

Multi response Optimization of Wire EDM Process Parameters

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Abstract. The paper presents the multi-response optimization of wire electrical discharge machining process. In this work the experiment has been conducted considering the four process parameters such as pulse-on-time, pulse-off-time, servo voltage and wire tension. The machining has been performed on D3 die steel using brass wire as an electrode. The cutting speed and surface roughness has been considered as process response. Taguchi based DOE has been adopted for design of experiment. The process parameter were optimized using MOORA approach for obtaining higher cutting speed and lower surface roughness.

1. Introduction

WEDM stands for wire electrical discharge machine, is a versatile machining technique used for manufacturing hantle of ever changing geometries, cutting of complex shapes. In WEDM process, a suitable voltage is applied across tool and workpiece separated by dielectric fluid, the liberated electron are accelerated due to presence of electric field and the ionization of dielectric fluid takes place causing the erosion of tool and workpiece. To meet the future demand and making the study easier MCDM techniques are used for making decision in presence of various conflicting criterions. In the present work, a MCDM approach MOORA (multi objective optimization on the basis of ratio analysis) is carried out to identify the optimal parametric combination. Kalirasu et.al [1] used MOORA method to study the machinability performance of jute/polyester composites using AWJM. They established the common optimum conditions using MOORA to obtain adequate execution on hybrid objective function using surface roughness (Ra) and kerf taper angle (Ta) with the effect of varying thickness. Gadakh V. S [2] explored the applications of new MODM method i.e. MOORA for solving multiple criteria optimization problem in milling process. They reviewed six decision making problems to demonstrate its application and suggested MOORA to be simple, computationally easy, and the top ranked alternative exactly matched with that derived by past researchers which prove applicability, potentiality and flexibility of this method. Majumder and Saha [3] focuses on application of hybrid MCDM approach MOORA coupled with PCA to ascertain optimal combination of input and output parameters for turning on ASTM A588 mild steel and a comparison between MOORA-PCA and TOPSIS-PCA was done revealing the effectiveness of MOORA over TOPSIS because of its ability to clarify process fluctuations. Majumder and Maity [4] optimized different responses of WEDM of titanium grade 6 using hybrid approach MOORA and PCA and suggested MOORA coupled with PCA to be a competent strategy for obtaining optimum process parameter. Chakrobarty [5] explores the application of almost new MODM method to aid the selection process, i.e. MOORA to solve six decision making problems, suggesting it to be a one



fold method, which is easy for calculative and is the best chosen substitute which exactly matched with what the past researchers derived proving its compatibility and sustainability. Patel and Maniya [6] uses combination of analytical hierarchy process (AHP) and MOORA to obtain optimum machining parameters of WEDM for EN31 alloy steel and proposed that results obtained using MOORA were satisfactory and proved its applicability and potentiality. Majumder et.al [7] uses combination of PCA-GRA to obtain the best cutting parameters of Inconel 800 by Wire Electrode Discharge Cutting (WEDC), and concluded that PCA-GRA hybrid gave less percentage error as compared to traditional GRA method. Madhavi et.al [8] proposes application of PCA to convert correlated responses into uncorrelated quality indices called individual principal components to solve the multi- response parameter optimization problems of turning process. Saha and Mondal [9] proposed hybrid approach of PCA and GRA to identify the optimal combination of process parameters in WEDM for manufacturing nanostructured hardfacing materials. To obtain optimum welding parameters in manual metal arc welding (MMAW), Saha and Mondal [10] used MADM approach PCA combined with GRA and studied its performance characteristics for nanostructured hardfacing materials; moreover comparison between TOPSIS-PCA and TOPSIS-AHP was done. Chalisgaonkar and Kumar [11] worked on developing a multi response optimization technique linking with the weight assessment concept in trim cut wire electric discharge machine (WEDM) for pure titanium considering various process parameters such as pulse on time, pulse off time, wire feed etc in finish cut WEDM process. Dewangan et.al [12] examined multi objective optimization to various EDM parameters for acquiring right preference measures in surface integrity of AISI P20 tool steel using PCA based GRA technique and obtained overall quality performance index (OQPI). For achieving better cut quality of AISI D3 tool steel, Sinha et.al [13] applied a hybrid outlook of Taguchi method and Principal component Analysis (PCA) for multi objective optimization in WEDM. Sankar et.al [14] implemented Principal Component Analysis (PCA) combined with GRA for optimizing machining parameters on jute fibre composites during milling process and suggested that PCA coupled with GRA excellently gained the optimal solution, which was proved with a confirmation test. Srinivas N. Grama et.al [15] used PCA and k-means clustering to improve robustness of thermal compensation model and reduce redundancy. Kant and Sangwan [16] used GRA coupled with PCA and RSM to attain optimum machining parameter to reduce the power consumption and surface roughness during machining and concluded the most important machining parameter to be feed, followed by depth of cut and cutting speed. Also the statistical importance was tested by ANOVA. Kamble et.al [17] considered a multi objective optimization of five process parameter for turning AISI 4340 steel to optimize multi- quality characteristics, using hybrid PCA and Taguchi method, where PCA was used to change multiple objectives to single objective. Talla et.al [18] performed a multi response optimization using PCA and GRA to obtain the optimum settings of process parameter for attaining maximum MRR and minimum surface roughness(Ra), by fabricating and machining aluminium/alumina MMC(metal matrix composites) using EDM. Mishra and Yadava [19] dealt with a prediction model for Laser Beam Percussion Drilling with the coupled methodology of Fine Element Method(FEM) and Artificial Neural Network(ANN), and GRA coupled with PCA to optimize LBPD with the predicted data of ANN model, which thus helped in determining the extent of HAZ.

2. Experimental condition

In the present experiment D3 die steel material was machined in wire EDM using brass wire as electrode. The physical and mechanical properties of the work material is shown below. The different parameters considered were pulse on time, pulse off time, servo voltage, wire tension and the different levels are also shown in the table. While the process response were cutting speed and surface roughness. where cutting speed was measured from the machine display itself and surface roughness from Taylor Hobson Taly Surf .Considering the various control factors L16 orthogonal array was made during the experiment Table 1 shows the process parameters with their levels. Table 2 shows the result of experimentation.

Table 1. Parameters and their levels

Parameters	Unit	Levels			
		L1	L2	L3	L4
Pulse-on-time	μs	110	115	120	125
Pulse-off-time	μs	30	35	40	45
Servo voltage	Volts	20	30	40	50
Wire tension	Kg-f	5	6	7	8

Table 2. Experimental results

Parametric combination					Experimental results	
Expt. No	Pulse-on-time (μs)	Pulse-off-time (μs)	Servo voltage (V)	Wire tension (Kg-f)	Cutting Speed (mm/min)	Surface Roughness (μm)
1	110	30	20	5	2.41	2.546
2	110	35	30	6	2.71	2.386
3	110	40	40	7	2.08	1.408
4	110	45	50	8	1.50	1.243
5	115	30	30	7	3.8	2.85
6	115	35	20	8	3.93	2.69
7	115	40	50	6	2.60	2.74
8	115	45	40	7	2.54	1.556
9	120	30	40	8	2.55	1.583
10	120	35	50	7	1.78	1.506
11	120	40	20	6	2.40	1.904
12	120	45	30	5	1.86	1.591
13	125	30	50	6	2.66	1.756
14	125	35	40	5	2.74	1.774
15	125	40	30	8	3.14	2.45
16	125	45	20	7	2.9	2.597

3. MOORA (Multi Objective Optimisation on the basis of Ratio Analysis)

In 2006, Brauers and Zavadskas, proposed a MADM approach MOORA(Multi objective optimization on the basis of ratio analysis), which is used simultaneously optimizing two or more contrary objectives subjected to certain restraints and suggested it to be absolutely sensible in problem solving assessment. Further they observed it to be one folded method, which is easy for calculative purposes and is the best chosen substitute which exactly matched with what the past researchers derived, proving its compatibility and sustainability with qualities like applicability, potentiality and flexibility. The steps involved are as follows:-

Determination of the problem: The first step involves the classification of all required alternatives and their characteristics.

Formation of decision matrix: The next step involves the preparation of decision matrix which depicts the performance characteristics with respect to different variable. The equation 1 is utilised to formulate the decision matrix.

$$P = \begin{bmatrix} x_{11} & x_{12} & \dots & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & \dots & x_{mn} \end{bmatrix}. \quad (1)$$

Where, x_{ij} = performance measure of i^{th} alternative on j^{th} attribute, m = number of alternatives and n = number of attributes.

Performance measure and Normalization: Here normalization of decision matrix is done making it dimensionless so that every component can be compared. The beneficial or non beneficial criteria does not impact in normalization of decision matrix, so its specification is necessary. This normalization method is equal to the ratio of performance measure of i^{th} alternative on j^{th} attribute to square root of sum of squares of individual alternative per criterion and it is calculated with the help of equation 2. Table 3 shows the decision matrix with its normalized value and ranking.

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}. \quad (2)$$

Where, x_{ij}^* = normalized value of i^{th} alternative on j^{th} criterion which lies between 0 and 1.

Overall assessment and evaluation: In this step the normalized performance measures are added for beneficial criterion and subtracted for non-beneficial criterion and it is calculated with the help of equation 3.

$$z_i = \sum_{j=1}^g x_{ij}^* - \sum_{j=g+1}^n x_{ij}^* \quad (3)$$

To fore choice an objective, it could be multiplied by its corresponding weight as few attributes were more influential than others. Thus, overall assessment value is calculated with the help of equation 4.

$$z_i = \sum_{j=1}^g w_j x_{ij}^* - \sum_{j=g+1}^n w_j x_{ij}^* \quad (4)$$

Where, w_j = weight of j^{th} criterion.

Ranking to overall assessment: In this step, the sorting of assessment values in descending order is done. The highest assessment is the best alternative i.e. the highest and lowest value of z_i represents the best and the worst alternative.

Table 3. Decision Matrix with its Normalized value and Ranking

Decision Matrix		Normalized Value		Overall Assessment and Ranking	
Cutting Speed (mm/min)	Surface Roughness (μm)	Cutting Speed (mm/min)	Surface Roughness (μm)	Z_i values taking $W_j = 0.5$	Ranking
2.41	2.546	0.225	0.302	-0.038	15
2.71	2.386	0.253	0.283	-0.015	13
2.08	1.408	0.194	0.167	0.013	6
1.5	1.243	0.140	0.147	-0.003	10
3.8	2.85	0.355	0.338	0.008	7

3.93	2.69	0.367	0.319	0.023	3
2.6	2.74	0.242	0.325	-0.041	16
2.54	1.556	0.237	0.184	0.026	1
2.55	1.583	0.238	0.188	0.025	2
1.78	1.506	0.166	0.178	-0.006	11
2.4	1.904	0.224	0.226	-0.0009	9
1.86	1.591	0.173	0.188	-0.007	12
2.66	1.756	0.248	0.208	0.019	5
2.74	1.774	0.255	0.210	0.022	4
3.14	2.45	0.293	0.290	0.001	8
2.9	2.597	0.270	0.308	-0.018	14

4. Results and Discussion

The experiment was conducted as per the design of experiment and the MOORA method was adopted for obtaining optimal parametric combination. As per the result obtained from the table 2 the experimental number 8 is having the ranking 1 corresponding to $T_{on} = 115 \mu s$, $T_{off} = 45 \mu s$, servo voltage = 40V and wire tension = 7 Kgf. This parameter and their ranges were considered to be the optimal parametric combination for achieving higher cutting speed and lower surface roughness.

5. Conclusion

The paper deals with the parametric optimization of WEDM process during machining of D3 die steel. The machining was conducted at normal polarity considering three input parameters and two performance criteria. The Taguchi based design of experiment was implemented for designing of experiments and accordingly the experiment was conducted. The MOORA method was utilises to determine the parametric combination in order to obtain the maximum cutting speed and minimum surface roughness. The results shows that higher cutting speed and lower surface roughness were obtained at $T_{on} = 115 \mu s$, $T_{off} = 45 \mu s$, servo voltage = 40V and wire tension = 7 Kgf. The above result may be useful in modern shop floor for machining of D3 die steel using wire electrical discharge machining.

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