Parametric optimization in wire cut EDM on 316 stainless steel

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Abstract

EDM offers numerous diversity. Wire cut EDM is one of the most emerging modern techniques for machining materials that offers more hardness while cutting and also offers resistance to generate intricate shapes by pedestrian methods. The optimum employment of the capacity of wire cut EDM requisites orthodox selection of machining parameters choosing SS316 as work piece. Using TAGUCHI'S L9 orthogonal array, no. of experiments to be conducted are finalised and Pulse-on time (T_{on}), Pulse-off time (T_{off}), Peak-current (Ip) & Wire feed rate were designated as input parameters. Three different levels of each parameter were plumped for shepherding the experiments. The responses quantified were Material Removal Rate (MRR), Kerf (width of cut) and Surface Roughness (Ra). One of the Multi Criteria Decision Making (MCDM) methods namely Grey Relation Analysis (GRA) is compassed to identify the optimum input parameter to generate higher assay of MRR and lower assay of Surface roughness and Kerf.

Keywords: Multi Criteria Decision Making (MCDM), SS316, Wire EDM, Taguchi's L9, GRA,

1. Introduction

Today's competitive world entertains miniaturization and quality of products. The urge of materials with dominant mechanical properties and superior quality is on surge[1]. The challenge to produce the miniaturised product combined with greater accuracy; transfix researchers to develop materials to be applied in sophisticated areas such as aerospace, missile, nuclear physics etc[2]. But this leads to difficult machinability for those materials conventionally. Hence the modern trend utilises unconventional energy sources like light, chemical, sound, electrical, mechanical, electrons, plasma and ions. EDM turned out to be one among the efficient non traditional machining ways that utilizes thermal and electrical energy combinely to erode material from work-piece[3]. As long as a material supports electrical conductivity, EDM can machine any material. It applies electrical energy for machining. But identifying the optimal combination of process parameters is required to avoid costly trial and error systems. Taguchi's orthogonal array[4] can turn out to be a great choice for minimizing unnecessary experimentation. It not only minimizes the number of experiments to be performed, but also suggests combinations of input parameters for comporting experimentations. MRR, surface roughness, kerf are the principal responses that sway the machining performance. But these responses are conflicting in nature and suggest a need for a multi-objective optimization method[5] to bridle this problem. Numerous models are proposed by researchers amongst which an effective approach available is multi criteria decision making (MCDM). Researchers found methods like grnn, MOORA[6] to sort out problems related to multi objective optimization. MOORA, TOPSIS combined with PCA can also be an alternate and hybrid approach to optimize process parameters in WEDM. MW, SDV, entropy, AHP and fuzzy methods were also suggested for optimizing process parameters of EDM[7]

2. Experimental Details

All the experiments were conducted on RATNAPARKHI 3240 NXG Wire EDM, with SS 316 as a work piece. Brass wire having 0.25 mm diameter was plumped for electrode. As Di-electric, De-ionized water has been employed. The experiments were planned by cutting the workpiece having 10 mm thickness in wire EDM. Present work is focused on to have a look on the upshot of Pulse-on time (T-on), Pulse-off time (T-off), Peak current (IP) and Wire feed rate on the Material Removal Rate (MRR), Surface roughness (Ra) & Kerf (width of cut). Parameters that are chosen as inputs followed by their corresponding levels are as mentioned in table 1.

Table 1: Input parameters with corresponding Levels

Input parameter	1st Level	2nd Level	3rd Level
Ton (µs)	35	40	45
Toff (µs)	36	39	42
Ip (A)	2	3	4
Wire feed (mm/min)	50	60	70

Experiments have been ushered following Taguchi's L9 orthogonal array and disparate amalgamation of input parameters for different experiment performed is reflected in following table 2.

Table 2: Parameters chosen as input for machining SS 316

Experiment	Input Parameters			
	Ton(μs)	Toff(μs)	IP(A)	W.F(mm/min)
1	35	36	2	50
2	35	39	3	60
3	35	42	4	70
4	40	36	3	70
5	40	39	4	50
6	40	42	2	60
7	45	36	4	60
8	45	39	2	70
9	45	42	3	50

Figure 1. Workpiece before machining.

Figure 2. Workpiece after machining.

The figure 1 and figure 2 indicate the workpiece before and after machining with Wire EDM.

1.1. Measured values of output responses

MRR, Roughness of surface (Ra) & Kerf have been measured after each experiment. MRR is calculated using a weighing machine and stop watch, R_a is computed by the help of Tally surf roughness tester and kerf is calculated using vernier calipers. Values that have been measured are recorded in table 3.

Table 3: Quantified values of output responses

Experiment	MRR(gm/sec)	Ra(µm)	Kerf(mm)
1	0.000794	2.552	0.53
2	0.00244	2.078	0.25
3	0.00574	2.067	0.18
4	0.00173	2.999	0.44
5	0.000754	2.174	0.38
6	0.00144	3.059	0.23
7	0.0015	2.248	0.48
8	0.00145	2.815	0.31
9	0.00109	2.232	0.52

2. Results and discussions

2.1. Grey Relational Analysis (GRA)

GRA, one of the recommended MCDM tools was identified to carry out by following four steps to fetch the optimized combination of process parameters from the experiments conducted.

Step A: Normalization of responses**:**

Larger value of MRR, Smaller value of R_a and minimal Kerf are generally choice of researchers as outputs. So in GRA, Larger the better equation as mentioned in (2) is selected to normalize the MRR and to normalize Ra & kerf, smaller the better equation as in (3) is picked.

Nominal is the best

$$Z_i(m) = \frac{|X_i(m) - X_o(m)|}{max\ X_i(m) - X_o(m)} \quad (1)$$

Larger is the better

$$Z_i(m) = \frac{X_i(m) - minX_i(m)}{maxX_i(m) - minX_i(m)} \quad (2)$$

Smaller is the better

$$Z_i(m) = \frac{maxX_i(m) - X_i(m)}{maxX_i(m) - minX_i(m)} \quad (3)$$

The final normalized data for all the output responses are as tabulated in table 4.

Table 4: Normalized data of response parameters

Experiment	MRR	Ra	Kerf
1	0.008022	0.511089	0
2	0.338147	0.988911	0.8
3	1	1	1
4	0.195748	0.060484	0.257143
5	0	0.892137	0.428571
6	0.137585	0	0.857143
7	0.149619	0.81754	0.142857
8	0.139591	0.245968	0.628571
9	0.067389	0.833669	0.028571

Step B: Sequence of Deviation: The data which is normalized d is selected for computing the deviation sequence of GRA by applying equation (4) and the output is as reflected in table 5.

$$\Delta Z(m) = |Z_o(m) - Z_i(m)| \quad (4)$$

Table 5: Sequence of deviation of output response

Experiment	MRR	Ra	Kerf
1	0.991978	0.488911	1
2	0.661853	0.011089	0.2
3	0	0	0
4	0.804252	0.939516	0.742857
5	1	0.107863	0.571429
6	0.862415	1	0.142857
7	0.850381	0.18246	0.857143
8	0.860409	0.754032	0.371429
9	0.932611	0.166331	0.971429

Step C: Grey Relational Coefficient (GRC): This can be computed by substituting the Sequence of Deviation in equation (6) and result is represented in table 6.

$$£_i(m) = \frac{\Delta_{min} + 0.5 * \Delta_{max}}{\Delta Y_i(\text{m}) + 0.5 * \Delta_{max}} \quad (6)$$

Table 6: GRC of output responses

Experiment	MRR	Ra	Kerf
1	0.335126	0.505607	0.333333
2	0.430347	0.978304	0.714286
3	1	1	1
4	0.383362	0.347339	0.402299
5	0.333333	0.822554	0.466667
6	0.366995	0.333333	0.777778
7	0.370266	0.732644	0.368421
8	0.367536	0.398714	0.57377
9	0.349013	0.750378	0.339806

Step D: GRA grade: GRA grade is computed by applying equation 7 that produces average of GRCs of responses of every experiment from table 6. The GRA grade followed by their rank for corresponding experiments is represented in table 7as shown below.

$$r_i = \frac{1}{r} \sum_{i=1}^{r} £_i(m) \quad (7)$$

Table 7: GRA grade with their corresponding ranks

Experiment	GRA grade	GRA Rank
1	0.391355	8
2	0.707645	2
3	1	1
4	0.377666	9
5	0.540851	3
6	0.492702	4
7	0.490444	5
8	0.446674	7
9	0.479732	6

The ranking is done from highest value of GRA grade to the lowest. First rank indicates optimum experiment to achieve high MRR, low R_a and kerf. Having a look on table 7 indicates the 3rd experiment has the 1st rank, where the following are the input parameters

T_{on} = 35 µs,

T_{off} = 42 µs,

I_P = 4 A,

W.F = 70 mm/min

3. Conclusion

The current research was aimed to determine the optimum process parameters while machining SS 316 on WEDM. Taguchi's L_9 OA has been used where 9 experimentations were performed to identify the best combination of inputs to generate optimum MRR, Surface Roughness (R_a) and Kerf.

One of the MCDM approach, Grey Relation Analysis (GRA) has been chosen as an optimization technique which swayed the best combination of inputs in the range of this study.

The results of GRA has recommended that, pulse-on time, T_{on} (35 µs at 1^{st} level), Pulse off time, T_{off} (42 µs at 3^{rd} level), Peak Current, I_P (4 A at 3^{rd} level) and Wire feed rate, W.F (70 mm/min at 3^{rd} level) is the optimized set of input parameters.

3. References

[1] R. R. Kumar, A. K. Jana, S. C. Mohanty, K. Mangapathi Rao, V. Guru Shanker, and D. Rohit Reddy, "Optimizing process parameters of die sinking EDM in AISI D2 steel by using TOPSIS using EDM oil as dielectric," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1057, no. 1, p. 012060, Feb. 2021, doi: 10.1088/1757-899X/1057/1/012060.

[2] A. K. Jana, R. Ranjith Kumar, S. C. Mohanty, K. Mangapathi Rao, V. G. Shanker, and A. Y. Reddy, "Parametric Optimization of Die Sinking EDM in AISI D2 Steel considering Canola oil as Dielectric using TOPSIS and GRA," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1057, no. 1, p. 012061, Feb. 2021, doi: 10.1088/1757-899X/1057/1/012061.

[3] P. Sreeraj, S. Thirumalai Kumaran, S. Suresh Kumar, M. Uthayakumar, and M. Pethuraj, "Application of MCDM based hybrid optimization of WEDM process parameters," *Mater. Today Proc.*, vol. 50, pp. 1186–1192, Jan. 2022, doi: 10.1016/j.matpr.2021.08.067.

[4] J. D. Patel and K. D. Maniya, "Optimization of WEDM Process Parameters for Aluminium Metal Matrix Material Al+SiC Using MCDM Methods," in *Advances in Manufacturing Processes*, Singapore, 2021, pp. 59–70. doi: 10.1007/978-981-15-9117-4_5.

[5] D. Bagal, A. Barua, S. Jeet, P. Satapathy, and D. Patnaik, "MCDM Optimization of Parameters for Wire-EDM Machined Stainless Steel using Hybrid RSM-TOPSIS, Genetic Algorithm and Simulated Annealing," *Int. J. Eng. Adv. Technol.*, vol. 9, pp. 366–371, Oct. 2019, doi: 10.35940/ijeat.A9349.109119.

[6] H. Majumder and K. Maity, "Prediction and optimization of surface roughness and micro-hardness using grnn and MOORA-fuzzy-a MCDM approach for nitinol in WEDM," *Measurement*, vol. 118, pp. 1–13, Mar. 2018, doi: 10.1016/j.measurement.2018.01.003.

[7] A. Singh, R. K. Ghadai, K. Kalita, P. Chatterjee, and D. Pamučar, "EDM PROCESS PARAMETER OPTIMIZATION FOR EFFICIENT MACHINING OF INCONEL-718,"

Facta Univ. Ser. Mech. Eng., vol. 18, no. 3, Art. no. 3, Oct. 2020, doi: 10.22190/FUME200406035S.

[8] S. C. Mohanty, A. K. Jana, R. K. Rachakonda, G. M. Kumar, and A. S. N. S. R. Teja, "Effect of Post-mixing Vacuum Degassing time of MWCNT/Epoxy Mixture and MWCNT Content on the Flexural Behaviour of MWCNT Filled Glass/Epoxy Composite," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1057, no. 1, p. 012004, Feb. 2021, doi: 10.1088/1757-899X/1057/1/012004.

[9] V. Guru Shanker, M. Bhargavi, M. Ashok, R. Ranjith Kumar, and A. kumar Jana, "Numerical and structural investigation of flow past a helical axis wind turbine," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1057, no. 1, p. 012037, Feb. 2021, doi: 10.1088/1757-899X/1057/1/012037.

[10] S. C. Mohanty, B. P. Singh, K. K. Mahato, D. K. Rathore, R. K. Prusty, and B. C. Ray, "Water absorption behavior and residual strength assessment of glass/epoxy and glass-carbon/epoxy hybrid composite," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 115, p. 012029, Feb. 2016, doi: 10.1088/1757-899X/115/1/012029.