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Multiresponse optimization of process variables of power mixed wire electrical discharge machining on AISI 304 stainless steel

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Wire Electrical Discharge Machining (WEDM) is widely used for machining conductive materials which are of great importance in several industrial applications. In this work, process variables optimization of Powder Mixed Wire Electrical Discharge Machining (PMWEDM) of AISI 304 stainless steel (SS) is studied using molybdenum wire as the tool material. This work illustrate the implementation of Taguchi technique and Genetic Algorithm (GA) to identify the optimal process variables of WEDM using dielectric medium mixed with Silicon Carbide(SiC) powder. Selection of optimum process variables for obtaining higher cutting efficiency and accuracy is a difficult task in WEDM due to presence of large number of control variables and complicated stochastic process mechanisms. In general, there is no perfect combination that can simultaneously result in both the maximum material removal rate (MRR) and the minimal surface roughness (Rq). The present work attempts to develop an appropriate machining strategy for a maximum process yield. MRR and Rq have been considered as measure of the machining performance with four different control parameters such as pulse on time, pulse off time, current and voltage. Experiments were conducted by Taguchi L_{18} (2^1 x 3^3) mixed orthogonal array. A multiple linear regression model is developed to relate the input and output variables and GA is used to optimize WEDM process variables. The optimized results for maximum MRR and minimum Rq are compared with and without powder mixed dielectric and confirmation tests were conducted.

Key Words: Powder Mixed Wire-EDM, MRR, Rq, Taguchi, GA.

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1. **Introduction:** Wire Electrical Discharge Machining (WEDM) is one of the non-traditional machining processes widely used for machining dies and tools, difficult-to-machine materials and intricate shapes. WEDM is a thermo- electrical process in which potential difference is applied across the work piece and wire electrode, ionization of dielectric takes place and a series of discrete sparks is generated across the two surfaces, which removes the metal from the work piece and flushed away by demineralised water. The work piece material used is AISI 304 SS. It is a nickel and chromium based alloy, has low thermal conductivity, heat capacity, high hardness and higher melting point. It is widely used in valves, refrigeration equipment, evaporators, cryogenic vessels due to corrosion resistant, high ductility, non- magnetic and retains solid phase up to 1400° Celsius [1]. Application also extended to hospital surgical equipment, marine equipment, fasteners, nuclear vessels, feed water tubing, etc. [2]. Many work have been attempted using powder- mixed dielectric fluid in EDM process, but very few work found using PMWEDM. Chin Chang Yeh et al [3] utilized two different dielectrics, pure water and pure water mixed with sodium pyrophosphate powder for machining polycrystalline silicon using WEDM process and studied its effects on cutting speed, kerf loss and surface roughness. Use of phosphorous dielectric increases the cutting speed by 2.4 times, reduces kerf loss and enhanced surface

roughness by 16% (due to smaller electrode voltage) than pure water dielectric. However the authors have not considered MRR in their study and used pure water in spite of this demineralised water was used. Geetha et al. [4] analyzed the performance characteristics of wire EDM with SS304 material with five process variables viz., pulse-on time, pulse-on time, wire tension and water pressure were take into account. The machining conditions of WEDM were brass wire of diameter 0.25mm and work piece material of SS 304 (L×160 B×75 H×16). MRR and Ra were taken as output. Then Response Surface Methodology (RSM) was used to develop the quantitative relationship between the input and output responses collected from central composite rotatable factorial design.The effect of the input parameters over the MRR and Ra plotted and tested for its adequacy using ANOVA (Analysis Of Variance). On the basis of the high values of multiple regression coefficients the second-order models are best fitting and later these models can be utilized for optimization.

Nixon Kuruvila and Ravindra [5] determined the parametric influence and optimized the process parameters of Wire-EDM for hot die steel using Taguchi`s technique and GA. They mathematically modeled by regression analysis method for showing the variation of minimum dimensional error, minimum Ra & maximum volumetric MRR with the machining parameters like pulse-on, current, pulse-off, bed speed and flush rate. Experiments were designed and conducted as per Taguchi`s L16 orthogonal array. They also assessed the heat affected zone characteristics and the micro hardness. Large spark intensity by high pulse-on, low pulse-off, high current, low flush rate and bed speed adopted for minimum dimensional deviation and kept all the five factors at low level for minimum surface roughness. For maximum MRR they adopted high spark intensity parameters, high bed speed and medium flush rate. It was concluded that the Maximum MRR can be augmented only by sacrificing the dimensional accuracy and surface finish. Sivakumar et al. [6] used standardized computer program using C language and easily manipulated to synthesize the optimal design tolerances for the components of an assembly. The GA has the capability to achieve multiple objectives and considerable reduction in computational effort. Sivakumar et al. [7] used GA for optimising turning operations under various economic criteria and numerous practical constraints, also this approach can be easily modified for other machining operation.

Anoop Kumar Singh et al. [8] conducted experiments using graphite-powder-mixed dielectric of 10g/l in electrical discharge machining of Super Co 605 and optimized by Taguchi method. The process parameters selected were flushing pressure discharge voltage, pulse on-time, polarity, peak current, and pulse off-time and studied the performance characteristics of Ra, tool wear and MRR. Experiments based on L18 orthogonal array were conducted and yields better surface roughness, lower tool wear and higher material removal rate when Taguchi method is used. Balbir Singh et al. [9] experimentally investigated the machining process of AA6061/10%SiC composite using EDM process with and without tungsten-powder-mixed dielectric fluid taking peak current, pulse on-time, pulse off-time, and gap voltage as machining parameters and surface characteristics like micro hardness, surface topography and white recast layer have been evaluated. Comparing with and without powder-mixed dielectric fluid, results reveal that PMEDM increases surface quality owing to decrease in number, size, and depth of craters formed while machining, reduces thickness of white recast layer but surface hardness is increased. Tzeng et al. [10] studied the effect of aluminum, chromium, copper, and silicon carbide powder as additives in dielectric medium on SKD 11 steel and found that concentration, density, size, electrical resistivity, and thermal conductivity have significant effect on EDM process performance. Chromium particles of 70–80 μm grain size produced maximum MRR, whereas copper particles have negligible effect due to high density. It was further reported that for the fixed concentration smaller the grain size, the MRR is higher with lower TWR.

Kuo-Wei Lin et al. [11] optimized the process of multiple quality characteristics like MRR and Ra for WEDM of magnesium alloy parts via the Taguchi method-based Gray analysis and showed improvement. Experimental study was conducted using L18 OA and analysis was done in ANOVA and F tests obtain the optimal single quality index, after which it was integrated with gray theory to construct the optimal, multiple quality characteristic index. However the authors have not considered Rq. Shah et al. **[12]** in his research, the process parameter optimization of Inconel-600 in WEDM is made using response surface methodology (RSM). The four inputs parameters namely peak current (IP), pulse- on time (T_{ON}), pulse-off time (T_{OFF}) and wire feed rate (WF) are taken to study the performance in measures of MRR. Each experiment was conducted under different conditions. Molybdenum wire and Taguchi's mixed L_{18} (2^1X3^3) orthogonal array is used. ANOVA is carried out and found that peak current, pulse-on time and pulse-off time are the most significant parameter on MRR.

From the foregoing literature survey it is observed that only limited work has been found on AISI 304 SS with pure water. Most of the literature discussed only about average surface roughness (Ra) but very few work found using root mean square surface roughness (Rq). The present work attempts to explore the influence of machining parameters of WEDM on AISI 304 SS using demineralised water has dielectric medium added with 1 g/l of SiC.

2. Experiment

2.1. Materials and methods: Molybdenum wire was used as wire material and AISI 304 SS as work material. In metallurgy stainless steel, also known as inox steel. Stainless steel differs from carbon steel by the amount of chromium present. SS type 304 is the most versatile and widely used stainless steel. It is still sometimes referred to by its old name 18/8 which is derived from the nominal composition of type 304 being 18% chromium and 8% nickel. Type 304 SS is an austenitic grade that can be severely deep drawn. This property has resulted in 304 being the dominant grade used in sinks and saucepans. Spectrography test was done on the workpiece material to confirm that the material is AISI 304 Stainless steel and the chemical composition is shown in the Table 1. Surface roughness of machined component was measured using Surface roughness tester 'MITUTOYO'-Japan (SJ-201P).

Table (1): Composition of AISI 304 stainless steel

Element	**Composition in**
Carbon	0.023
Silicon	0.415
Manganese	1.57
Nickel	9.31
Chromium	19.2
Molybdenum	0.147
Sulphur	0.0213
Phosphorous	0.0179
Copper	0.424
9*-	0.027
Fe(Iron)	68.84

2.2. Experimental design: After performing a detailed study of the range of four machining parameters pulse-on time, pulse-off time, voltage and peak current the levels has been selected for experimentation. The input parameters and their levels are shown in the Table 2. Other factors like product shape, work piece height, wire material, wire diameter, angle of cut, work piece material, work piece hardness and length of cut were kept constant during experimentation in order to avoid their affect on the measure of process performance.

Table (2): Process parameter and their levels

Machining Parameter	**Symbol**	**Unit**	**Level**		
			1	**2**	**3**
Pulse On Time (T_{on})	A	µs	15	25	35
Pulse Off Time (T_{off})	B	µs	4	5	6
Peak Current (I)	C	Ampere	2	3	4
Voltage (V)	D	Volt	0*	1*	-

* Machine input parameters for 0 is 75 V and 1 is 100 V

The experiments are planned based on the orthogonal array. The experiments were conducted according to Taguchi L18 orthogonal array (3^3 x 2^1) **[8, 11, 12]** obtained from Minitab software as shown in Table 3. The Taguchi method apparently has consistency in experimental design, analysis, reduction in time and cost of experiments.

Table (3): Layout of L18 orthogonal array for Experimentation

Expt. No.	**Random Run**	**Pulse-on (µs)**	**Pulse-off (µs)**	**Current (A)**	**Voltage (V)**
1	10	15	4	2	0
2	4	15	5	3	0
3	16	15	6	4	0
4	8	25	4	2	0
5	14	25	5	3	0
6	2	25	6	4	0
7	18	35	4	3	0
8	6	35	5	4	0
9	12	35	6	2	0
10	13	15	4	4	1
11	1	15	5	2	1
12	7	15	6	3	1
13	17	25	4	3	1
14	11	25	5	4	1
15	5	25	6	2	1
16	3	35	4	4	1
17	15	35	5	2	1
18	9	35	6	3	1

2.3. Experimental setup: The experiments were performed on DK7720 CH high precision 4 axis CNC WEDM. The basic parts of the WEDM machine consists of a wire, a worktable, a servo control system, a power supply and dielectric supply system. The WEDM allows the operator to choose input parameters according to the material and height of the work piece and tool material from a manual provided by the WEDM manufacturer. According to Trezise [13], the fundamental limits on machining accuracy are dimensional consistency of the wire and the positional accuracy of the worktable. In this machine all the four axes movements are (four simultaneously) controlled by closed loop dc motor system. The Figure.1 shows the machine while machining the work piece producing discrete spark.

For each set of parameters, the chosen work piece was cut to a length 20mm (5 x 5 mm) square piece with 25 mm height as shown in Figure.2 and spark gap is taken as 0.02mm on either side. Time taken was noted down, as the time delays due to wire breakage or power failure were automatically taken care of by the control system. Each piece was cleaned and the surface finish Rq was measured. Average of the readings taken at four places perpendicular to the direction of cut was chosen as the surface roughness value.

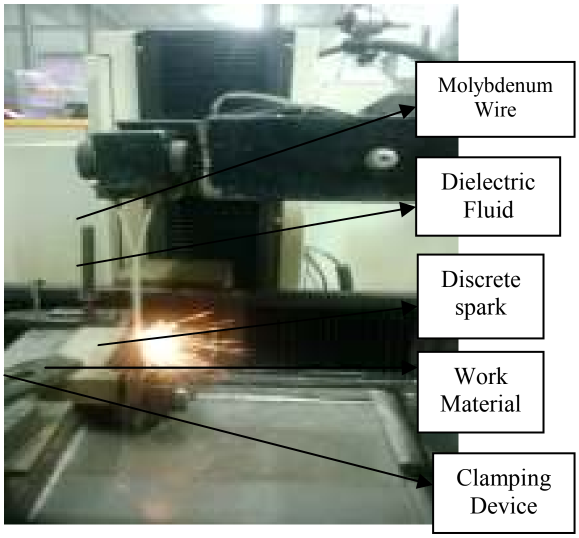

Figure (1): Discrete spark produced during PMWEDM.

By using the DOE created in Table 3, the experiments were conducted on the WEDM machine for three trials and their respective time taken for machining the profile was noted. With the time taken, the material removal Rate (MRR) is calculated using the equation (1) and (2), where Vc cutting length / time (mm/min), h height of the workpiece (mm), b breadth of the work piece (mm), Wg spark gap (mm) and d diameter of the wire (mm) and the surface roughness (Rq) of the machined profiles were also obtained (in µm)by measuring the mean absolute deviation.

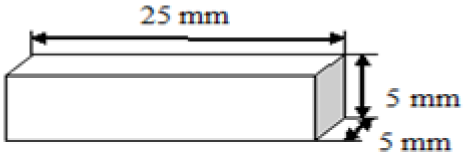

Figure (2) Isometric view of work piece

$$MRR = Vc \times b \times h \ (mm3/min) \quad ---(1)$$

$$b = 2Wg + d \quad ---(2)$$

Among the surface roughness average (Ra) is the arithmetic average of the absolute values of the roughness profile ordinates, roughness depth (Rz) is the maximum surface roughness value in a single point and root mean square roughness (Rq) is the root mean square average of the roughness profile ordinates. Among these Rq was selected for study, as it gives the correct roughness value and given by the equation (3)

$$Rq = ((Rz_1^2 + Rz_2^2 + Rz_3^2 + \ldots + Rz_n^2)/n) \quad ---(3)$$

2.4. Silicon carbide powder mixed in dielectric: Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral mossainite. Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics which are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bullet proof vests. Silicon carbide is a popular abrasive in modern lapidary due to the durability and low cost of the material. In manufacturing, it is used for its hardness in abrasive machining processes such as grinding, honing, water jet cutting and sand blasting. Particles of silicon carbide are laminated to paper to create sand pipers and the grip tape on skateboards. In this work SiC powder of mesh value 40 was mixed with dielectric.

At the beginning of the process several tests were conducted to determine the optimum quantity of powder. Series of experiments were conducted using deminerlised water (50 liters). Then 1g/l of silicon carbide is added and the results were observed. Correspondingly for every set, 1g/l is added and the spark pattern, time, condition of water were studied. When 1g/l was added there was a reduction in time by 10% resulting in increase of MRR. And when the quantity of powder mixed was increased like 2g/l, 3g/l and 4g/l there was no significant change. So finally 1g/l was selected as the optimal quantity since it showed improvements in terms of MRR and Rq.

3. Results & discussion: Design optimization can be defined as the process of either maximizing functional or effect minimizing undesirable effect, which may be called objective function and it may also satisfy a certain set of specified requirements called constraints. For example, quantities such as surface roughness, cost and weight are to be minimized which forms the objective function. Many methods have been developed and are in use of design optimization. All these methods use mathematical programming techniques for obtaining solutions. This work attempts an approach towards non-traditional techniques for design optimization of machining process.

Initially in the present investigation, the Taguchi technique **[14]** was used to optimize the process variables for better metal removal rate and SR in WEDM using the Minitab software. The characteristic that higher value represents better machining performance, such as MRR is called 'higher is better, HB'. Inversely, the characteristic that lower value represents better surface finish is called 'lower is better` LB. Therefore,"HB" for the MRR and "LB" for the Rq were taken and the loss function (L) for objective of HB and LB is defined as **[15]**:

$$L_{HB} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y^2_{MRR}} \quad ---(4)$$

$$L_{LB} = \frac{1}{n} \sum_{i=1}^{n} y^2_{Rq} \quad ---(5)$$

The results of the response measures are converted into S/N ratio using equation (6) & (7), the S/N ratio values are calculated for MRR and Rq taking mean value of three trails.

S/N ratio for MRR $=-10\log(L_{HB})----(6)$

S/N ratio for Rq $=-10\log(L_{LB})----(7)$

Table 4 shows the experimental outcome of mean MRR and Rq, with signal to noise ratio of MRR and Rq and the minimized value of Z calculated from Eq. (11) without mixing powder with the dielectric medium.

Table (4): Experimental results (without powder).

Exp No.	**Mean (MRR)**	**Mean (Rq)**	**S/N Ratio (MRR)**	**S/N Ratio (Rq)**	**Value of Z**
1	4.558267	3.519167	13.1760	-10.9288	0.114979
2	5.12557574	3.595	14.1949	-11.1140	0.100083
3	5.7837442	4.1125	15.2442	-12.2821	0.11744
4	4.93817756	3.570833	13.8713	-11.0554	0.105075
5	6.07357063	4.221667	15.6689	-12.5097	0.11551
6	6.37447804	4.928	16.0889	-15.1656	0.161328
7	7.6972225	4.9525	17.7267	-13.8965	0.114313
8	7.94983161	5.53	18.0072	-14.8545	0.15153
9	3.83005557	4.77	11.6641	-13.5704	0.242824
10	11.9119471	5.086667	21.5197	-14.1287	-0.031
11	6.20725745	4.159167	15.8580	-12.3801	0.105518
12	6.76600255	4.385133	16.6066	-11.8565	0.103047
13	11.3217955	5.510833	21.0783	-14.8243	0.025096
14	11.142346	5.835833	20.9395	-15.3221	0.057952
15	5.95735213	5	15.5011	-13.9794	0.182583
16	13.4753005	6.2025	22.5908	-15.8513	0.001116
17	7.56531083	5.643333	17.5765	-15.0307	0.174911
18	8.94810523	5.8575	19.0346	-15.3542	0.140968

The plots from the Figure.3 & 4 lead to the conclusion that the MRR increases when $T_{on,}$ voltage and current increases and decreases when T_{off} decreases.

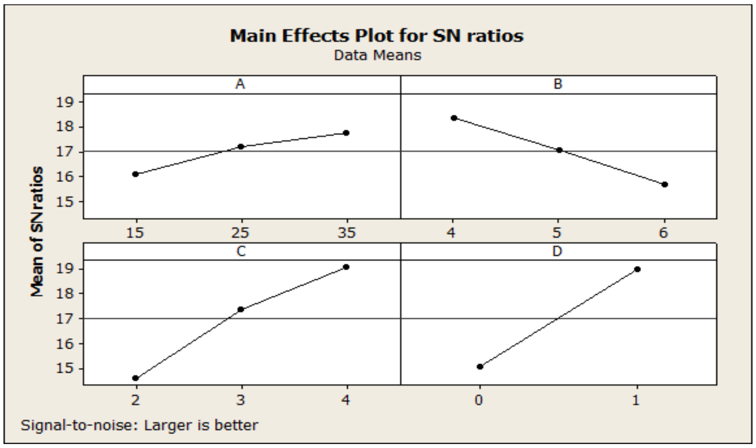

Figure (3): Effect of control factors plot of S/N ratio on MRR (without powder).

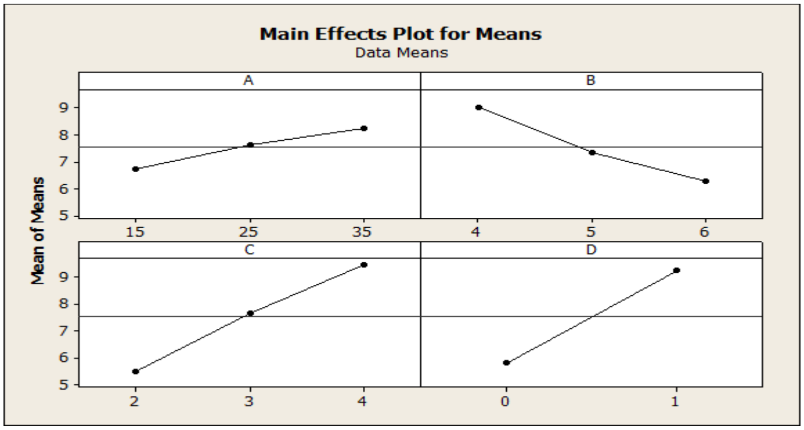

Figure (4): Effect of control factors plot of raw data on MRR (without powder)

The plots from the Figure.5 & 6 lead to the conclusion that Rq increases when T_{off} increases and decreases when $T_{on,}$ voltage and current decreases.

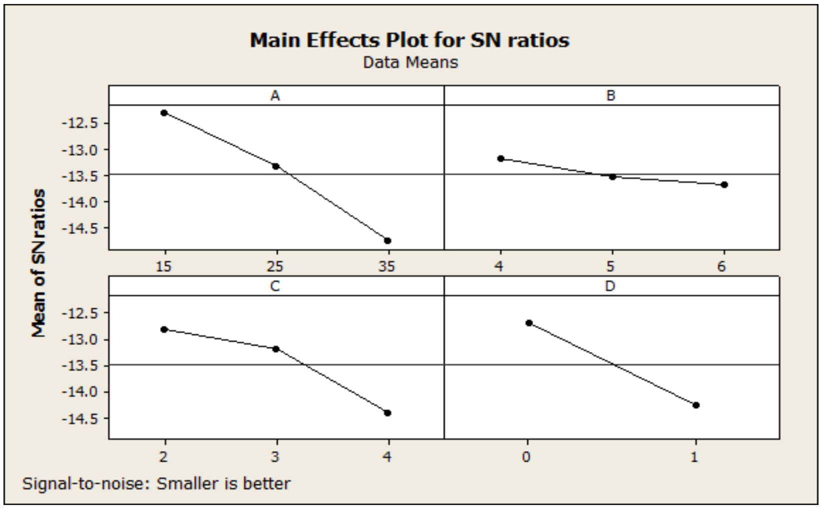

Figure (5): Effect of control factors of S/N Ratio on Rq (without powder).

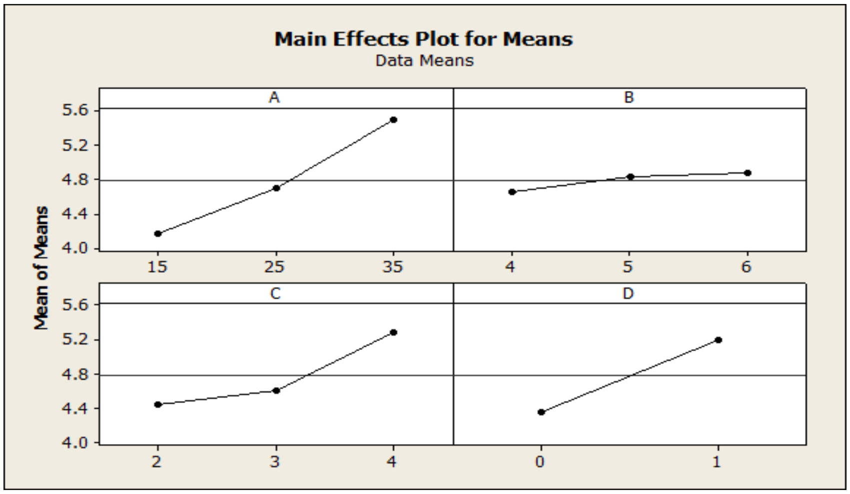

Figure (6): Effect of control factors of raw data on Rq (without powder).

The regression technique **[16]** was employed to know the effect of T_{on}, T_{off}, voltage and current on MRR and Rq. With the recorded data, the predicted model for MRR and Rq is expressed as follows:

$$MRR = 4.7886 + 0.0759419A - 1.35358B + 1.9651C + 3.4405D ------(8)$$

S = 0.393201; R^2 (adj) = 97.99%

$$Rq = 0.884853 + 0.0666249A + 0.108008\ B + 0.423468\ C + 0.844695D ---(9)$$

S = 0.234274; R^2 = 93.8%; R^2(adj) = 91.9%

The predicted R^2 value and the adjusted R^2 value were found to be in good agreement.
For maximization and minimization the following equation (10) & (11) are used respectively.

$$Z = (0.5) * (MRR\ / 13.5) - (0.5) * (Rq\ /6.5) --- (10)$$

$$Z = (0.5) * (Rq/6.5) - (0.5) * (MRR\ / 13.5) --- (11)$$

Since, the program objective was written for minimization, equation (11) was chosen for further optimization using GA. In this work, the behavior of four control factors viz., A, B, C, D, and two response viz., MRR and Rq were studied. The experimental observations are further transformed into a signal-to-noise (S/N) ratio.

By substituting the mean of MRR and Rq values in the combined objective function(11),the optimal value obtained by Taguchi method and that minimum value of Z = - 0.031, and the corresponding parameter combination for this minimum value is (15-4-4-1). For this combination, the MRR and Rq are found using the equations (8) and (9). The corresponding MRR and Rq values from the above equations are shown in Table 6.

In order to arrive at an optimal solution using GA reproduction, cross over probability (Pc), mutation probability (Pm) and the number of generation of particular generation are varied and number of feasible solutions was obtained.

Population size	: 70
Total no. of generations	: 300
Cross over probability (Pc)	: 0.8500
Mutation probability (Pm)	: 0.1500
String length	: 40

Using the combined objective function (11) in the visual C++ program for GA, the minimum value obtained is **Z =0.055** and this is shown in figure.7. For this corresponding parameter combination is (15.723 - 4.029 - 3.935 - 0.974) and optimal MRR and Ra value is shown in Table 7.

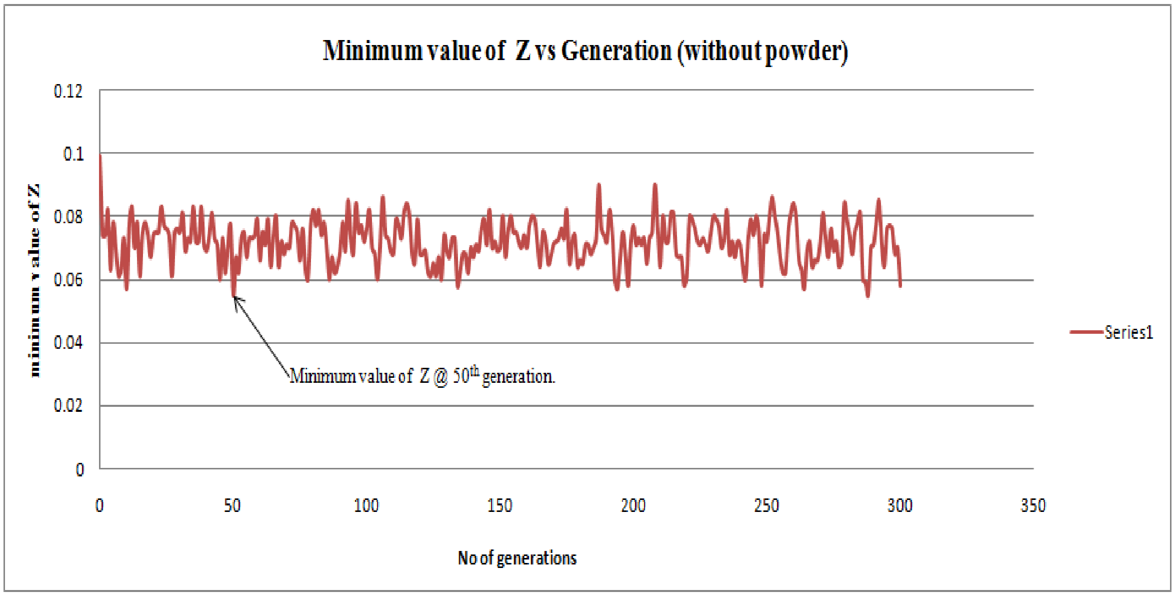

Figure (7): Variation of optimal value with respect to number of generations (without powder)

Table 5 shows the experimental outcome of mean MRR and Rq, with signal to noise ratio of MRR and Rq and the optimized value of Z calculated from Eq. (11) when SiC powder mixed with the dielectric medium.

Table (5): Experimental results of SiC Suspended in dielectric fluid

Exp. No.	**Mean MRR**	**Mean Rq**	**S/N Ratio (MRR)**	**S/N Ratio (Rq)**	**Z Value**
1	5.12698814	4.02	14.1972	-12.0845	0.207535
2	5.74125688	4.16	15.1801	-12.3819	0.201787
3	6.05425886	4.295	15.6412	-12.6593	0.204563
4	5.70861966	4.191666	15.1306	-12.4477	0.205597
5	6.81241778	4.598333	16.6660	-13.2520	0.209166
6	7.35473095	4.564167	17.3313	-13.1872	0.189954
7	8.06453831	4.444167	18.1316	-12.9558	0.158064
8	9.36124991	4.920833	19.4267	-13.8408	0.16216
9	4.26042593	4.236667	12.5891	-12.5405	0.252756
10	13.5697499	5.121667	22.6514	-14.1882	0.054829
11	6.89476613	4.7125	16.7704	-13.4650	0.216943
12	7.83009107	4.290833	17.8753	-12.6508	0.151306
13	12.48529	5.070833	21.9280	-14.1016	0.082568
14	12.7120138	5.1925	22.0843	-14.3075	0.086719
15	6.84799413	4.579167	16.7113	-13.2157	0.206389
16	16.7942739	5.5861	24.5032	-14.9422	0.000419
17	8.40926178	4.608333	18.4952	-13.2709	0.162508
18	10.208534	4.6729	20.1793	-13.3917	0.114712

The regression model was developed with the recorded data to know the effect of T_{on}, T_{off}, voltage and current on MRR and Rq with SiC powder mixed in dielectric and is expressed as follows:

$$MRR = 4.87 + 0.0990A - 1.60B + 2.38C + 4.14D --- (12)$$

$$S = 0.605597; \quad R^2 = 97.5\%; \quad R^2\ (adj) = 96.8\%$$

$$Rq = 3.91 + 0.0156A - 0.150B + 0.278C + 0.489D --- (13)$$

$$S = 0.176959 \quad R^2 = 86.3\% \quad R^2\ (adj) = 82.1\%$$

The predicted R^2 value and the adjusted R^2 value were found to be in good agreement.

The plots from the Figure.8 & 9 lead to the conclusion that the MRR increases more than without powder when $T_{on,}$ voltage and current increases and decreases when T_{off} decreases.

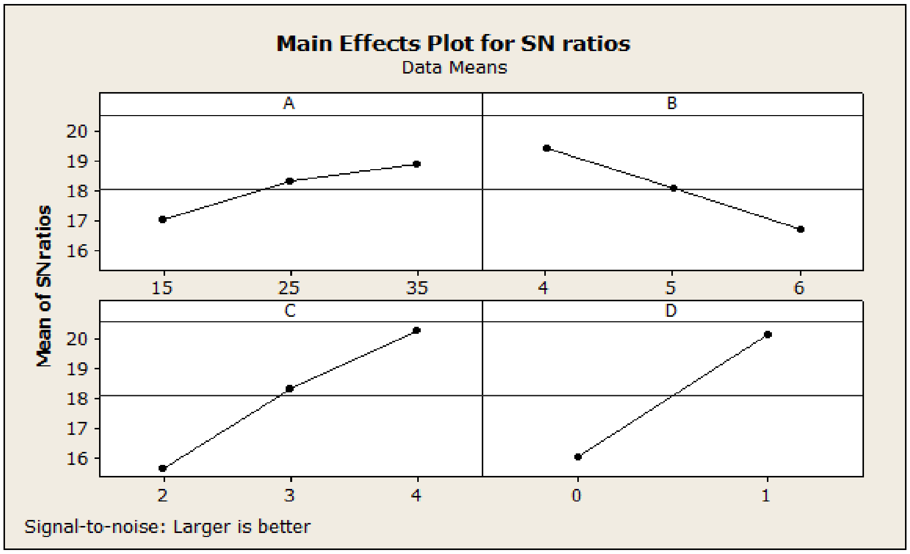

Figure (8): Effect of control factors of S/N Ratio on MRR (with SiC powder)

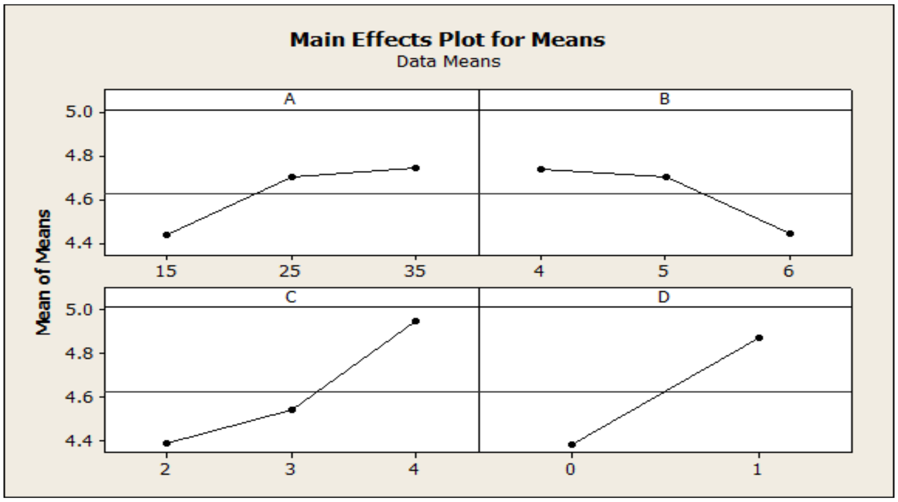

Figure (9): Effect of control factors of raw Data on MRR (with SiC powder)

The plots from the Figure.10 & 11 lead to the conclusion that Rq increases more than without mixing powder than when T_{off} increases and decreases when $T_{on,}$ voltage and current decreases.

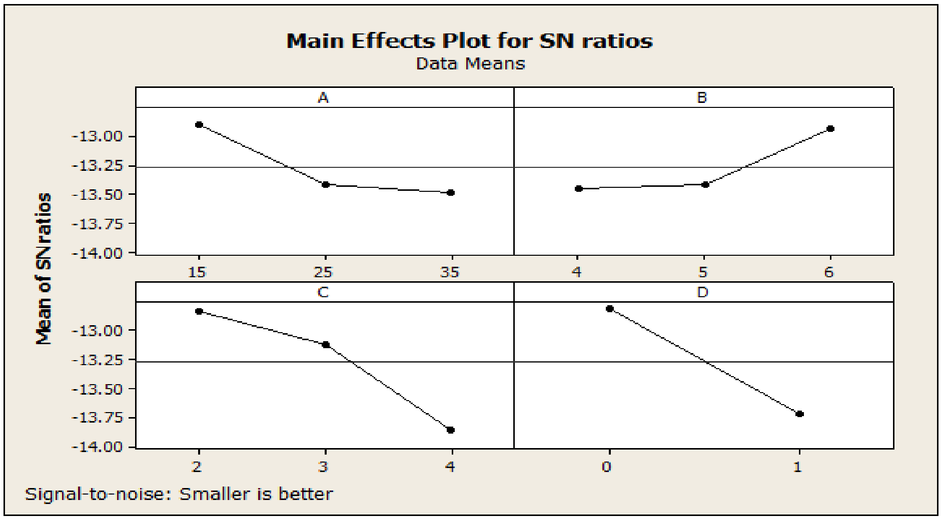

Figure (10): Effect of control facrs of S/N Ratio on Rq (with SiC powder).

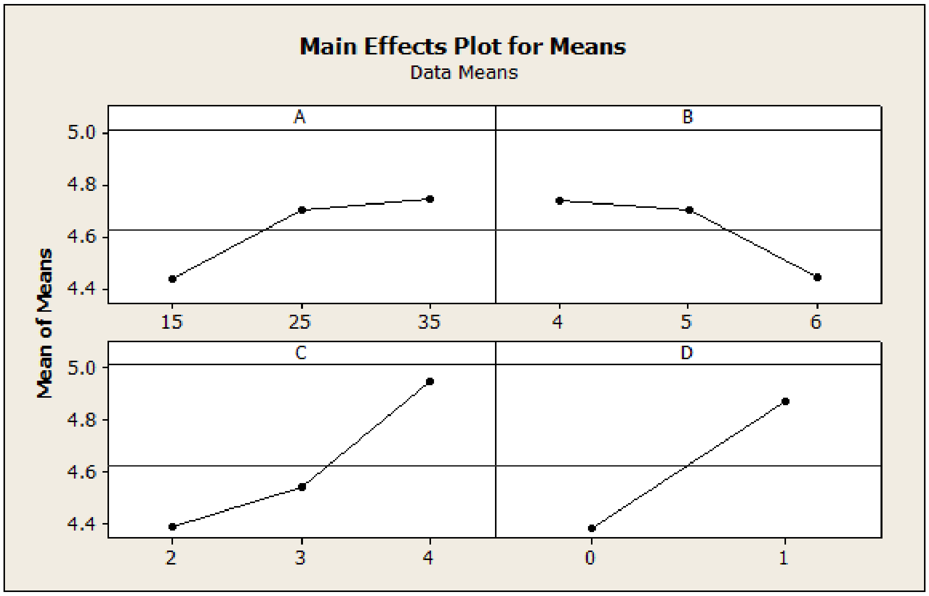

Figure (11): Effect of control factors of raw data on Rq (with SiC powder)

For SiC powder mixed in dielectric minimization equation is as follows:

$$Z = (0.5) * (Rq \ / \ 6) - (0.5) * (MRR \ / \ 17) --- (14)$$

By substituting the mean of MRR and Rq values in the combined minimization equation (14), the optimal value obtained is Z = 0.000419 and the corresponding parameter combination for this minimum value is 35-4-4-1. For this combination, the MRR and Rq are found using the equations (12) & (13) and the corresponding optimal MRR and the Rq values are shown in the Table 6.

Using the combined objective function (14) through GA, the minimum value obtained among 150 generations of 70 population is Z = -0.007 and this is shown in Figure.12. For this corresponding parameter combination is (16.016 - 4.041 - 3.935 - 0.994) and the optimal MRR and Rq are shown in Table 7.

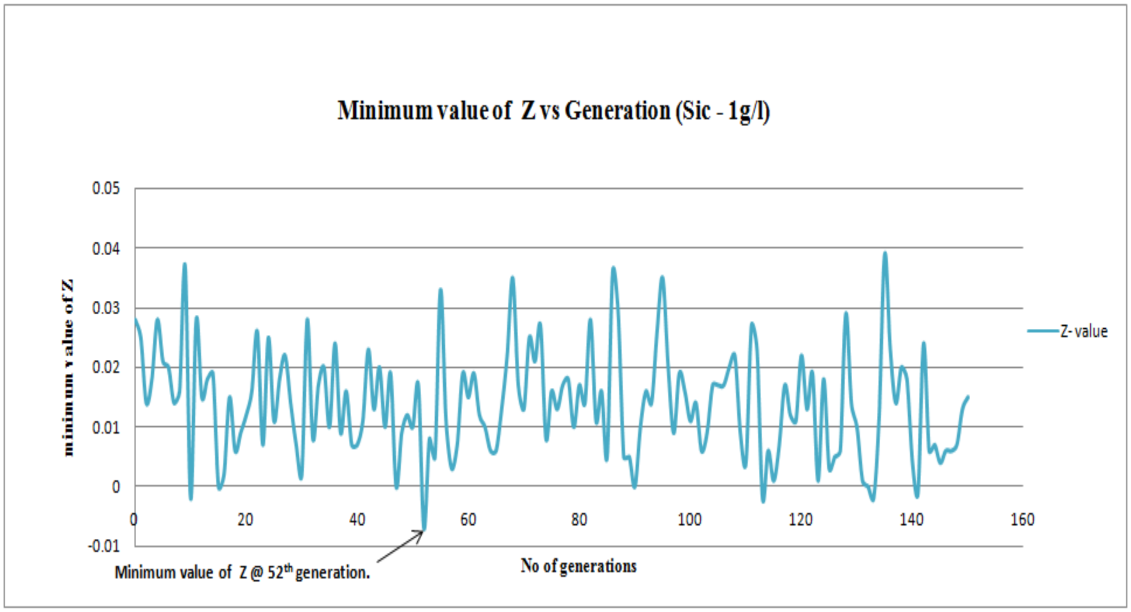

Figure (12): Variation of optimal value with respect to number of generations (with SiC powder)

Table (6): Result comparison using Taguchi

Dielectric Mixed	Response Variables	Taguchi	Confirmation
Without Powder	MRR(mm^3/min)	11.81431	12.26518
	Rq(µm)	4.854826	4.920833
With SiC Powder	MRR(mm^3/min)	15.595	16.64126
	Rq(µm)	4.457	4.936667

Table (7): Result comparison using GA.

Dielectric Mixed	Response Variables	GA	Confirmation
Without Powder	MRR(mm^3/min)	11.6153	12.60032
	Rq(µm)	4.857393	4.418333
With SiC Powder	MRR(mm^3/min)	13.47209	14.17784
	Rq(µm)	4.133893	4.274167

From Table 6 and 7 it is evident that adding 1g/l of SiC powder with the dielectric fluid improves the MRR and Rq to a considerable extend than without adding powder. Table 6 and 7 also shows the results of confirmation experiment using the optimal machining parameters.

4. Conclusions : An experimental investigation has been made on WEDM of AISI 304 stainless steel with Silicon Carbide powder suspended in dielectric medium and without powder. A multiple linear regression model was developed to model the various process variables. A multi-objective optimization of PMWEDM process variables by using Taguchi and GA techniques was employed. The Taguchi analysis results reveal that the machining process variables (25-5-4-1) show the optimal MRR and Rq with a deviation of 5% with and without mixing Silicon Carbide powder in dielectric medium. From GA results, it was found that Silicon Carbide powder suspended in dielectric medium with process variables (35-4-4-1) yields the best MRR and Rq. The validity of the obtained optimized process variables results were confirmed with experimental results and the deviation is less than 6%.

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