). Experiments were conducted according to L_{16} Orthogonal Array Design. The optimum parameters value combination was found which would yield minimum Surface Roughness (SR) and minimum kerf width. The performance parameters are shown below Table 4

Table 4 Performance Parameter

Kerf width (microns)	Surface Roughness (µm)
0.132	1.784
0.184	1.872
0.158	2.127
0.358	1.157
0.132	1.25
0.205	1.687
0.138	2.872
0.176	1.567
0.252	1.679
0.227	2.343
0.468	2.078
0.258	2.354
0.264	2.213
0.354	1.948
0.357	2.589
0.357	2.109

7.DETERMINATION OF COMBINED S/N RATIO

Experiments are performed on a CNC wire-cut EDM machine. Surface roughness at the machined surface is determined using the Surfcorder and the kerf width is determined using tool maker's microscope. The determined values are provided in Table 4. After determining the output responses, Taguchi's signal to noise (S/N) ratio is determined for individual responses and then the combined S/N ratio is calculated by taking the average of the two separate individual S/N ratio as in Table 5

Table 5 Combined S/N ratio

Signal to Noise (S/N ratio)		Combined S/N ratio
Kerf width	Surface Roughness	
17.589	-5.028	6.280
14.704	-5.446	4.629
16.027	-6.555	4.736
8.922	-1.267	3.828
17.589	-1.938	7.825
13.765	-4.542	4.611
17.202	-9.164	4.019
15.090	-3.901	5.594
11.972	-4.501	3.735
12.879	-7.395	2.742
6.595	-6.353	0.121
11.768	-7.436	2.166
11.568	-6.900	2.334
9.020	-5.792	1.614
8.947	-8.263	0.342
8.947	-6.482	1.233

8. Effects of Combined S/N ratio:

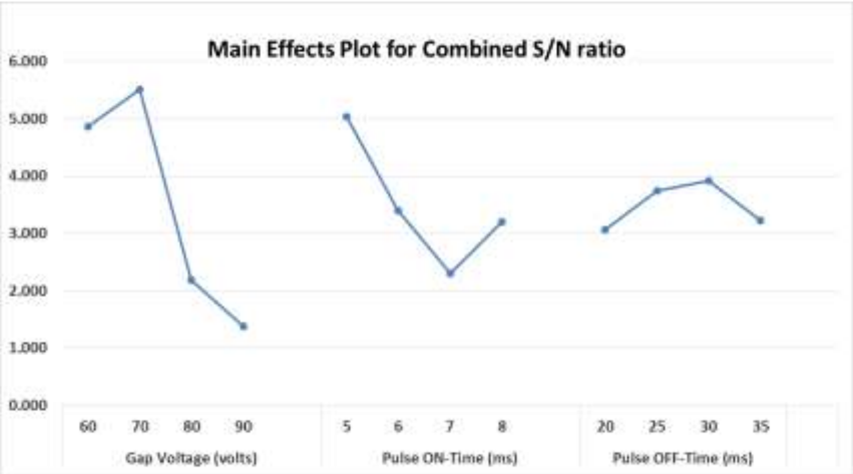
With the calculated combined S/N ratio, response table is developed to determine the optimum machining parameters for wire-cut EDM process. Table 7.4shows the developed response table for all the levels of the input parameters.

Table 6 Response table for combined S/N ratio

Factors	Level 1	Level 2	Level 3	Level 4	Max - Min
Gap Voltage	4.868	5.513	2.191	1.381	4.132
Pulse ON-Time	5.044	3.399	2.305	3.205	2.739
Pulse OFF-Time	3.061	3.740	3.920	3.231	0.859

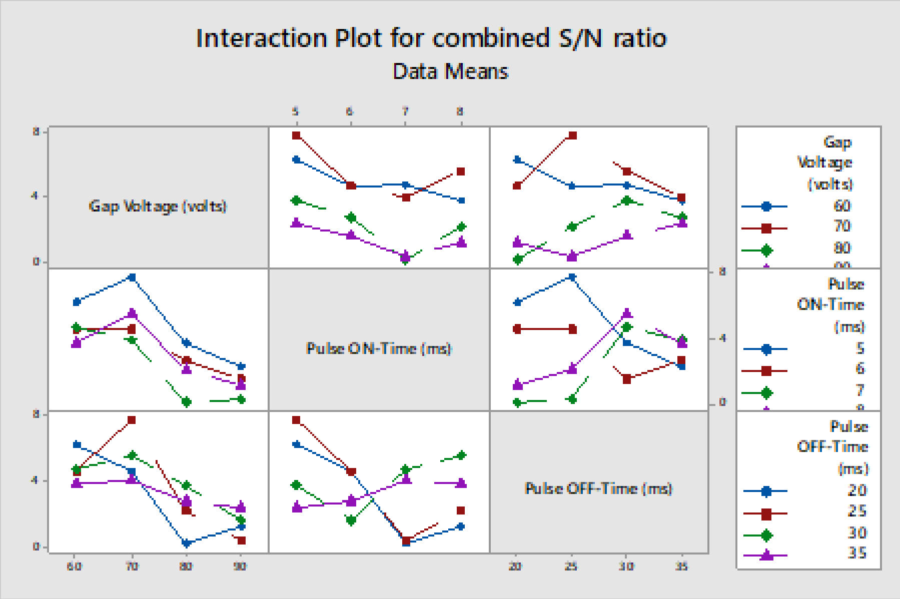
From the response table, main effects plot is drawn for the combined S/N ratio as shown in Fig. 6(a). From the figure, the optimum conditions achieved are: gap voltage of 70 volts, pulse ON-Time of 5 ms and pulse OFF-Time of 30 ms.

Fig 6(a) Main effects plot for Combined S/N ratio



For the given machining parameters, the combined single to noise ratio of a performance parameters such as gap voltage, pulse on time and pulse off time, the in interaction plot for combined S/N ratio were framed ,which is shown in fig 6(b).

Fig 6(b) Interaction plot for combined S/N ratio



9. ANALYSIS OF VARIANCE:

Analysis of variance (ANOVA) is a statistical technique used to evaluate the size of the difference between sets of scores. ANOVA is applied to a data set and these data may have been collected in either an experimental or non-experimental manner. It is most commonly applied to the results of the experiment to determine the percent contribution of each parameter over the output responses. Study of the ANOVA table for a given analysis helps to determine which of the factors need control and which do not. ANOVA is used to provide a measure of confidence. This technique does not directly analyze the data, but rather determines the variability (variance) of the data.

In order to determine the most contributing parameter towards the output response, ANOVA table is generated. Table 7 shows the ANOVA for the combined S/N ratio. It is observed that the gap voltage influences more than any other parameter by 70.20%, followed by pulse on time by 22.63%. The influence of pulse off time is very least. The percentile contribution of the input parameters over the calculated combined S/N ratio is shown below table.

Table 7 ANOVA table for combined S/N ratio

Factors	DoF	SS	MS	F Value	P Value	% Contribution
Gap Voltage	3	48.5049	16.1683	38.2735		70.20%
Pulse ON-Time	3	15.6358	5.2119	12.3377		22.63%
Pulse OFF-Time	3	1.9937	0.6646	1.5731		2.89%
Error	7	2.9571	0.4224			4.28%
Total	16	69.0914	4.3182			100.00%

Where ,

DoF – Degree of freedom

SS – Sequencial sum of square

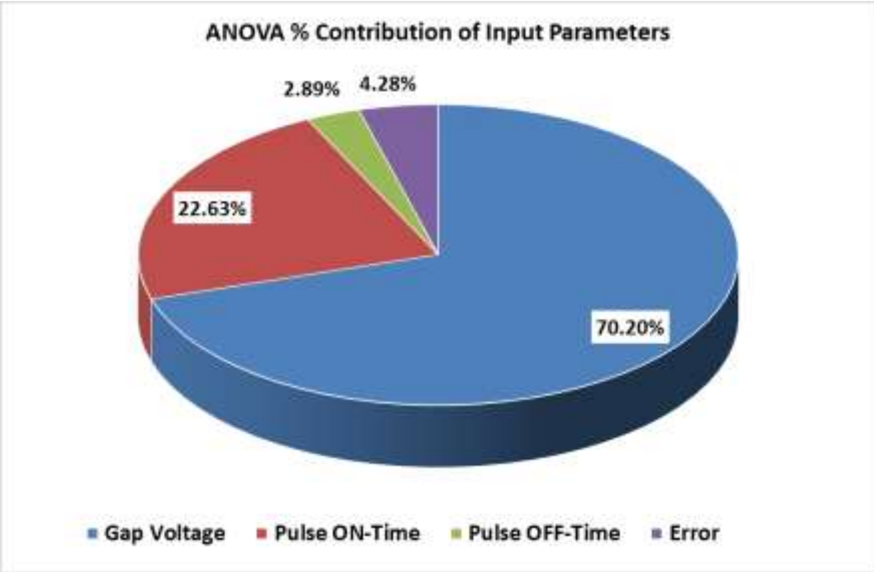
MS – Mean sum of square

F – Fisher value

P – Probability value

ANOVA shows the percentage of contribution of input parameters of gap voltage, pulse on time, pulse off time to find the best optimum condition

Figure 7.5 ANOVA % Contribution of Input Parameters



10. CONCLUSION

In this work, three performance parameters kerf width and surface roughness are investigated by varying the three machining parameters on Al7075 alloy with brass wire as electrode in wire electric discharge machine. The performance parameters included are gap voltage, pulse on time (Ton) and Pulse off time (Toff). Experiments were conducted according to L_{16} Orthogonal Array Design. The optimum parameters value combination was found which would yield minimum Surface Roughness (SR) and minimum kerf width. The following conclusions have been drawn:

1. The optimum conditions achieved are: gap voltage of 70 volts, pulse ON-Time of 5 ms and pulse OFF-Time of 30 ms.
2. From ANOVA, it is obvious that the influence of gap voltage is 70.20%, followed by pulse on time by 22.63%. The influence of pulse off time is very least.
3. Multi-objective optimization is performed by calculating the individual S/N ratio and then transferring that to combined S/N ratio, which provides a better result.