Optimization of Machining Parameters for Wire EDM of AMCs (LM5/ZrO_2) using Taguchi Technique

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Abstract: *Aluminium alloy with high toughness, hardness, and impact resistance, is increasingly in demand in the aerospace and mechanical industries. Machine tools have seen rapid growth over the past two decades, but they are still not commonly used to their maximum potential. The inability to use machine tools at their peak output thresholds is at the core of the problem. Practicing engineers and researchers were intrigued by the difficulty of reaching a meticulous analysis of effective parameters. AMCs-LM5/3,6,9% ZrO_2 fabricated by stir casting process are machined in Wire EDM to choose the optimum parameters by changing the Pulse on Time, Pulse off Time, Gap Voltage and Wire Feed. Achieving a good surface finish, as well as a better MRR and less kerf in the WEDM machining is of paramount importance. The experiments were conceded using the Taguchi's L_{27} OA to obtain the desired effects. ANOVA determines the parameters that affect the Wire EDM, and also the relative contribution of machining parameters. The optimum levels of process parameters, for maximum MRR, minimum SR and minimum kerf were calculated. S/N ratio analysis determines the parameter that has the most impact on the response. A confirmation experiment was done for the best combination of parameters.*

Key Words: *AMCs, Taguchi Technique, Wire EDM, ANOVA & S/N Ratio*

1. INTRODUCTION

MMCs have promising applications for sophisticated structural and general engineering materials. They are sometimes strengthened by Al_2O_3, SiC, B_4C, inorganic compound chemical element and recently with ZrO_2. Al-ZrO_2 alloys are used because the matrix material-Aluminium is increasingly in demand in aerospace, automobile and marine applications [1]. Matrix, reinforcement, and processing must be properly incorporated to improve physical and corrosion characteristics [2]. AMCs are attractive for their alike mechanical properties and are cheaper than all alternative matrix materials. AMCs machining is terribly difficult with the standard machining method, both traditional and non-traditional, due to their extreme abrasive properties [3]. EDM will be used efficiently for MMCs machining. The Pulse on Time and the Gap Voltage were the main parameters for maximum MRR while machining AMCs [4]. The most important parameter in accomplishing minimum surface roughness and kerf is the Pulse on Time [5]. Many researchers have done WEDM machinability and optimization of parameters of AMCs reinforced with B_4C, SiC, Fly Ash, etc., [6]. This research work deals with the Wire EDM machinability and optimisation of LM5/ZrO_2 composites which are not reported before by any researcher. The response variables like MRR, surface roughness and kerf in response to the input parameters of WEDM are presented here.

2. LITERATURE SURVEY

Standard metal alloys do not match the criteria; there is a growing demand for innovative materials in aerospace and automobile industries. MMCs have grown more popular in contrast to monolithic alloys due to their greater specific elasticity, heat resistance, and extreme specific strength [7]. The form and type of reinforcement impact the material properties, part fabrication and ease of processing [8].

Due to their low fabrication costs, the current focus is on MMCs; their end properties are ruled by many factors like processing technique, weight fraction, matrix composition, reinforcement's size, type, and secondary processing, morphology and process heat treatment [9,10]. Effective transition of load from matrix to reinforcement is based on the interface between them [11]. Reinforcement enhances temperature resistance, stiffness and strength, and reduces MMC density.

Since most ceramics are available as particles, there is a widespread choice of possible reinforcements for composites [12]. Ceramics are better reinforcements in aluminium alloy to improve properties [13]. Larger ZrO_2 particles were typically homogeneous while the smaller particles resulted in agglomeration, segregation, and porosity.

The density of the composites reduced when adding more volume of ceramic particles and fine particle size; the porosity and hardness of the composites escalate as the particles increased and the particle size decreased. Microstructural characterisation revealed the even distribution of ZrO_2 particles. The fabrication of composites by stir-casting technique is investigated. To improve its dispersion, pre-treatment of ZrO_2 particles is required. Preheating temperatures beyond 300°C result in particle accumulation and this process contributes to the sintering of particles and to the development of lumps [14].

DOE is a method to design and perform experiments and to develop, evaluate and infer the data so that relevant assumptions can be drawn economically and effectively [15]. It has proven successful in enhancing process performance and variability in processes. DOE deals with specifying the trails and settings needed to solve the problem [16]. The DOE among the different research techniques is more logical and relevant. The factorial technique is still one of the essential statistical techniques suggested for the DOE in engineering research [17].

WEDM is an unconventional machining process used to fabricate parts with complex shapes and contours. WEDM is a focused thermoelectric machining process of precisely machining components with multifaceted shapes with unpredictable hardness, with strident edges that are difficult to machine through traditional machining processes. This is based on the repetition of EDM sparks, using the non-contact material removal. WEDM has developed from a simplistic means of manufacturing dies and instruments to the finest option of creating micro-scale parts with reasonable SR and dimensional precision. Using wire electrode, WEDM creates complex 2D & 3D patterns by means of electrically conductive work pieces [18]. Not too much work on wire EDM has been published. Most of the published study was done in MMC reinforced by SiC. Very little work is done on ZrO_2 reinforced composites. Most useful MMCs on WEDM process have not been tested.

To govern the parameters during Al/SiC-MMC machining experiments were conducted using the Taguchi method, CNC-wire cut-EDM parameters are optimised [19]. A L_{18} mixed OA was utilized to calculate the S/N ratio and the ANOVA and the F-test values were used to specify the relevant machining parameters influencing the machining efficiency. Dry WEDM process experiments for the Al/SiC MMC machining. Experiments were planned and implemented based on Taguchi's L_{27} OA. ANOVA classifies the vital factors [20]. The machining of Al_2O_3p/6061Al composites with WEDM shows that the MRR, the surface roughness and the kerf width depend on the fraction of the volume of reinforcement particles [21]. The S/ N of SR, MRR and kerf were done for all experiments [22]. Taguchi's DoE approach is used to achieve the combination of parameters for MRR maximization as well as reducing SR & kerf [23, 24].

Using ANOVA, the degree of value of the parameters is established on MRR and kerf. Examination of the S/N ratio is used to achieve the optimal machining parameters. Interestingly, the optimum parameter level for all of the responses varies widely [25].The effect of machining parameters in the finish cut of WEDM, it is found that the SR can be enhanced by both the pulse duration and the discharge current [25].

The effect of electric parameters on the SR shows that a coarse surface was attained for high energy as well as low energy. The electrical parameter has an effect on the cutting rate. Wire breakage occurs at small pulse duration and low machining voltage to cut reinforced material from particles [26].

Taguchi's parameter method was used to investigate the influence of different parameters during the wire electric discharge machining for selecting optimum machining conditions. The mathematical models for MRR and SR were established to optimize each performance measure using nonlinear regression analysis [27]. The SR was considered better in composites compared with the unreinforced alloy [28]. Rajyalakshmi and Venkata Ramaiah (2013) applied Taguchi-based GRA for Inconel 825 wire cut electric discharge machining (WEDM) with multi-objective optimisation. The approach associates the DOE with GRA to decide the optimum machining parameters [29].

Since only trivial research work is completed on AMCs with Zirconium di oxide reinforcement particles, an attempt is made to fabricate LM5/ ZrO_2. AMC plates of size 100mm x 10mm x 5mm with matrix LM5 and ZrO_2 (3%, 6%, 9%) as reinforcement were used as the work piece material. 0.25mm diameter brass wire is used as tool that acts as an electrode, for conducting the WEDM experiments.

3. EXPERIMENTAL DETAILS

3.1 Materials

LM5 aluminium alloys have high resistance to corrosion among all cast aluminium alloys. They have bright polished surface finish and have the ability to anodize with a pleasant usual appearance of aluminium. They are therefore popular in food processing equipment, decorative castings, and pipe fittings in chemical and marine systems, dairy and ornamental / architectural applications [30].

ZrO_2 is a crystalline white oxide of zirconium, also known as Zirconia. The exceptional strength and very minimal thermal conductivity is another excellent combination of properties of Zirconia. Zirconia is one of the ceramic materials which are widely studied.

3.2 Fabrication of Composites

LM5 alloys need more care in preparation because they are more responsive in the existence of oxygen, atmospheric moistness, etc., [31]. Tiny ingots of LM5 alloys were put in a crucible and liquefied to the desired temperature of 850^0C in a furnace.

The LM5 aluminium alloy/ZrO_2 composites (3, 6, and 9%) were then produced by means of stir casting method. The ZrO_2 particles of size 60 to 80 μm were preheated at 250°C for the period of 20 minutes in a preheating furnace to get rid of the moisture.

Then the preheated ZrO_2 was further added into the liquefied aluminium. The mechanical stirrer continuously stirs the mixture. The stirring time was maintained around 7 minutes at an impeller speed of 400 rpm.

In the meantime, Argon gas is passed into the melt to eradicate the annoying gases in the liquefy melt and also to progress the quality of aluminium composite castings.

The melt pouring temperature was sustained at 750 ^{0}C and casted in a permanent die which is preheated to 650^{0}C.

3.3 Wire EDM of Composites

Wire EDM is an unconventional machining process where electricity is used effectively to cut any material that conducts electricity using a copper or brass wire as an electrode. The attraction of electrical charges produces a regulated spark as the wire gets close to the element, melting and igniting it, vaporizing small substance particles.

The spark takes out a small portion of the wire, but after the wire is removed, since passing through the work piece once, the system automatically throws-out the used wire and advances fresh wire. Fast hundreds of thousands of sparks per second is produced in the process but then the wire under no circumstances comes into interaction with the work piece. When wire EDM is being performed, deionized water which is a dielectric is used to cool and flush the machining area. During the cutting process, high-pressure upper and lower flushing nozzles clean away microscopic particles from the adjacent region of the wire, in many cases submerging the entire component in the dielectric fluid.

The fluid also serves as a non-conductive barrier in the machining area, preventing the development of electrically conductive channels [32].

As the wire gets nearby to the material, the electric field's force overwhelms the barrier, causing current to pass amongst the wire and the work piece and ensuring an electrical spark. The material removal is started by an electric spark.

3.4 Design of Experiments

The studies were designed to compare the results of the Pulse on Time, Pulse off Time, Gap Voltage, Wire Feed, and Reinforcement % utilising an OA of L_{27}. The process variables and their levels are shown in Table 1.

Table 1. Process Parameters and their Levels

Level	Pulse on Time (μs)	Pulse off Time (μs)	Gap Voltage (V)	Wire Feed (m/min)	Reinforcement %
1	110	30	20	3	3
2	115	40	30	6	6
3	120	50	40	9	9

4. RESULTS AND DISCUSSIONS

The experimental findings on WEDM of LM5/ ZrO_2 AMCs are presented in this section. MRR, SR, and Kerf are the subjects of analysis. Optimal process parameters were nominated by Taguchi's S/N ratio study, and confirmation experiments were carried out. Figure 1 shows the Photograph of WEDM Machined AMCs.

Fig. 1 Photograph of WEDM Machined AMCs

4.1 Experimental Results

The aim of these WEDM experiments is to investigate the effect of input parameters on response characteristics. Table 2 shows the investigational outcomes for MRR, SR, Kerf and their S/N ratios. L_{27} OA comprises 27 rows to equate to the number of experiments; 3 levels and 13 columns were selected.

Table 2. Experimental details and outcomes of MRR, SR and Kerf

Ex. No.	A	B	C	D	E	MRR (mm^3/min)	SR (μm)	Kerf (mm)	S/ N of MRR	S/N of SR	S/N of Kerf
	Pulse on Time (μs)	**Pulse off Time (μs)**	**Gap Voltage (V)**	**Wire Feed (m/min)**	**Reinforcement Percentage (wt %)**						
1	110	30	20	3	3	4.32	3.34	0.277	12.70	-10.46	11.15
2	110	30	30	6	6	3.68	3.18	0.313	11.32	-10.05	10.09
3	110	30	40	9	9	2.81	2.9	0.304	8.96	-9.25	10.34
4	110	40	20	6	9	4.55	3.24	0.303	13.15	-10.20	10.37
5	110	40	30	9	3	3.95	3.33	0.313	11.94	-10.45	10.09
6	110	40	40	3	6	2.78	2.95	0.313	8.89	-9.40	10.09
7	110	50	20	9	6	4.09	3.1	0.307	12.24	-9.83	10.26
8	110	50	30	3	9	3.62	3.27	0.305	11.18	-10.29	10.31
9	110	50	40	6	3	3.01	3.41	0.304	9.59	-10.64	10.34
10	115	30	20	3	3	7.73	5.41	0.322	17.76	-14.66	9.84
11	115	30	30	6	6	5.37	3.77	0.331	14.60	-11.52	9.60
12	115	30	40	9	9	4.32	3.61	0.324	12.71	-11.14	9.79
13	115	40	20	6	9	6.97	3.58	0.331	16.86	-11.07	9.60
14	115	40	30	9	3	6.28	5.54	0.34	15.95	-14.87	9.37
15	115	40	40	3	6	4.18	3.42	0.331	12.43	-10.68	9.60
16	115	50	20	9	6	6.64	3.31	0.332	16.44	-10.40	9.58
17	115	50	30	3	9	5.37	3.35	0.313	14.59	-10.49	10.09
18	115	50	40	6	3	4.53	3.74	0.34	13.13	-11.45	9.37
19	120	30	20	3	3	8.11	5.19	0.338	18.18	-14.30	9.42
20	120	30	30	6	6	7.44	3.99	0.341	17.43	-12.01	9.34
21	120	30	40	9	9	5.37	3.84	0.313	14.59	-11.69	10.09
22	120	40	20	6	9	8.90	4.2	0.341	18.98	-12.45	9.34
23	120	40	30	9	3	6.77	3.84	0.35	16.62	-11.68	9.12
24	120	40	40	3	6	5.47	4.33	0.319	14.76	-12.73	9.92
25	120	50	20	9	6	8.71	4.12	0.341	18.80	-12.30	9.34
26	120	50	30	3	9	6.94	3.86	0.341	16.82	-11.73	9.34
27	120	50	40	6	3	5.85	4.08	0.341	15.34	-12.20	9.34

4.2 Analysis and discussion of results of MRR

The Taguchi's parametric technique was used to perform the WEDM experiments. The effects of WEDM parameters on nominated characteristics – MRR are discussed in this section. Experimental results are used to quantify the S/N ratio of responses for every variable at various levels. The response graphs were used to investigate the parametric main effects on responses. S/N data were subjected to analysis of variance (ANOVA) in order to classify relevant variables and measure their impacts on responses. Analysing the response graphs and ANOVA table, the most favourable values of process variables, experiments with L_{27} OA were conceded out to examine the impact of input parameters on the response MRR. The MRR escalates with the increase of the Pulse on Time and declines with the increase of the Pulse off Time and Gap Voltage, as seen in Figure 2. This is because the discharge energy rises with the Pulse on Time ensuing to a higher MRR. The number of discharges within a given time frame upsurges as the Pulse off Time reduces, resulting in a higher MRR. The typical discharge gap widens as the Gap Voltage rises, resulting in a lower MRR [33]. The effect of Wire Feed and reinforcement are less. MRR is also visible to be lowest at the first level of the Pulse on Time and highest at the second level of the Pulse off Time.

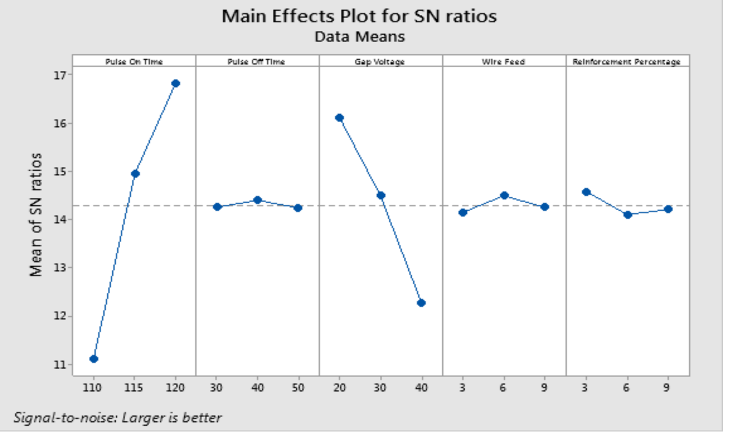

Fig. 2 Response graphs for MRR

4.3 Optimal levels selection for MRR

The average of each response characteristic for every levels of each factor is displayed in Table 3. The average value of each element to the response is shown by the ranks. According to the delta values and ranks, the Pulse on Time takes the biggest impact on MRR, trailed by the Gap Voltage. MRR is the 'higher the better' style consistency characteristic, and it can be shown from Figure 2 that the third level of the Pulse on Time, the second level of the Pulse off Time and the Wire feed, the first level of the Gap Voltage and the Reinforcement Percentage provide the maximal MRR.

Table 3. Response Table for MRR

Level	Pulse on Time	Pulse off Time	Gap Voltage	Wire Feed	Reinforcement Percentage
1	11.11	14.25	**16.13**	14.15	**14.58**
2	14.94	**14.40**	14.50	**14.49**	14.10
3	**16.84**	14.24	12.27	14.25	14.21
Delta	5.73	0.16	3.86	0.34	0.48
Rank	1	5	2	4	3

ANOVA determines the value of the input variables in relation to MRR. $F_{(0.05, 2, 22)} = 3.443$. As can be seen in ANOVA Table 4, the Pulse on Time and the Gap Voltage are significant [34]. The pooled up error includes the variables Wire Feed, Percentage Reinforcement, Pulse off Time, the interactions of the Pulse on Time with the Pulse off Time, the Pulse on Time with the Gap Voltage, the Pulse on Time with the Wire Feed and the Pulse on Time with the Percentage Reinforcement.

Table 4. ANOVA Table for MRR

Source of Variation	DoF	Sum of Squares	Mean sum of Squares	F_0	P	Contribution (%)
Pulse on Time	2	153.234	76.617	333.96	0	67.84
Gap Voltage	2	67.589	33.7946	147.3	0	29.93
Pooled Error	22	5.047	0.2294			2.23
Total	26	225.87				100.00

4.4 Confirmation Experiments for MRR

The optimal parameters are utilized in the confirmation experiments as well as in predicting the MRR. The variables at level A_3, B_2, C_1, D_2, E_1 (the Pulse on Time 120 µs, the Pulse off Time 40 µs, the Gap Voltage 20 V, the Wire Feed 6 m/min, and the Reinforcement 3 percentage) are the optimal parameters for achieving the maximum MRR, as seen in Figure 2. The experimental MRR value is 8.65 mm^3/min, while the predicted MRR value is 8.58 mm^3/min.

4.5 Analysis and discussion of results of SR

Table 5 and Figure 3 show that the SR values of all parameters at levels 1, 2, and 3 for S/N analysis. The SR decreases as the Pulse on Time decreases. It decreases as the Gap Voltage, the Pulse off Time, and the reinforcement are increased. The reason is the discharge energy varies with the Pulse on Time, and greater discharge energy creates a much larger crater, resulting in a higher SR on the work piece. The number of discharges reduces as the the Pulse off Time increases, resulting in improved surface accuracy due to steady machining [35]. The average discharge gap widens as the Gap Voltage rises, resulting in improved surface precision. The effect of the Wire Feed is not significant.

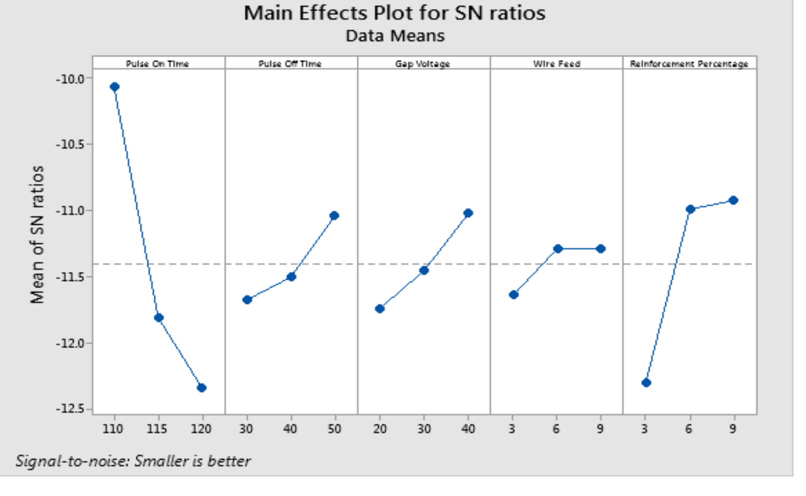

Fig. 3 Response Graphs for SR

4.6 Optimal Levels selection for SR

S/N data for each level of each factor is shown in Table 5. The findings of the experiments are evaluated in order to decide the best parameters. Since SR is a ‘lower is better' form of output characteristic, Figure 3 shows that the Pulse on Time first level, second level of wire feed, the Pulse off Time, the reinforcement and the Gap Voltage third level in the WEDM process have the lowest SR. ANOVA shows the prominence of the process variables in relation to SR.

$F_{0.05, 2, 6}$ = 5.143 and $F_{0.05, 4, 6}$ = 4.534 are the F-values from the table at the 5% significance level. So, according to ANOVA Table 6, the most prominent parameter is the Pulse on Time, followed by the Reinforcement Percentage. The pooled up error includes the variables Wire Feed, interactions of the Pulse on Time with the Wire Feed.

Table 5. Response Table for SR

Level	Pulse on Time	Pulse off Time	Gap Voltage	Wire Feed	Reinforcement Percentage
1	**-10.06**	-11.67	-11.74	-11.64	-12.3
2	-11.81	-11.50	-11.45	**-11.29**	-10.99
3	-12.34	**-11.04**	**-11.02**	-11.29	**-10.92**
Delta	2.28	0.64	0.72	0.35	1.38
Rank	1	4	3	5	2

Table 6. ANOVA Table for SR

Source of Variation	DoF	Sum of Squares	Mean sum of squares	F_0	P	Contribution (%)
Pulse on Time	2	25.603	12.8015	25.51	0.001	45.21
Pulse off Time	2	1.967	0.9833	1.96	0.221	3.47
Gap Voltage	2	2.378	1.1891	2.37	0.174	4.20
Reinforcement Percentage	2	10.889	5.4446	10.85	0.010	19.23
Pulse on Time*Pulse off Time	4	3.605	0.9012	1.8	0.248	6.37
Pulse on Time*Gap Voltage	4	2.755	0.6887	1.37	0.347	4.87
Pulse on Time* Reinforcement Percentage	4	6.419	1.6046	3.2	0.099	11.34
Residual Error	6	3.011	0.5019			5.31
Total	26	56.626				100.00

4.7 Confirmation Experiments for SR

The optimal parameters are used in the confirmation experiments as well as in predicting the SR. The findings of the experiments are evaluated to decide the preeminent parameters. The variables at level A_1, B_3, C_3, D_2, E_3 that is the Pulse on Time 110 µs, the Pulse off Time 50 µs, the Gap Voltage 40 V, the Wire Feed 6 m/min and the Reinforcement Percentage 9%, are the optimum parameters for achieving the minimum SR, as seen in Figure 3 and response Table 5. The predicted SR is 3.18 µm, while the experimental SR is 3.14 µm.

4.8 Analysis and Discussion of Results of Kerf

Table 7 and Figure 4 depict the kerf width (k_w) for each parameter for S/N data at levels 1, 2, and 3. The k_w reduces with a reduction in Pulse on Time. It decreases with increase in Gap Voltage, Pulse off Time, Wire Feed and reinforcement. The reason is the discharge energy rises with the Pulse on Time and larger discharge energy yields a higher crater, resulting a larger k_w on the work piece. The number of discharges reduces as the Pulse off Time escalates, resulting minimized kerf due to steady machining. The average discharge gap broadens as the Gap Voltage rises; results in improved surface finish [36]. The effect of Wire Feed is not significant.

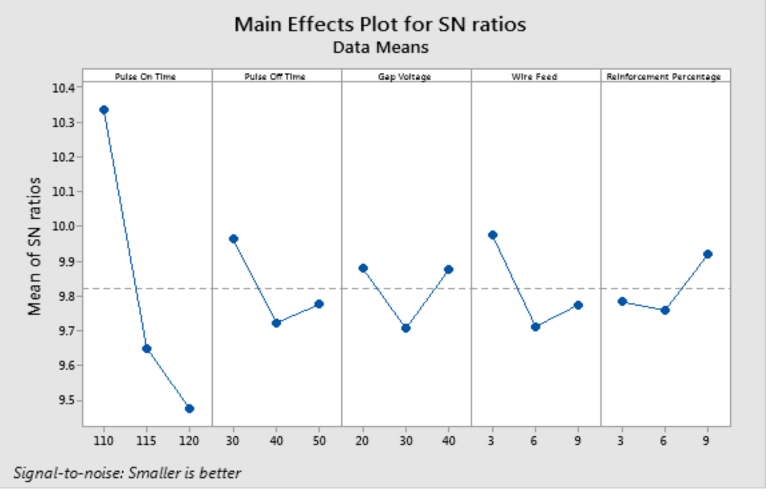

Fig. 4 Response graphs for Kerf

4.9 Optimal Levels Selection for Kerf

Table 7 displays the response for each level of each factor, the average of each output characteristics (S/N data). Since k_w is a 'lower is better' quality characteristic, Fig 4 shows that the level one of the Pulse on Time, Gap Voltage, Pulse off Time, and Wire Feed, as well as the level 3 of reinforcement, are responsible for the lowest k_w in the WEDM operation. ANOVA was used to determine the value of the process variables in relation to k_w. $F_{0.05, 2, 8}$ = 4.459 and $F_{0.05, 4, 8}$ = 3.838 are the F-values from the table at the 5% significance level. So, according to ANOVA Table 8, the utmost significant parameter is the Pulse on Time, and the interactions between the Pulse on Time and the Gap Voltage are also relevant. The Wire Feed, Pulse off Time, Reinforcement Percentage, and the interactions of the Pulse on Time with the Gap Voltage and the Reinforcement all help to reduce kerf (cutting width).

Table 7. Response Table for Kerf

Level	Pulse on Time	Pulse off Time	Gap Voltage	Wire Feed	Reinforcement Percentage
1	**10.338**	**9.964**	**9.879**	**9.976**	9.783
2	9.650	9.724	9.707	9.713	9.759
3	9.475	9.776	9.877	9.775	**9.921**
Delta	0.863	0.24	0.172	0.263	0.162
Rank	1	3	4	2	5

Table 8. ANOVA Table for Kerf

Source of Variation	DoF	Sum of Squares	Mean sum of squares	F0	P	Contribution (%)
Pulse On Time	2	3.7475	1.87374	100.56	0	64.47
Pulse Off Time	2	0.2863	0.14316	7.68	0.014	4.93
Gap Voltage	2	0.1759	0.08795	4.72	0.044	3.03

Wire Feed	2	0.3391	0.16954	9.1	0.009	5.83
Reinforcement Percentage	2	0.1368	0.06841	3.67	0.074	2.35
Pulse On Time*Gap Voltage	4	0.5965	0.14912	8	0.007	10.26
Pulse On Time* Reinforcement %	4	0.3813	0.09532	5.12	0.024	6.56
Residual Error	8	0.1491	0.01863			2.57
Total	26	5.8124				100.00

4.10 Confirmation Experiments for Kerf

The optimal parameters are used in the confirmation experiments as well as in predicting the k_w. The findings of the experiments are evaluated in order to decide the best parameters. The variables at level A_1, B_1, C_1, D_1, E_3 that are the Pulse on Time 110μs, the Pulse off Time 30μs, the Gap Voltage 20V, the Wire Feed 3m/min, and the Reinforcement 9 percentage are the parameters for achieving minimum k_w. The experimental value of k_w is 0.282 mm, while the predicted value is 0.288mm.

5. CONCLUSIONS

The purpose of this research work is to find the optimal machining parameters of Wire EDM for achieving maximum MRR, minimum SR and minimum k_w by Taguchi Technique. The following results were obtained:

i) The Pulse on Time (64.84%) has the leading statistical influence on MRR along with the Gap Voltage (29.92%). The error allied with ANOVA for MRR is 2.23% that shows 95% confidence level.

ii) The Pulse on Time (45.21%) has the leading statistical influence on SR along with Reinforcement Percentage (29.54%). The error allied with ANOVA for SR is 4.32 % that shows 95 % confidence level.

iii) The Pulse on Time (64.47%) has the leading statistical influence on k_w accompanied by the interaction of the Pulse on Time and the Gap Voltage (10.26%). The error allied with ANOVA for k_w is 2.57%, which shows 95% confidence level.

iv) The confirmatory experiments show that the Taguchi technique is the best suited for identifying the ideal process parameters for maximum MRR, minimum SR and Kerf.

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