OPTIMIZATION OF PROCESS PARAMETERS OF SINKER EDM BY MIXING SIC POWDER IN DIELECTTRIC FLUID USING GREY-RELATIONAL TAGUCHI TECHNIQUE

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ABSTRACT :

EDM process is based on thermoelectric energy between the work piece and an electrode. Material removal rate (MRR) is an important performance measure in EDM process. Since long, EDM researchers have explored a number of ways to improve and optimize the MRR including some unique experimental concepts that depart from the traditional EDM sparking phenomenon. Despite a range of different approaches, all the research work in this area shares the same objectives of achieving more efficient material removal coupled with a reduction in tool wear and improved surface quality. In this paper, by varying parameters like pulse on time, pulse off time& abrasive particle Concentration the MRR is increased & TWR as well as surface roughness is improved. These responses are optimized by using Grey Relational Taguchi Technique for **H-13 Die steel & Copper Electrode.**After confirmation test for optimized parameters the MRR is increased ,surface finish & TWR is improved.

Key Words: Material removal rate, Powder mixed EDM, Dielectric fluid, Design of experiment, Abrasive particle size.

1. INTRODUCTION:

Electrical discharge machining is one of the widely used non-conventional machining process. Advancement in material science over the recent years has forced to the development of advanced materials having better mechanical properties. Advanced materials like Die steel, super alloys are the key materials having wide spread industrial applications. It can be successfully employed to machine electrically conductive parts regardless of their hardness and toughness.

The discharging sparks occur between the electrode and the conductive work piece flushed with or submerged in a Dielectric fluid. The EDM process has the advantage of spark erosion in order to machine the hard to cut material and then easily achieve the required shapes and sizes with better dimensional accuracy.

The abrasive particles of Silicon Carbide (Sic) are mixed into the dielectric fluid of EDM. The current conducting particles cause electric field positive and negative charges gather respectively at the top and bottom of the abrasive particles. Near the abrasive particles the electric filed density is the highest and discharge breakdown at the beginning will occur when the electrical filed density surpasses the breakdown resistant capability. Discharge breakdown then causes a short circuit between the two abrasive particles and the redistribution of electric charges. The electric charges then leads to the discharge between these two abrasive particles and other abrasive particles resulting in series discharge and accordingly the discharge breakdown between the electrode and the work piece takes place. Thus it has been found that the addition of Abrasive particles wideness the discharge gap thus decreasing the gap voltage of the dielectric fluid. This leads to formation of evenly distributed, large dia. and shallow craters. Thus subsequently improving the surface finish.. After testing the machined surface of the work piece reveals more uniform surface with less cracks and the part can be utilized directly.

2. LITERATURE REVIEW :

The brief summary of the review of the available Literature is given below.

Raghuraman.S, Thiruppathi.K, Panneerselvam.T, Santosh.S was investigated optimization of EDM parameters using Grey Relational Taguchi Technique For Mild steel IS 2026,This paper aims to investigate the optimal set of process parameters such as current, pulse ON and OFF time in Electrical Discharge Machining (EDM) process to identify the variations in three performance characteristics such as rate of material removal, wear rate on tool, and surface roughness value on the work material for machining Mild Steel IS 2026 using copper electrode. Taguchi method used to find the optimal levels of parameters.

SubhakantaNayak, B.C.RoutaraThis paper discusses the application of the Taguchi method to optimize the machining parameters for machining of tungsten carbide inelectro-discharge machining (EDM) for individual responses such as material removal rate, electrode wear rate and surface roughness. Moreover, amulti-response performance characteristic was used for optimization of process parameters with application of grey relational analysis. The machiningparameters are selected as current,

pulse-on-time and pulse-off-time where as the response variables selected as material removal rate (MRR),electrode wear rate (EWR) and surface roughness (Ra).

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Kuang- yuankung investigated the effects of powder mixed electrical machining of cobalt-bounded tungsten carbide with different grain sizes and different concentration of Aluminum powder particles suspended in the dielectric fluid using dielectric fluid with conductive Aluminum powder can effectively disperse the discharging energy dispersion in order to improve the machining efficiency. The MRR increases with an increase of aluminum powder concentrationafter a certain limit the aluminum powder concentration leads to decrease in MRR takes place. Tool Wear decrease with the increase of the grain size.

Zing and Lee reported the investigations of powder mixed EDM on SKD11 material using kerosene-mixed with Aluminum, Chromium, copper additives, significant improvements in the material removal and improving the resistance of machined surface from corrosion and abrasion. Van and Oven investigated the effect of suspended aluminum and silicon carbide powders, considerable improvement in MRR was observed.

Pecas and Henrique's carried out the work on Silicon powder mixed dielectric on EDM. They observed that by addition of 2g/lit of silicon powder the operating time and surface roughness decreases. The average surface roughness depends on the machining area .

Literature Review reveals that, the work has been carried out by mixing the Sic metal powder in dielectric fluid, which influencethe performance of EDM. This needs further investigation. In this paper the influence of (Sic) powder on H-13Die steel has been made to obtain an optimal setting of MRR,TWR&SR in powder mixed Electrical discharge machining. Design of experiments had been used to plan and analyze the results.

3. WORK MATERIAL:

AISI H-13 Die steel was selected as work material to carryout the experiment, H-13 Die steel is also known as 1.2080, is an air hardening high carbon high chromium tool steel. It displays excellent abrasion &wear resistance. It is heat treatable and will offer a hardness in the rage 58-64 HRC. It is used in Manufacturing of Blanking tools, thread rolling dies, Drawing dies &Pressing tools for the ceramics & cold Rolls for multiple roller stands.

Table 1-Chemical composition of AISI H-13 Die Steel

Material	C	Cr	Mn	MO	Si	V	S	P	Fe
H13	0.395	5.25	0.35	1.475	1.00	1.00	0.0025	0.0125	Balance %wt

3.1 Taguchi Method:

Taguchi method is an experimental technique which is useful in reducing the number of experiments is required by using orthogonal array and also tries to minimize the effects of factors out of control. The greatest advantage of Taguchi method is to decrease the experimental time, to reduce the cost and to find out the significant factors in a lesser time period. It focuses on determining the parameter settings producing the best levels of quality characteristics with minimum variations.

It converts the objective function values to signal to Noise ratio to measure the performance of the control factors. The S/N ratio takes both the mean and variability into account. Signal to Noise ratio is the ratio of the mean to the standard deviation. The S/N ratio depends on the criteria of the quality characteristics to be optimized. The following type of S/N ratios are defined.

1)Lower - the- Better Type (LB)

$$\eta = S/N = -10 \log [1/n \Sigma^{n}_{1} Yi^{2}]$$

2) Larger - the- Better Type (LB)

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η=S/N = - 10 log [1/n Σ^{η}1/ Yi^2]

Where Yi is the measured response inIth run.
n= No. of observations in a row

3.2 Grey Relational Analysis:

Taguchi's method is focused on the effective application of engineering strategies rather than advanced statistical techniques. The primary goals of Taguchi method are

- A reduction in the variation of a product design to improve quality and lower the loss imparted to society.
- A proper product or process implementation strategy, which can further reduce the level of variation.

The steps involved in Taguchi- Grey Relational Analysis are:

STEP 1:

The transformation of S-N Ratio values from the original response values was the initial step. For that the equations of larger the better, smaller the better rand nominal the best were used. Subsequent analysis was carried out on the basis of these S/N ratio values. This is shown in table5.2.

Type 1: $S/N_{HB} = -10\log_{10}[(\frac{1}{n})(\Sigma\frac{1}{Y_{ij}^2})]$

Type 2: $S/N_{LB} = -10\log_{10}[\Sigma\frac{Y_{ij}^2}{n}]$

Type 3: $S/N_{NB} = 10\log_{10}[\frac{1}{S^2}]$

Where Y_{ij} is the value of the response
'j' in the ith experiment condition, with i=1, 2, 3,…n; j = 1,2…k
and S^2 are the sample mean and variance

STEP 2:

In the 2nd step of the grey relational analysis , pre-processing of the data was first performed for normalizing the raw data for analysis. This is shown in Table 5.3. Yij is normalized as Zij (0 ≤ Zij ≤ 1) by the followingformula to avoid the effect of adopting different units and to reduce the variability. The normalized output parameter corresponding to the larger-the-better criterion can be expressed as

$$Zij = \frac{y_{ij} - \min(y_{ij}, i = 1,2,\ldots n)}{\max(y_{ij}, i = 1,2,\ldots n) - \min(y_{ij}, i = 1,2\ldots n)}$$

Then for the output parameters, which follow the lower-the-better criterion can be expressed as

$$Zij = \frac{\max(y_{ij}, i = 1, 2, \ldots, n) - y_{ij}}{\max(y_{ij}, i = 1, 2, \ldots, n) - \min(y_{ij}, i = 1, 2, \ldots, n)}$$

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STEP 3:

The grey relational coefficient is calculated to express the relationship between the ideal (best) and actual normalized experimental results. Before that the deviation sequence for the reference and comparability sequence were found out. These are given in Table 3.4 and grey relational coefficient is given in Table 5.5. The grey relational coefficient can be expressed as.

$$\xi_i(k) = \frac{\Delta_{\min} + \zeta\Delta_{\max}}{\Delta_{0i}(k) + \zeta\Delta_{\max}}$$

Where, $\Delta_{0i}(k)$ is the deviation sequence of the reference sequence and comparability sequence.

$$\Delta_{0i}(k) = \| y_0(k) - y_i(k) \|$$

$$\Delta_{\min} = \underset{\forall j \in i}{\min} \; \underset{\forall k}{\min} \| y_0(k) - y_j(k) \|$$

$$\Delta_{\max} = \underset{\forall j \in i}{\max} \; \underset{\forall k}{\max} \| y_0(k) - y_j(k) \|$$

Denotes the sequence and y_{ij} (k)denotes the comparability sequence. ζ is distinguishing or identified coefficient. The value of ζ is the smaller and the distinguished ability is the larger. ζ = 0.5 is generally used.

STEP 4:

The grey relational grade was determined by averaging the grey relational coefficient corresponding to each performance characteristic. It is given in the Table 5.6. The overall performance characteristic of the multiple response process depends on the calculated grey relational grade. The grey relational grade can be expressed as. Where, γ_i is the grey relational grade for the j^{th} experiment and k is the number of performance characteristics

4. EXPERIMENTATION:

Experiments were conducted on Tool Craft A-50 EDM Machine. The existing work tank of the Machine require huge amount of dielectric fluid for flushing. The mixing of abrasive with the whole of the dielectric fluid is avoided the different levels of concentrations of abrasive were to be mixed into the dielectric for experimentation. Therefore the new system is developed for the circulation of abrasive mixed dielectric fluid. The schematic diagram of new developed system is shown in fig1. The new Abrasive circulation system is designed for 6 liters of dielectric fluid.

The new Abrasive mixed dielectric circulation system consists of a container called Machining tank. This container is placed in the main Dielectric tank of EDM and machining is carried out. The work piece is fixed on a fixture assembly for machining. A stirring system is developed to avoid the abrasive particle settling at the bottom of the tank.

The input parameters Discharge current, pulse on time, powder Concentration, were taken as per the requirement. These values were taken as per the L_9orthogonal array as given in table. Experiments were carried out on a General EDM and by adding powder as Silicon Carbide to dielectric fluid, where the powder is circulated during the experiment for reuse. The Response Was

considered as MRR,TWR&SR for each run was calculated on the basis of weight difference before and after the machining by using electronic weighing machine& SR Was measured by Surf Tester. New EDM machine set up is Shown in Fig 1.

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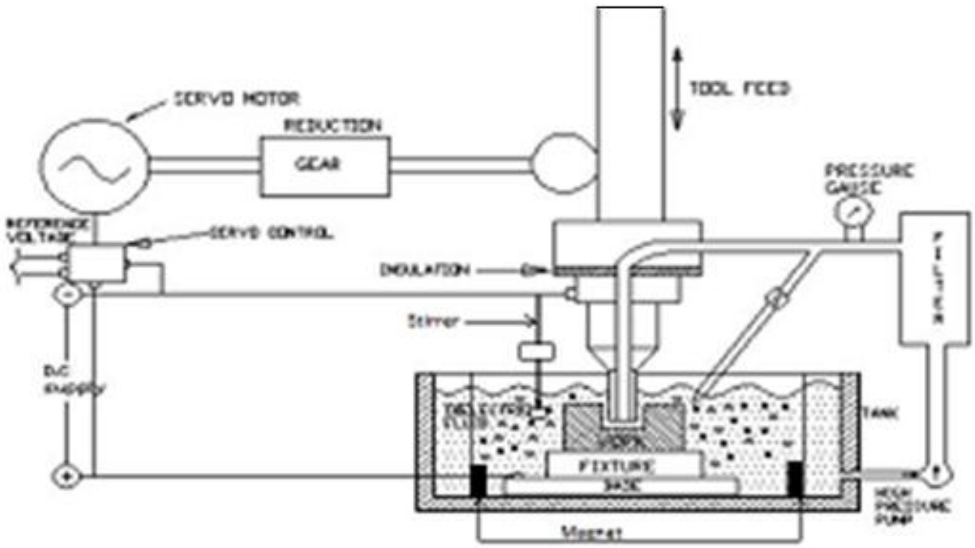

Fig.1 Schematic diagram of PMEDM

No. on Parameters = 3

Total Degree of freedom (DOF) for 7 parameters = 3x (3-1) = 6

Therefore minimum no. of experiment = Total DOF +1 = 6 +1 = 7

Minimum No. of experiments considered are = 9

L9 orthogonal array of Taguchi is selected. `

Fig. 2 EDM Set Up

Fig.3 PMEDM Set Up

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Fig.4 Surface Test SJ-210

Table 4.2. 1: L9 Orthogonal Array

Expt. No.	Parameters		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 4.2.2: Process Levels & Parameters

Process Parameters	Levels		
	1	2	3
Discharge current(Amp)	6	9	12
Pulse ON time (μs)	60	120	180
Sic Powder(gm)	3	6	9

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➢ Material removal rate:

The material removal rate of the work piece is the volume of the material removed per minute. It can be calculated using the following relation.

$$MRR = \frac{(W_i - W_f) \times 1000}{(D_w \times t)}$$

MRR– Material Removal Rate (mm3/min)

Wi- Initial weight of work piece (gm)

Wf- Final weight of work piece (gm)

Dw- Density of the work piece (gm/mm3)

t- Period of trial (min)

➢ Tool Wear Rate:

The tool wear rate (TWR) of the electrode is the amount of the tool wear per minute. It can be calculated using the following equation.

$$TWR = \frac{(T_i - T_f) \times 1000}{(D_e \times t)}$$

TWR - Tool wear rate (mm3/min)

Ti - Initial weight of tool (gm)

Tf - Final weight of tool (gm)

De - Density of the tool (gm/mm3)

t- Period of trial (min)

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5 . Results & Discussion:

Table5.1 Experimental Readings

Exp. No.	Current (Amp)	Pulse on Time(µs)	Sic Powder(gm)	MRR mm^3/min	TWR mm^3/min	Surface Roughness (µm)
1	6	60	3	5.2564	0.111	5.715
2	6	120	6	6.2820	0.149	4.316
3	6	180	9	5.9829	0.186	6.605
4	9	60	6	11.3247	0.223	6.809
5	9	120	9	11.0256	0.186	3.469
6	9	180	3	10.1282	0.223	6.207
7	12	60	9	17.7350	0.223	8.046
8	12	120	3	16.6666	0.223	7.526
9	12	180	6	16.0256	0.260	5.306

Table 5.2 Signal-to-Noise ratio

Exp. No.	Response Values			S/N ratios		
	MRR (mm^3/min)	TWR (mm^3/min)	SR (µm)	MRR (dB)	TWR (dB)	SR (dB)
1	5.2564	0.111	5.715	14.4138	19.0935	15.1403
2	6.2820	0.149	4.316	15.9620	16.5363	14.5117
3	5.9829	0.186	6.605	15.5382	14.6097	15.5572
4	11.3247	0.223	6.809	21.0805	13.0339	16.6617
5	11.0256	0.186	3.469	20.8480	14.6097	16.2167
6	10.1282	0.223	6.207	20.1106	13.0339	15.8576
7	17.7350	0.223	8.046	24.9766	13.0339	18.1116
8	16.6666	0.223	7.526	24.4380	13.0339	17.5313
9	16.0256	0.260	5.306	24.0963	11.7005	17.2736

Table 5.3 Normalized Signal-to-Noise ratios

Expt. No.	Current (A)	Pulse on Time(µs)	Sic Powder(gm)	Normalized S/N Ratios		
				MRR	TWR	SR (Ra)
1	6	60	3	0.0000	0.0000	0.8253
2	6	120	6	0.1465	0.3458	1.0000
3	6	180	9	0.1064	0.6064	0.7095
4	9	60	6	0.6311	0.8196	0.4027
5	9	120	9	0.6091	0.6064	0.5263
6	9	180	3	0.5393	0.8196	0.6261
7	12	60	9	1.0000	0.8196	0.0000
8	12	120	3	0.9490	0.8196	0.1611
9	12	180	6	0.9166	1.0000	0.2327

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Table 5.4 Deviation sequences

Exp. No.	Current (A)	Pulse on Time(µs)	Sic Powder(gm)	Deviation sequences		
				MRR	TWR	SR
1	6	60	3	1.0000	1.0000	0.1747
2	6	120	6	0.8535	0.6542	0.0000
3	6	180	9	0.8936	0.3936	0.2905
4	9	60	6	0.3689	0.1804	0.5973
5	9	120	9	0.3909	0.3936	0.4737
6	9	180	3	0.4607	0.1804	0.3739
7	12	60	9	0.0000	0.1804	1.0000
8	12	120	3	0.0510	0.1804	0.8389
9	12	180	6	0.0834	0.0000	0.7673

Table 5.5 Grey Relational Co-efficient

Exp. No.	Current (A)	Pulse on Time(µs)	Sic Powder(gm)	Grey Relational Co-efficient		
				MRR	TWR	Surface Roughness
1	6	60	3	0.3333	0.3333	0.7410
2	6	120	6	0.3694	0.4332	1.0000
3	6	180	9	0.3587	0.5595	0.6325
4	9	60	6	0.5754	0.7348	0.4556
5	9	120	9	0.5612	0.5595	0.5129
6	9	180	3	0.5204	0.7348	0.5721
7	12	60	9	1.0000	0.7348	0.3333
8	12	120	3	0.9074	0.7348	0.3334
9	12	180	6	0.8570	1.0000	0.3945

From the above GRC We need to be find out the GRG, By Average of each Experiment up to nine Experiments.

Table 5.6 Grey Relational Grades

Exp. No.	Current (A)	Pulse on Time(µs)	Pulse off Time(µs)	Grey relation Grade	Rank
1	1	1	1	0.4692	9
2	1	2	2	0.6008	5
3	1	3	3	0.5169	8
4	2	1	2	0.5886	6
5	2	2	3	0.5445	7
6	2	3	1	0.6091	4
7	3	1	3	0.6893	2
8	3	2	1	0.6778	3
9	3	3	2	0.7505	1

The Fig. 5 shows the Grey relational grades for the maximum MRR, minimum TWR and minimum Ra. Since the experimental design is orthogonal, it is possible to separate out the effect of each machining parameter on the grey relational grade at different levels . The mean of the grey relational grade for each level of the machining parameters is summarized and shown in below Table 5.7. The higher grey relational grade represents that the corresponding experimental result is closer to the ideally normalized value. In other words, optimization of the complicated multi - response characteristics can be converted into optimization of a single grey relational grade.

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Since the experimental design is orthogonal, it is then possible to separate out the effect of each machining parameter on the grey relational grade at different levels. Basically, the larger the grey relational grade, the better is the multiple performance characteristics. However, the relative importance among the machining parameters for the multiple performance characteristics still needs to be known so that the optimal combinations of the machining parameter levels can be determined more accurately. GRG Rank, it shows that which one is Larger GRG, that Shows thebetter multiple performance characteristics in the Powder Mixed EDM. Next go to an optimal levels

Fig 5 Grey Relational Grades for Maximum MRR, Minimum TWR and Minimum Ra

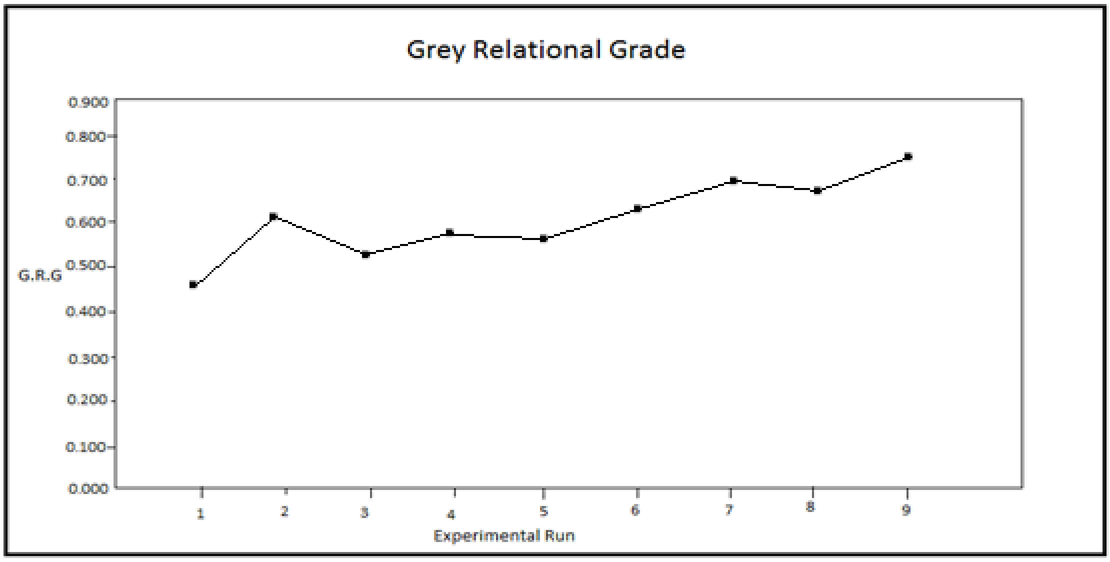

Table 5.7 The Main Effects of the Factors on the Grey Relational Grade

Parameter	Level 1	Level 2	Level 3	Max-Min	Rank
Current	**0.5289**	**0.5807**	0.7038	**0.1749**	**1**
Pulse on- Time	**0.5823**	**0.6057**	0.6255	**0.0432**	**3**
Sic Powder (gm)	**0.5833**	0.6466	**0.5835**	**0.0633**	**2**

The above table gives the optimal levels of process parameters as per the GRG. The optimal level of Parameter, current is level 3 as 0.7038, pulse on time, level 3 as 0.6225 & Sic powder, level 2 as 0.6466.

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Table 5.8 Results of ANOVA for multiple performance Characteristics
Analysis of Variance for GRG, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	2	0.049632	0.049632	0.024816	13.55	0.067
On time	2	0.002819	0.002819	0.001410	0.79	0.558
Abrasive	2	0.007734	0.007734	0.003867	2.17	0.315
Error	2	0.003558	0.003558	0.001779		
Total	8	0.063743				

S = 0.0421786 R-Sq = 94.42% R-Sq (adj) = 77.67%

The ANOVA investigates which PMEDM process parameters significantly affect the performance measures. This is revealed by separating the total variability of the GRGS. This is measured by the sum of squared deviation from the total mean of the GRG into contribution by each process parameter & error. In addition F test(fisher test) and P value (probability) is also determined. Table 5.8 shows the results of ANOVA for multiple performance characteristics. Current is most significant process parameter, affecting the multiple performance measures as 55%.The other factors having significant effects, Pulse on time as 20% & powder Concentration 25%.

6. Confirmation Tests:

The confirmation test for the optimal parameters with its levels was conducted to evaluate quality characteristics for EDM of AISI H-13. Table6.1 shows highest grey relational grade indicating the initial process parameter set o f A1B1C1 for the best multiple performance characteristics among the nine experiments. By Using the A3B3C2 optimal Set up Experimental Results are as Shown in below Table.

Table 6.1 Results of Performance measures for initial & optimal Parameters

	Initial Machining Parameters	Optimal process parameters	
		Predicted	Experiment
Combination Level	A1B1C1	A3B3C2	A3B3C2
MRR(mm3/min)	5.2564	16.4126	17.0216
TWR(mm3/min)	0.111	0.272	0.283
Ra(µm)	5.716	7.410	8.156
GRG	0.4692	0.7557	0.7662

As per the Grey Relational Grade the confirmation results of the optimal experimental values of metal removal rate is increased from 5.2564 mm3/min initial value to 17.0216mm3/min experimental values. At the same time tool wear is improved from 0.111mm3/min initial value to0.283mm3/min& Surface roughness is improved from 5.716µm initial value to 8.156µm optimal experimental values.

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7. CONCLUSIONS:

Taguchi - Grey Relational Analysis technique is applied in this work to improve the multi-response characteristics such as MRR (Material Removal Rate), TWR (Tool Wear Rate) and Surface Roughness of H- 13 die steel during EDM process. The conclusions of this work are summarized as follows:

- As per the experimentation work the MRR increases with increase in current & subsequently SR &TWR increases.
- The addition of Sic Powder to the die-electric fluid, the MRR increases & at the same time the TWR & SR reduces to the certain level of concentration.
- The optimal level of setting as per the GRG A3B3C2
- MRR increases from 50% to75 %. TWR improved from 60% to 80% & SR is improved from 55% to 85%.
- It represents the present study clearly shows that the MRR,TWR & SR in the powder mixed EDM process can be improved effectively through this approach

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