International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 3 [March. 2024] PP: 131-134

Multi Response Optimization in Powder Mixed EDM Using Taguchi-Dear Analysis

Phan Thanh Chuong, Giang Nguyen Hoang
College of economics and techniques, Group 8 - Thinh Dan Ward - Thai Nguyen City
Coressponding author: thanhchuong.com@gmail.com

Abstract: *The application of EDM is very popular for shaping products in the fields of molds, etc. Therefore, improving the machining efficiency of this technology is essential. Multi objective optimization of process parameters in EDM is very limited with the help of thin film coated micro tool which brought benefits for industry. In this presented research work, the technology parameters (Workpiece, Electrode, Electrode polarity, Ton, I, Toff, Powder concentration) in PMEDM using titanium powder were optimized and MRR and SR were selected as response variables. Taguchi is combined with DEAR method to solve this multi-objective decision problem. The results showed that Taguchi – DEAR is the right solution for multi-target decision in PMEDM.*
Keywords: *PMEDM, MRR, SR, SKD61.*

I. Introduction

Since PMEDM process associates with more than one machining characteristics, it is important to introduce the multiple response decision making methodology for optimizing the process parameters in such process [1]. Various multi response optimization techniques are available to optimize the process parameters such as Taguchi Grey relational analysis (TGRA), response surface methodology (RSM), Artificial Neural Network (ANN) approach and assignment of weight method [2-3]. The incompatible value of Grey coefficient may lead to poor selection of process parameters in any machining process. The assignment of weight method provides lower adaptability for non-linear machining process. The interpretation of the RSM results needs highest specialist knowledge to gain the optimal combination [4-6]. ANN based model predictive control and optimization can be used for optimizing the process parameters. Nevertheless the prediction accuracy depends on the number trials used for deriving the empirical relationship [7]. The steps involved in such approaches are very tedious. Taguchi – Data Envelopment Analysis based Ranking (DEAR) based multiple criteria decision making (MCDM) is a very simplest and efficient approach [8]. It has been proved that the accuracy of the Taguchi-DEAR method has considerable accuracy on determining the optimal process parameters in any manufacturing process.

Even though many literatures are available on optimizing the EDM process parameters, only very little attention has been given to analyze the influence of parameters on performance measures such as material removal and surface roughness of machined alloy in powder mixed EDM (PMEDM) process. There is no literature available to obtain multiple optimal response parameters in PMEDM process using Taguchi-DEAR based MCDM method. Hence the present investigation has been carried out. In the present study an experimental investigation has been attempted on machining various stainless steel using PMEDM process.

II. Experiments and Methods

Owing to its importance in manufacturing field, three different types of stainless steel have been utilized as workpiece material in the present study. Since the experiments have to be performed under smaller, medium and larger level rating of spark energy. Due to its importance on determining the machining characteristics, material removal rate (MRR) and surface roughness (R_a) have been selected as the response parameters in the present study. The material removal rate has been found by finding the weight difference of the workpiece before and after the machining process. It is denoted by mm^3/min. The average line surface roughness of side of the machined workpiece surface has been computed using TALYSURF CCI LITE non-surface roughness tester as per ISO 4287 standard with high pass filtering. The multi response optimization has been performed to obtain higher material removal rate and lower surface roughness for enhancing the machinability of PMEDM process. Since the present study has been considered seven input process parameters along with three levels, L_{27} orthogonal table design has been chosen based on Taguchi design of experiments.

III. Taguchi-DEAR Methodology

In Data Envelopment Analysis based Ranking (DEAR) Methodology, a combination of original responses is plotted into a ratio so that the better suitable levels can be computed based on this ratio. The value can be assumed as MRPI to compute the optimal combinations of the input parameters of AWJM process. The following rules are involved in DEAR methodology:

1. Compute the weights (w) for each response for all experiments. Weight of performance measure is fraction between the responses at any trial to the summation of all measures.
2. Convert the response data into weighted data by multiplying the obtained value with its own weight.
3. Find the ratio between larger the better (LB) and smaller the better (SB).
4. Treat this value as multi response performance index (MRPI).

MRPI is the ratio between the summation of LB data to the summation of SB data. In the present study, material removal rate has been considered as LB quality characteristics whereas the surface roughness has been considered as SB quality characteristics. The following Eq. (1-3) has been used to find the MRPI for the present study.

$$MRPI = \frac{MRPI_{MRR}}{MRPI_{R_a}} \qquad (1)$$

$$MRPI_{MRR} = MRR * W_{MRR} \qquad (2)$$

$$MRPI_{R_a} = R_a * W_{R_a} \qquad (3)$$

The weights for all the response variables have been computed as the following Eq. (4-5).

$$W_{MRR} = \frac{MRR}{\sum MRR} \qquad (4)$$

$$W_{R_a} = \frac{{}^{1}/_{R_a}}{\sum {}^{1}/_{R_a}} \qquad (5)$$

IV. Results and Discussion

The machining processes have been performed based on the L_{27} based Taguchi methodology on machining workpiece specimens using PMEDM process. Table 1. shows the experimental results of all 9 trials have been conducted.

Table 1. Experimental results in PMEDM

S. No	Factors							MRR (mm^3/min)	R_a (μm)
	Workpiece	Electrode	Electrode polarity	T_{on} (μs)	I (A)	T_{off} (μs)	Powder concentration (g/l)		
1	SKD61	Cu	-	5	8	38	0	10.487	3.35
2	SKD61	Cu	+	10	4	57	10	8.169	3.21
3	SKD61	Cu	-*	20	6	85	20	3.152	2.56
4	SKD61	Cu*	+	10	6	85	0	10.239	3.55
5	SKD61	Cu*	-*	20	8	38	10	14.304	3.61
6	SKD61	Cu*	-	5	4	57	20	0.089	1.45
7	SKD61	Gr	-*	20	4	57	0	37.466	4.78
8	SKD61	Gr	-	5	6	85	10	23.575	3.24
9	SKD61	Gr	+	10	8	38	20	38.843	4.35
10	SKD11	Cu	+	20	4	85	0	18.882	4.16
11	SKD11	Cu	-*	5	6	38	10	3.857	2.05
12	SKD11	Cu	-	10	8	57	20	14.496	3.20
13	SKD11	Cu*	-*	5	8	57	0	10.608	3.35
14	SKD11	Cu*	-	10	4	85	10	0.320	2.04
15	SKD11	Cu*	+	20	6	38	20	23.577	4.57
16	SKD11	Gr	-	10	6	38	0	23.885	4.57
17	SKD11	Gr	+	20	8	57	10	59.669	4.45
18	SKD11	Gr	-*	5	4	85	20	17.159	2.74
19	SKT4	Cu	-*	10	6	57	0	1.252	2.55
20	SKT4	Cu	-	20	8	85	10	20.745	4.31
21	SKT4	Cu	+	5	4	38	20	4.374	2.46
22	SKT4	Cu*	-	20	4	38	0	0.198	2.26
23	SKT4	Cu*	+	5	6	57	10	6.782	2.89
24	SKT4	Cu*	-*	10	8	85	20	19.682	3.50

25	SKT4	Gr	+	5	8	85	0	10.649	3.23
26	SKT4	Gr	-*	10	4	38	10	25.970	3.24
27	SKT4	Gr	-	20	6	57	20	54.360	5.65

Table 2. MRPI values of Experiments

Trial No.	Weights		$MRPI_{MRR}$	$MRPI_{R_a}$	MRPI
	MRR (mm^3/min)	R_a (μm)			
1	0.02266	0.034101	0.23764	0.114239	2.080201
2	0.017652	0.035588	0.144197	0.114239	1.262236
3	0.006811	0.044625	0.021468	0.114239	0.187921
4	0.022125	0.03218	0.226533	0.114239	1.982977
5	0.030908	0.031645	0.442112	0.114239	3.87006
6	0.000192	0.078785	$1.71E^{-05}$	0.114239	0.00015
7	0.080957	0.023899	3.033134	0.114239	26.55078
8	0.050941	0.035259	1.200937	0.114239	10.5125
9	0.083932	0.026262	3.260187	0.114239	28.53831
10	0.0408	0.027461	0.770394	0.114239	6.743707
11	0.008334	0.055726	0.032145	0.114239	0.281386
12	0.031323	0.0357	0.45406	0.114239	3.974651
13	0.022922	0.034101	0.243155	0.114239	2.128481
14	0.000691	0.055999	0.000221	0.114239	0.001937
15	0.050945	0.024998	1.201141	0.114239	10.51429
16	0.051611	0.024998	1.232729	0.114239	10.79079
17	0.128933	0.025672	7.693332	0.114239	67.3442
18	0.037077	0.041693	0.636211	0.114239	5.569121
19	0.002705	0.0448	0.003387	0.114239	0.029649
20	0.044826	0.026506	0.929916	0.114239	8.140097
21	0.009451	0.046439	0.04134	0.114239	0.361876
22	0.000428	0.050548	$8.47E^{-05}$	0.114239	0.000742
23	0.014655	0.039529	0.099388	0.114239	0.869998
24	0.042529	0.03264	0.837058	0.114239	7.327252
25	0.02301	0.035368	0.245039	0.114239	2.144966
26	0.056116	0.035259	1.45734	0.114239	12.75694
27	0.117462	0.020219	6.38522	0.114239	55.89353

The MRPI value of each trial with different combinations of input PMEDM process parameters has been computed using Taguchi - DEAR approach. Table 2. shows the MRPI values of the present study. Table 3. shows the consolidated MRPI of all the input process parameters with all levels. The parameters have been computed by the summing the all MRPI values for corresponding level of each process factors. The maximum level value of each process parameters indicates the optimal level of input factors on determining the performance measures in any machining process. It has been found that the optimal combination of input process parameters of PMEDM process in the present study are SKD11 (workpiece), Gr (Electrode), positive (polarity) and 20 µs (pulse on time), 8A (current), 57 µs (pulse off time) and 20 g/l (Powder concentration) respectively. The higher value of max – min indicates the higher significance of process parameters on machining characteristics. It has been observed that electrode material significantly affects the machinability due to its influence on determining discharge energy over the surface of the work piece specimens.

Table 3. Total MRPI values in AWJM process

Factors	Levels			Max – Min
	1	2	3	
Workpiece	8.331682	11.92762	9.725006	3.595936
Electrode	2.562414	2.96621	24.45568	21.89327
Polarity	10.15496	13.30695	6.522399	6.784552
Pulse on time	2.660964	7.407194	19.91615	17.25518
current	13.9498	5.916388	10.11812	8.033414
Pulse off time	7.688288	17.56152	4.734498	12.82702
Powder concentration	5.828033	11.67104	12.48523	6.657201

V. Conclusions

In the present study Taguchi- DEAR multiple response optimization methodology has been utilized to compute optimal process factors on machining various workpiece specimens using PMEDM process. From the experimental investigation, the following conclusions have been obtained.

(i) The optimal process parameters of PMEDM process has been found as SKD11 (workpiece), Gr (Electrode), positive (polarity) and 20 µs (pulse on time), 8A (current), 57 µs (pulse off time) and 20 g/l (Powder concentration) respectively among the chosen parameters and their ranges.

(ii) Tool electrode material has higher influence on determining the machining characteristics due to its importance on determining discharge energy in PMEDM process.

References

[1]. H. Li, and J. Wang, An experimental study of abrasive water jet machining of Ti-6Al-4V, International Journal of Advanced Manufacturing Technology, 81 (1) (2015) 361- 369. doi: 10.1007/s00170-015-7245-5.

[2]. A. Dhanawade, and S. Kumar, Multi-performance optimization of abrasive water jet machining of carbon epoxy composite material, Indian Journal of Engineering and Materials Science, 25 (5) (2018) 406-416. doi: http://nopr.niscair.res.in/handle/123456789/45869.

[3]. D. Patel, and P. Tandon, Experimental investigations of thermally enhanced abrasive water jet machining of hard-to-machine metals, CIRP Journal of Manufacturing Science and Technology, 10 (1) (2015) 92-101. doi: 10.1016/j.cirpj.2015.04.002.

[4]. N. Kumar, and M. Shukla, Finite element analysis of multi-particle impact on erosion in abrasive water jet machining of titanium alloy. Journal of Computational and Applied Mathematics, 236 (18) (2012) 4600-4610. doi: 10.1016/j.cam.2012.04.022.

[5]. Muthuramalingam, and B. Mohan, Application of Taguchi-grey multi responses optimization on process parameters in electro erosion. Measurement, 58 (1) (2013) 495-502. doi: 10.1016/j.measurement.2014.09.029.

[6]. T. Geethapriyan, K. Kalaichelvan, and T. Muthuramalingam, Multi performance optimization of electrochemical micro-machining process surface related parameters on machining Inconel 718 using Taguchi-grey relational analysis, La Metallurgia Italiana, 2016 (4) (2016) 13-19.

[7]. T. Muthuramalingam, and B. Mohan, Taguchi-grey relational based multi response optimization of electrical process parameters in electrical discharge machining, Indian Journal of Engineering and Materials Science, 20 (6) (2013) 471-475. doi: http://nopr.niscair.res.in/handle/123456789/25590.

[8]. B. Simsek, Y. T. Ic and E.H. Simsek, A RSM-Based Multi-Response Optimization Application for Determining Optimal Mix Proportions of Standard Ready-Mixed Concrete, Arabian Journal for Science and Engineering, 41(4) (2016) 1435 -1450. doi: 10.1007/s13369-015-1987-0.