Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 01, January -2018

Multi Response Optimization of Powder Mixed EDM of Titanium Alloy using Grey Relational Analysis

BSV Ramarao

Professor, Department of Mechanical Engineering
Aurora's Scientific & Technological Institute, Hyderabad

Abstract -*Electric Discharge Machining is extensively used for the manufacturing of different components including complex shapes on the normal materials and even on the hardened materials like ceramics, super alloys and steels. Considerable work has been done on the EDM in different aspects. Here, in this research paper Titanium alloy has been tested to determine the response parameters like MRR, TWR & SR when an additive is mixed in the dielectric fluid. Taguchi L27 has been selected and experiments were conducted to determine the response parameters and then multi response optimization has been done usingGrey Relational Analysis.*

KEY WORDS: *GRA, Euclidean distance, MTOPSIS, GRC & Pi*

I. INTRODUCTION

In Powder Mixed EDM suitable material in the form of powder will be mixed into the dielectric fluid in tank. For better circulation of the dielectric fluid a stirring system is used. The constant reuse of powder in the dielectric fluid can be done by the special circulation system. Various powders of particle can be added into the dielectric fluid. Spark gap provided by the additives particles. The powder particles of the material get energized & behave like a zigzag way manner. under the sparking zone, the particles of the material powder come close to each other & arrange themselves in the form of chain like structure between the workpiece surface & tool electrode. The interlocking between the different powder particles occurs in the direction of flow current. The chain formation helps in bridging the discharge gap between the electrodes. Because of bridging effect, the insulating strength of the dielectric fluid decreases resulting in easy short circuit. This causes early explosion in the gap and series discharge' starts under the electrode area.

When voltage is applied, the powder particles become energized and behave in a zigzag fashion. These charged particles are accelerated due to the electric field and act as conductors promoting breakdown in the gap. This increases the spark gap between tool and the work piece. Under the sparking area, these particles come close to each other and arrange themselves in the form of chain like structures. The faster sparking within a discharge causes faster erosion from the work piece surface and hence the material removal rate increases.

Parameters of this machine are mainly classified into two categories i.e. Process Parameters &Performance Parameters. The process parameters in EDM are used to control the performance measures of the machining process. Process parameters are generally controllable machining input factors that determine the conditions in which machining is carried out. These machining conditions will affect the process performance result, which are gauged using various performance measures. Performance Parameters These parameters measure the various process performances of EDM results.

II. LITERATURE SURVEY

PMEDM is extended usage of EDM, where some selected powders are mixed in dielectric fluid for the better results of the response parameters. The floating particles impede the ignition process by creating a higher discharge probability and lowering the breakdown strength of the insulating dielectric fluid. As a result, MRRis increased, TWR and SR are lowered due to the improvement in sparking efficiency.

In 2008 Kang and Kim studied EDM in order to investigate the effects of EDM process conditions on the crack susceptibility of a nickel based super alloy revealed that depending on the dielectric fluid and the post-EDM process such as solution heat treatment, cracks exist in recast layer could propagate into substrate when a 20% strain tensile force was applied at room temperature [1]. When kerosene as dielectric, it was observed that carburization and sharp crack propagation along the grain boundary occurred after the heat treatment. However, using deionized water as dielectric the specimen after heat treatment underwent oxidation and showed no crack propagation behaviour

In the same year Han-Ming Chow and other scientist investigated the effect of using pure water and a SiC powder for titanium (Ti) alloy in micro-slit EDM, and found that by using pure water as an EDM dielectric fluid for titanium alloy yields a high MRR and relatively low electrode wear and small expanding-slit by employing negative polarity (NP) processes [2]. Pure water and a SiC powder cause high conductivity; therefore, the gap was larger than using pure water in the EDM processes. Pure water and a SiC powder could disperse the discharging energy that refines the surface roughness effectively and also attains a higher MRR simultaneously than that of pure water.

Azad et al. [3] optimized multiple performances of micro-EDM process parameters for a set of target performances when Ti-6Al-4V is EDMed. It has been revealed that the most influential factors are voltage and current in the optimization of single quality characteristics. These factors are not influential in multiple quality characteristics. The predicted optimum condition has been verified experimentally. Ekmekci et al. [4] investigated the effect SiC powder added dielectric fluid on surface modification by using SEM and EDX analysis of plastic mould steel. They used dielectric fluid as tap water and mixed SiC particles at various conditions. Experiments were conducted in parametrical order; the investigated input parameters are discharge current, pulse on duration and concentration of SiC particles and electrolytic copper as electrode material with reverse polarity. It has been concluded that high discharge current and low pulse on duration conditions are well suitable for the tap water mixed SiC particles dielectric fluid.

Zakaria et al. [5] studied the effect of tantalum carbide (TaC) powder mixed dielectric fluid on EDM of SUS 304 steel. Pure copper electrode was employed with straight polarity. The TaC powder mixed (25g/L) in kerosene was used as a dielectric fluid. The process parameters are discharge current, pulse on time and pulse off time on the measured performance characteristics like micro-hardness and corrosion characteristics. It has been observed that as the discharge current increases, micro-hardness is decreased. They concluded that TaC powder added kerosene can increase the corrosion resistance of workpiece rather than compared it without addition of TaC powder. Rajiv Kumar Sharma et al. [6] optimized PMEDM process parameters while machining of cobalt-bonded tungsten carbide with electrolytic copper. GRA-Taguchi method was applied to optimise the multi-performance characteristics of micro-hardness and SR. The measured input process parameters are pulse on time, pulse off time, discharge current, and powders. They observed that the analytical and experimental results indicated the most significant parameters as powder, pulse on time and discharge current.

Murahri et al. [7-10] conducted experiments on the addition of surfactant and surfactant with graphite and B4C powder into the dielectric fluid and compare the results with without the addition of surfactant into the dielectric fluid while machining of Ti-6Al4V using modified EDM process. It has been observed that, surfactant with graphite powder addition into the dielectric fluid show better performance compared to that of B4C powder addition. Although the influence of various dielectrics onthe stability of electrical discharge machining of titanium alloy has been studied extensively, including the material removal, surface roughness and recast layer thickness and the profile of the work piece and electrode to the best of our knowledge, there is little work reported in open literature regarding the use of drinking water as dielectric fluid for EDM of Titanium alloy.Ramarao et al. [11] has conducted around 30 experiments to determine the permissible range of input parameters to fit it into the orthogonal array which is to be considered for the main experiment. They have considered MRR, TWR and SR as the performance measures for their trail experiments.

Here in this research paper, Titanium grade V material has been considered for making indentations along with the copper tool material, where drinking water is as the dielectric fluid. Orthogonal array L27 has been selected from the design of experiment for the response parameters MRR, TWR and SR. Multi response optimization technique i.e. Grey Relational Analysiswas applied to analyse.

III. EXPERIMENTAION

3.1 Selection of workpiece material

Here, the material of the workpiece is Ti-6Al-4V alloy. The size of the workpiece is of the dimensions - length 100 mm, width 50 mm and thickness 5 mm. MurahariKolli et al. [7-10] described the properties of the titanium alloy and are presented in below Table 1.

Table1: Properties of Titanium alloy

Property	**Values**
Hardness (HRC)	32-34
Melting point ($^{\circ}$C)	1649-1660
Density (g/cm^3)	4.43
Ultimate tensile strength (MPa)	897-950
Thermal conductivity (W/m K)	6.7-6.9
Specific heat (J/kgK)	560
Mean coefficient of thermal expansion (W/kg K)	8.6x10^{-6}
Volume electrical resistivity (ohm-cm)	170
Elastic Modulus (GPa)	113-114

3.2 Selection of the dielectric:

Drinking Water:

Even though many dielectric fluids are available for the study of EDM, water is selected as the dielectric fluid here because it is environmental friendly. Drinking water is colorless, odorless, harmless, and easily available. The specifications of Drinking water is listed in Table 2 below.

Table 2: Specifications of Drinking water

Characteristic	Value
Appearance	White / Almost colourless
Odour	None
Density	0.9998 g/ml
Specific Gravity	1
Boiling point	99.98^0C
Flash Point (0^0C)	Non-Flammable
Thermal conductivity	0.6065 W/m·K
Viscosity	0.890
Copper corrosion	Almost zero (2.5 µm/year)
Conductivity	5-50 mS/m
Dielectric strength	60-70v/m

3.3 PERFORMANCE MEASURES:

The performance measures considered here for the evaluation are Material Removal Rate (MRR), Tool Wear Rate (TWR), and Surface Roughness (SR). They are calculated using the following formulae,

Material Removal Rate (MRR):

The Material Removal Rate is calculated based on the workpiece weight loss for a particular time period and the relevant equation is given below,

Material Removal Rate,MRR $= [\frac{(Wi - Wf)}{(D \ X \ t)}]$ X 1000

W_i = Initial Weight in grams; W_f=Final Weight in grams

D=Density of the workpiece material in gm / cm^3

t = Time Period of the experiment in minutes

Units of MRR is mm^3/min

Tool Wear Rate (TWR):

TWR is calculated on the basis of the material lost by the tool during the process, based on the change of weight of the tool material before and after the machining process which is shown in the below equation,

Tool Wear Rate,TWR $= \left[\frac{(T_i - T_f)}{(D \ X \ t)}\right]$ X 1000

T_i = Initial Weight in grams: T_f=Final Weight in grams

Surface Roughness (SR):

The third machining parameter is surface roughness, SR. This measurement can be performed by using Talysurf, a portable type profilometer, in terms of Ra. Orthogonal array for L27 was obtained using MINITAB17.

3.4 Analysis using GRA:

The optimization related to the problem having more than one objective function is called Multi objective optimization. This is the area where more than two objective functions are solved simultaneously. Here in this section, there are three performance measures are considered such as MRR, TWR,and SR for the characterization of EDM.

Grey Relational Analysis is measurement method in the theory of the grey system which analyses the information required (uncertain & insufficient) between one factor and the remaining in the given system.

In this section, the methodology of the grey relational analysis is discussed and solved the Taguchi problem which was done in the previous. This kind of optimization i.e. multi-objective optimization can be performed as follows,

1. Normalization of different responses

   'Higher the better (HTB) or 'Lower the better (LBT)' condition is chosen for each response based on the desired objective. For this experiment HBT and LBT were chosen for MRR, TWR and SR respectively.

$$y_i(k) = \frac{x_i(k) - min\, x_i(k)}{max\, x_i(k) - min\, x_i(k)}$$

   For LBT, the equation for normalization is,

$$y_i(k) = \frac{max\, x_i(k) - \ x_i(k)}{max\, x_i(k) - min\, x_i(k)}$$

Where $y_i(k)$ is i[th] normalized response value and $x_i(k)$ is observed value for the i[th] run of the k[th] response.

2. Calculating grey relation coefficient (GRC)
   Grey relation coefficient ($\zeta_i(k)$) is calculated using the following equation:

$$\zeta_i(\mathrm{k}) = \frac{\Delta_{min} + \zeta_i \Delta_{max}}{\Delta_i(k) + \zeta_i \Delta_{max}}$$

Where Δ_{min} and Δ_{max} are the global minimum and maximum values of normalized values respectively of the k[th] response. ζ is the distinguishing factor whose value lies between 0 and 1. Its purpose is to expand or compress the range of grey relation coefficient. In this experiment the distinguishing factor considered is 0.5.

3. Calculating the grey relation grade (GRG)
   Performance of the multi response is evaluated by GRG. It is the weighted summation of all the GRC's and is calculated using the following equation.

$$\Upsilon = \frac{1}{n}\sum_{i=1}^{n} \zeta_i\,(k)$$

The calculated GRC and GRG values are given below.

No	Normalized values			Deviation sequences			Grey rel. coefficient			GRG
	MRR	TWR	SR	MRR	TWR	SR	MRR	TWR	SR	
1	0.2420	0.4500	0.5108	0.7580	0.5500	0.4892	0.3975	0.4762	0.5054	0.4597
2	0.0000	0.3367	0.7568	1.0000	0.6633	0.2432	0.3333	0.4298	0.6728	0.4786
3	0.3749	0.6205	0.1683	0.6251	0.3795	0.8317	0.4444	0.5685	0.3755	0.4628
4	0.4901	0.1807	0.8015	0.5099	0.8193	0.1985	0.4951	0.3790	0.7158	0.5300
5	0.0106	0.3059	0.7079	0.9894	0.6941	0.2921	0.3357	0.4187	0.6313	0.4619
6	0.1273	0.0000	0.4481	0.8727	1.0000	0.5519	0.3643	0.3333	0.4753	0.3910
7	0.1293	0.1810	0.4493	0.8707	0.8190	0.5507	0.3648	0.3791	0.4759	0.4066
8	0.1755	0.2171	0.4890	0.8245	0.7829	0.5110	0.3775	0.3897	0.4946	0.4206
9	0.1271	0.1383	0.3163	0.8729	0.8617	0.6837	0.3642	0.3672	0.4224	0.3846
10	0.5194	0.8400	0.7705	0.4806	0.1600	0.2295	0.5099	0.7576	0.6854	0.6509
11	0.5504	0.8919	0.5802	0.4496	0.1081	0.4198	0.5265	0.8222	0.5436	0.6308
12	0.4266	0.8680	0.2330	0.5734	0.1320	0.7670	0.4658	0.7911	0.3946	0.5505
13	0.4701	0.6868	0.7286	0.5299	0.3132	0.2714	0.4855	0.6148	0.6482	0.5828
14	0.3603	0.7593	0.8557	0.6397	0.2407	0.1443	0.4387	0.6750	0.7760	0.6299
15	0.4791	0.7509	0.6786	0.5209	0.2491	0.3214	0.4898	0.6675	0.6087	0.5886
16	0.4984	0.8260	0.4954	0.5016	0.1740	0.5046	0.4992	0.7418	0.4977	0.5796
17	0.2910	0.7291	0.7009	0.7090	0.2709	0.2991	0.4136	0.6486	0.6257	0.5626
18	0.3659	0.7453	0.0000	0.6341	0.2547	1.0000	0.4409	0.6625	0.3333	0.4789
19	0.7705	0.9924	0.6619	0.2295	0.0076	0.3381	0.6854	0.9850	0.5966	0.7557
20	0.7090	0.9505	0.7591	0.2910	0.0495	0.2409	0.6321	0.9099	0.6749	0.7389
21	0.7675	0.9490	0.4879	0.2325	0.0510	0.5121	0.6826	0.9074	0.4940	0.6947
22	1.0000	0.9242	0.8125	0.0000	0.0758	0.1875	1.0000	0.8684	0.7273	0.8652
23	0.6724	0.9186	1.0000	0.3276	0.0814	0.0000	0.6041	0.8599	1.0000	0.8214
24	0.7173	0.8972	0.8634	0.2827	0.1028	0.1366	0.6388	0.8294	0.7854	0.7512
25	0.7974	0.9372	0.9664	0.2026	0.0628	0.0336	0.7117	0.8883	0.9371	0.8457
26	0.6593	1.0000	0.9351	0.3407	0.0000	0.0649	0.5947	1.0000	0.8851	0.8266
27	0.9460	0.9540	0.4465	0.0540	0.0460	0.5535	0.9025	0.9158	0.4746	0.7643

The grey relational coefficient of 0.8652 which is maximum among all the remaining values for the 22ndrun of the design of experiments which are conducted here. The relevant values of the 22nd run is, Discharge current is 20 Amp, Pulse ON time is 45 µs, Pulse OFF time is 24 µs, and Powder concentration is 10 g/lit.

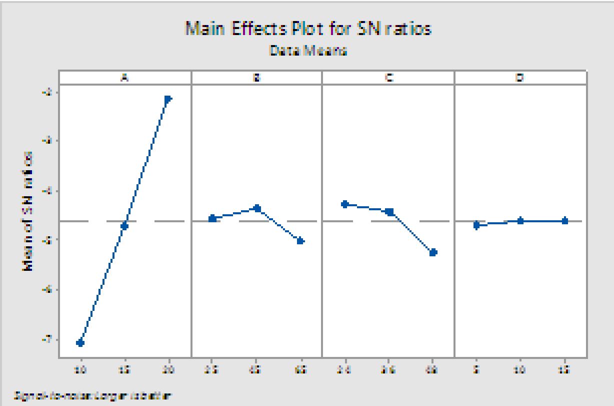
IV. Analysis of Results

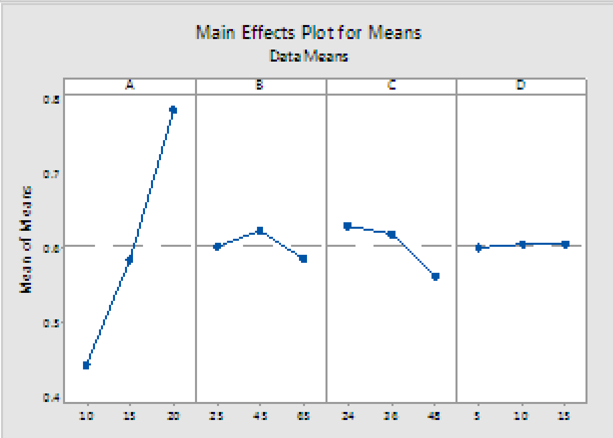
The obtained GRG is considered a single response for the designed experiment and analysis of variance(ANOVA) is carried out in to know which parameters significantly affect the multi objective response. ANOVA is given the below table. From the table, it can be observed that only A is significant for the optimum multi response. Remaining factors B, C and D are found insignificant.

The below figure shows the main effects plot of means and SN ratios for GRG. The maximum GRG values were observed at A of 20 Amp, B of 45 µs, C of 24 µs and D of 10 / 15 g/lit. Hence, the combination of these processes parameter values gives the optimum results for the multi response.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	2	0.528533	0.264266	138.20	0.000
B	2	0.006944	0.003472	1.82	0.191
C	2	0.023607	0.011803	6.17	0.009
D	2	0.000161	0.000080	0.04	0.959
Error	18	0.034419	0.001912		
Total	26	0.593664			





V. Conclusions

Some of the outcomes have been drawn from the current study. Addition of powder particles in the dielectric has increased MRR and decreased the SR. For the designed experiment the maximum MRR was obtained at a powder concentration at 10 g/lt. Minimum value of SR is obtained at a powder concentration of 10 g/lt. Minimum value of TWR is also obtained at a powder concentration of 10 g/lt. Finally, the recommended levels of the input parameters are at A of 20 Amp, B of 45 µs, C of 24 µs and D of 10 g/lit.

BIBLIOGRAPHY:

[1] Kang, S. H., Kim, D.E., "Effect of electrical discharge machining process on crack susceptibility of nickel based heat resistant alloy.", Materials Science and Technology, Vol. 21, (2005) pp.817– 823.
[2] Chow, H. M., Yang, L. D., Lin, C. T., Chen, Y. F., "The use of SiC powder in water as dielectric for micro-slit EDM machining." Journal of materials processing technology, Vol. 195, (2008) pp. 160–170
[3] Azad M. S., Puri A. B. (2012) Simultaneous optimization of Multiple performance characteristics in Micro-EDM drilling of Titanium alloy. International Journal of Advanced Manufacturing Technology 61: 1231-1239
[4] BulentEkmekci., FevziUlusoz., NihalEkmekci., HamidullahYasar. (2014) Suspended SiC particle deposition on plastic mold steel surface in powder mixed electrical discharge machining. Proceedings of Institute of Mechanical Engineers Part B: Journal of Engineering Manufacture DOI: 10.1177/0954405414530902.
[5] ZakariaMohd Zain., Mohammed Baba Ndaliman., Ahsan Ali Khan., Mohammad Yeakub Ali. (2014) Improving micro-hardness of stainless steel through powder mixed electrical discharge machining. Proceedings of Institute of Mechanical Engineers Part B: Journal of Engineering Manufacture 228(18): 3374-3380.
[6] Rajiv Kumar Garg., KuladeepOjha. (2013) Parametric optimization of PMEDM process with chromium powder suspended dielectric for Triangular Electrodes. Advanced Materials Research 816-817: 23-27
[7] MurahariKolli and Adepu Kumar, Influence of Span 20 Surfactant and Graphite Powder Added in Dielectric Fluid on EDM of Titanium alloy, Bonifring Journal, 2014, Vol. 4 (2), 63- 67
[8] MurahariKolli and AdepuKumarParametric Optimization of Boron Carbide Powder Added Electrical Discharge Machining of Titanium Alloy, Applied Mechanics and material, 2014, Vol. 592-594, PP.578- 586.
[9] MurahariKolli and Adepu Kumar, Surfactant and Graphite Powder Assisted Electrical Discharge Machining of Titanium Alloy, ProcIMechE part B: Journal of Engineering Manufacture, 1-17, 2015, DOI: 10.1177/0954405415579019.
[10] MurahariKolli and Adepu Kumar, Optimization of Surfactant mixed EDM parameters on Ti–6Al–4V Alloy using GRA-Taguchi Method, Journal of Material in Technologie, DOI:mit.imt.si/Revija/ mit 249-2016, ImpactFactor:0.555.
[11] BSV Ramarao, Dr. P Shailesh&Dr. M Sreenivasarao," Obtaining the Output Parameters for Different Powder Concentration in PMEDM", International Journal of Advance Engineering and Research Development, Volume 3, Issue 6, June -2016 e-ISSN (O): 2348-4470 p-ISSN (P): 2348-6406.

