Process Parameter Optimization of Die sink EDM for machining of Inconel-625 alloy with brass electrode by using MOORA method

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Abstract: This paper aimed to find out the optimum process parameter of EDM while processing of INCONEL 625 work piece using brass electrode tool. Experiments are designed by using Taguchi's L9 orthogonal array. Pulse on time, flushing pressure and peak current have been used as variable process parameters. Material removal rate and tool wear rate have been taken as response characteristics. Effect of the individual input parameter on output response variables have been studied. Multi-objective optimization by ratio analysis (MOORA) method is used in order to optimize the response variables i.e. to get maximum MRR and minimum TWR. ANOVA method is applied to get an idea about most significant process parameter and their contribution on machining of Inconel 625 alloy by using Brass.

***Keywords*:** MOORA, Optimization, ANOVA, EDM

1. Introduction

Machining of Inconel 625 is very challenging task for traditional machine. EDM is one of the modern machining process best suitable for machining of very hard and tough materials. In this process electrical energy is being used to produce electrical sparks, which removes material by melting and vaporization. This process depends on a number of input parameters which directly impact output responses. So it is necessary to select proper input parameters for control of output variables. In this experiment, Taguchi's L9 orthogonal array is used for setting of input parameters. MOORA method is used for optimization and responses are analyzed by using ANOVA technique.

Vijay Varma and Ram Sajeevan [1] selected L9 orthogonal array for finding optimal process factors of die sink EDM. Uttam Kumar et al [2] selected Vikor index method used for optimizing the process variable of EDM process for machining of high carbon steel with copper electrode. Sahoo et al [3] Analysed of wire edm process parameters for micromachining of high carbon high chromium steel by using MOORA technique. Avijeet Satpathya et al [4] used TOPSIS technique for the optimization of machining parameter for machining a metal matrix composite called AlSiC-20%SiC. Jung and Kwon [5] chosen Gray relational approach method to optimize EDM PROCESS parameters. Annand et al [6] used Grey relational analysis to optimize the process parameters of EDM in presence of magnetic field. Jaharah et al [7] found that there is no tool wear rate at high highest current, high pulse on time and low pulse off time for machining of AISI H13 tool steel using copper tool on EDM.

Vijay Verma and Rohit Sahu [8] used full factorial design approach to obtain optimized process variables for machining of titanium V grade alloy on EDM process. Sahu et al [9] applied Grey relational analysis (GRA) method in Electro discharge machining of Ti-alloy (Ti6Al4V) and 316LStainless Steel. Mandal and Sarkar [10] used selection of best intelligent manufacturing system (IMS) under fuzzy MOORA conflicting MCDM environment. Kalibatas and Turskis [11] used Multi-criteria evaluation of inner climate by using MOORA method. Gadakh [12] Applied of MOORA method for parametric optimization of milling process. Bara et al [13] applied Grey Relational Analysis for Multi-response Optimization of Nd:YAG Laser for Micro-drilling of 304 Stainless Steel. Brauers and Zavadskas [14] Robustness of the multi-objective MOORA method with a test for the facilities sector. Bara et al [15] applied Desirability Function Approach for Multi Response Optimization of Nd:YAG Laser Micro Drilling Characteristics of 304 Stainless Steel.

2. Experiments

2.1. Materials

Nickel-chromium and molybdenum based Inconel 625 (**Table. 1)** is used as work bit material for the testing. Brass is used as cathode for the machining of Inconel-625. The electrodes are prepared in cylindrical form with diameter equivalent to 12 mm and length equal to 120 mm. The chemical composition of brass cathode is offered in table 2.

Table. 1. Inconel-625 Chemical Composition

Carbon	Nickel	Chromium	Molybdenum	Nibodium	Titanium
0.087%	64.3%	20.6%	8.37%	3.25%	0.1%
Cobalt	Manganese	Silicon	Phosphorous	Sulphur	
0.4%	0.36%	0.25%	0.014%	0.012%	

Table 2. Brass Cathode Chemical Composition

Copper	Zinc	Lead	Strontium	Ferrous	Nickel
58.8%	37.2%	2.7%	0.5%	0.9%	0.16%

2.2 Methods

The experimental design proposed by Taguchi's L_9 orthogonal arrays is used to organize the parameters with their levels.

MOORA Methodology

The multi-objective optimization by ratio analysis (MOORA) technique uses simultaneously beneficial and non-beneficial criteria for ranking the alternatives from a set of available options. This method has been successfully applied in various engineering/management fields.

Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) is a technique used to determine the percent contribution of each process variables.

2.3 Experimentation

Experimental procedure

Before placing the work piece on to the machining set up the initial weights of the work piece are measured using 1mg accuracy digital weighing machine and noted for every outing. Similar method implemented to the tool cathodes. EDM 30 oil is used as dielectric fluid in the testing. Using pumping mechanism, the dielectric fluid is packed in the entire set up container. Work piece is coupled to the negative terminal and electrode is coupled to the positive terminal of DC power source. Then the work piece is held on the machine table using a specially intended fixture and allowed to machining. The electrode is progressed downwards to provide feed; servo control mechanism is used. The approximate time for every machining is taken as 15 min. After every 15 min the machining is stopped and work piece are removed from set up. Once the machined work pieces are dried, final weights are measured and recorded. Finally, the outcome is used to decide the effects of Current(I), pulse on time(T-ON) and flushing pressure(P) on the MRR as well as on TWR.

Fig. 1. CNC DIE SINK EDM MACHINE

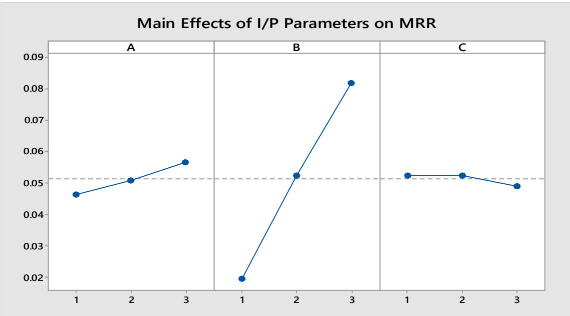
Fig. 2. Holes prepared by EDM

3. Results and Discussions

The specimens of Inconel 625 were prepared and machined on die sink EDM machine in accordance with experimental design. Experimental responses are measured and recorded as shown in table 3.

Table. 3. Experimental results with brass electrode

EXPT. NO.	T-ON (us)	CURRENT (A)	PRESURE (Psi)	MATERIAL REMOVAL RATE	TOOL WEAR RATE
1	110	5	2.5	0.01741	0.01197
2	110	10	5	0.04782	0.03251
3	110	15	7.5	0.07369	0.04245
4	120	5	5	0.01950	0.01211
5	120	10	7.5	0.05131	0.03433
6	120	15	2.5	0.08177	0.04483
7	130	5	7.5	0.02186	0.01441
8	130	10	2.5	0.05810	0.03251
9	130	15	5	0.09033	0.04495



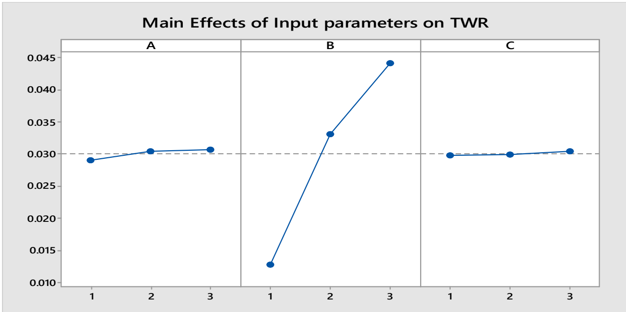


Fig. 3. Main Effects of input Factors on Material removal rate **Fig. 4.** Main Effects of input factors on Tool wear rate

3.1 MOORA Method Table

Tables 4. Optimized data by MOORA Method

Expt. No.	MRR (X^*_{ij})	TWR (X^*_{ij})	MRR (V^*_{ij})	TWR (V^*_{ij})	Y*	Rank
1	0.1010	0.1220	0.0505	0.0610	-0.0105	7
2	0.2773	0.3314	0.1387	0.1657	-0.0271	9
3	0.4274	0.4328	0.2137	0.2164	-0.0027	4
4	0.1131	0.1235	0.0565	0.0617	-0.0052	5
5	0.2976	0.3500	0.1488	0.1750	-0.0262	8
6	0.4742	0.4570	0.2371	0.2285	0.0086	2
7	0.1268	0.1469	0.0634	0.0735	-0.0101	6
8	0.3369	0.3314	0.1685	0.1657	0.0028	3
9	0.5239	0.4583	0.2619	0.2291	0.0328	1

Table 5. Response table of MOORA method

Factors	Level-1	Level-2	Level-3	Max-Min	Rank
T_{on}	-0.013428	-0.007599	0.008500	0.021928	2
IP	-0.008593	-0.016833	0.012900	0.029733	1
FP	0.000275	0.000191	-0.012991	0.013266	3

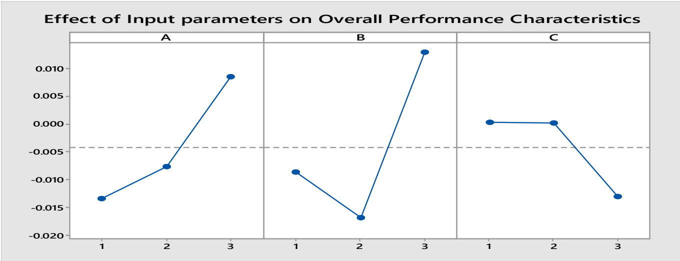


Fig. 5. Optimum level of machining performance

Optimum level for rise of MRR and decrease of TWR through additional significance to TWR is $(T_{on})_1$, $(IP)_1$ and $(FP)_3$.

3.2 ANOVA Results

Table 6 shows ANOVA results for complete performance

Table 6. ANOVA result

Factors	SS	DOF	MS	% Involvement
T_{on}	0.000774	2	0.000387	29.03226
IP	0.001414	2	0.000707	53.03826
FP	0.000350	2	0.000175	13.12828
Error	0.000128	2	0.000064	4.8012
Total	0.002666	8	0.001333	100

From the above, it is shown that the MRR and TWR is mostly affected by Current (The % contribution is 53.04 %) next followed by Pulse on time (the % contribution is 29 %).

4. Conclusions

After successful application of MOORA method and ANOVA the following conclusion can be drawn:

- Increase in pulse on time and current MRR and TWR increases.
- Flushing pressure has less significance on MRR and TWR.
- Optimum settings for maximum MRR and minimum TWR with more importance to TWR are $(T_{on})_1$, $(IP)_1$ and $(FP)_3$ i.e. Pulse on time 130 µs, Current 15 A and Flushing pressure 5 Psi.
- The overall effect of Inconel 625 is mainly affected by peak current with brass electrode. Remaining factors playing very less significant role compared to current. Inconel-625 super alloy can be machined easily with high accuracy by EDM process.

References

[1] Vijay Vermaa and Ram Sajeevan,” Multi process parameter optimization of Die-sinking EDM on Titanium alloy (Ti6Al4V) using Taguchi approach”, Materials Today: Proceedings 2 (2015) 2581 – 2587.

[2] Uttam Kumar, Mohantya, Jaydev Ranab and Abhay Sharmaa, ” Multi-objective optimisation of electro discharge machining (EDM) parameter for sustainable machining”, Materials Today: Proceedings 4 (2017) 9147–9157

[3] S. K. Sahoo, S. S. Naik and J. Rana (2019), Experimental Analysis of Wire EDM Process Parameters for Micromachining of High Carbon High Chromium Steel by Using MOORA

Technique, In: Micro and Nano Machining of Engineering Materials, Materials Forming, Machining and Tribology, Springer, https://doi.org/10.1007/978-3-319-99900-5_7.
[4] Avijeet Satpathya, S Tripathyb, N Pallavi Senapatic, Mihir Kumar Brahmad, "Optimisation of EDM process parameters for AlSiC-20% SiC reinforced metal matrix composite with multi response using TOPSIS" Materials Today: Proceedings 4 (2017) 3043–3052
[5] J.H.Jung and W.T Kwon, "Optimization of EDM process for multiple performance characteristics using Taguchi method and Grey relational analysis", Journal of Mechanical Science and Technology, 24 (5), 2010,pp. 1083-1090.
[6] G. Anand, S.Satyanarayana and Manzoor Hussain, "Optimization of Process Parameters in EDM with Magnetic Field Using Grey Relational Analysis with Taguchi Technique", Materials Today: Proceedings 4 (2017) 7723–7730.
[7] Jaharah,Liang and , Wahid S Z, "Performance of copper electrode in EDM of AISI H13 Harden steel", Internatinal Journal of Mechanical and Material Engineering, Volume. 3, No.1, 2008, pp: 25-29.
[8] Vijay Verma and Rohit Sahu, "Process parameter optimization of die-sinking EDM on Titanium grade – V alloy (Ti6Al4V) using full factorial design approach", Materials Today: Proceedings 4 (2017) 1893–1899.
[9] Anshuman Kumar Sahu, Pragyan Paramita Mohanty and Sarat Kumar Sahoo (2017), "Electro discharge machining of Ti-alloy (Ti6Al4V) and 316LStainless Steel and Optimization of process parameters by Grey relational analysis (GRA) method" Advances in 3D Printing & Additive Manufacturing Technologies, Springer, Chapter-6, Page: 1-14.
[10] Mandal, U.K. and Sarkar, B., Selection of best intelligent manufacturing system (IMS) under fuzzy MOORA conflicting MCDM environment, International Journal of Emerging Technology and Advanced Engineering, 2(2012) 301-310.
[11] Kalibatas, D. and Turskis, Z., Multi-criteria evaluation of inner climate by using MOORA method, International Journal of Information and Control, 37(2008) 79-83.
[12] Gadakh, V.S., Application of MOORA method for parametric optimization of milling process, International Journal of Applied Engineering Research, 1(2011) 743-758.
[13] A. Bara, S. K. Sahoo and S. S. Naik (2017), Multi-response Optimization of Nd:YAG Laser for Micro-drilling of 304 Stainless Steel Using Grey Relational Analysis, In: Advances in 3D Printing & Additive Manufacturing Technologies. Springer, 2017, pp. 101-110
[14] Brauers, W.K.M., and Zavadskas, E.K., Robustness of the multi-objective MOORA method with a test for the facilities sector, Technological and Economic Development of Economy, 15(2009) 352-375.
[15] A. Bara, S. K. Sahoo, S. S. Naik, A. K. Sahu and S. S. Mahapatra (2018), Multi Response Optimization of Nd:YAG Laser Micro Drilling Characteristics of 304 Stainless Steel using Desirability Function Approach, Materials Today: Proceedings, 5,18975–18982.