Parametric optimization of WEDM control variables on magnesium AZ91 alloy by TOPSIS method

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Abstract. Multi-Criterion Decision Making (MCDM) strategies have gotten much consideration from scientists and professionals in assessing, evaluating and positioning choices over assorted manufacturing industry. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) continues on working attractively crosswise over various application territories. This paper proposes the TOPSIS-based Taguchi enhancement way to deal with decide the ideal WEDM process parameter for machining of magnesium AZ91 alloy by zinc coated wire electrode. This experiment was outlined with L27 orthogonal cluster. The test ponders were directed under shifting Pulse on time, Pulse off time, current, gap voltage, speed and tension of wire. The impact of the machining variables over kerf width (KW) and cutting speed (CS) is dictated by utilizing examination of fluctuation. The parameters corresponding to experiment run number 2 are Pulse on time 106 units (Level 1), Pulse off time 60 units (Level 3), peak current 70 units (Level 1), gap voltage 40 units (Level 3), wire feed 4 units (Level 1) & wire tension 4 units (Level 1) are the best combination to achieve better cutting speed& kerf width

Keywords: TOPSIS, WEDM, Taguchi method, AZ91, cutting speed & Kerf width criterion

1. Introduction
Manufacturing sector is growing rapidly by accommodating technology modernization. The mechanism for machining hard reinforced materials, intricate shapes & different contours which are very difficult for machining by conventional techniques which created many unconventional methods. CNC EDM machine was developed in the year 1969. WEDM which involves moving very thin electrode continuously. Electrode wire materials like pure brass, diffused coated and zinc coated wire of diameter ranges from 0.05-0.35 are widely applied in industry. The gap generally between work and wire electrode is generally ranges from 25 to 50 microns and is continuously maintained by a modern computer program controlled coordinating system. To achieve smooth surface quality on the tool and in the component, optimum process variables setting is a very important. Machining control variables are optimized by using different methods for improving the better quality. Taguchi method which is widely applied mainly experimental design in manufacturing application. It allows optimization of few parameters in machining by turning, milling, Electro Discharge Machining, wire cut EDM, welding, grinding etc. The optimization is achieved with lesser number of tests by this overall cost and time is saved.

2. Materials& method

| Al  | Zn  | Mn  | Fe  | Si  | Cu  | Zr  | Mg  |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 8.84| 0.61| 0.18| 0.02| 0.02| 0.005| 0.002| Balance |
2.1. Machining control variables
Six information process variables Wire EDM, to be specific, Pulse on time, Pulse off time, current, gap voltage, the wire drum speed & tension were considered their consequences for kerf & CS while machining the AZ91 alloy. The scopes of these procedure parameters were considered on the premise of the pilot tests. The levels of different variables & their assignments are exhibited in Table 2.

| Symbol | Process variables | Level -1 | Level -2 | Level -3 |
|--------|-------------------|----------|----------|----------|
| A      | Pulse on time     | 106      | 116      | 126      |
| B      | Pulse off time    | 40       | 50       | 60       |
| C      | Pulse current     | 70       | 150      | 230      |
| D      | Gap Voltage       | 20       | 30       | 40       |
| E      | Wire speed        | 4        | 6        | 8        |
| F      | Wire tension      | 4        | 8        | 12       |

Fig. 1 Kerf width for AZ91 magnesium alloy.

2.2. Taguchi Method of experimental design
Taguchi strategy is a proficient apparatus for the outline of a great assembling framework. It also effectively solves some more complex problems in manufacturing (Roy 1990). It is a strategy in view of OA tests, which give much decreased change to the try different things with ideal setting of process control parameters. The six control parameters, that is, Pulse on time (A), Pulse off time (B), current (C), Gap voltage (D), wire drum speed (E) and wire tension (F) at three levels were picked in this examination. The tests were finished by Table 3. This table just speaks to specific level of the different elements of the procedure at which the examinations would be directed. Kerf width is considered to be as least as conceivable in the WEDM procedure. Kerf width is an imperative component of laser cutting procedure that gives the benefit of this innovation contrasted with different strategies for form cutting.

2.3. Experimental Set Up
Analyses were led on Electronica Sprint cut CNC wire cut electrical discharge machine to think about the surface finish quality and KW mostly influenced by the machining control parameters at various levels. WEDM is a start disintegration process. The flashes are produced between the work & the wire terminal. Dielectric liquid is ceaselessly encouraged into the machining zone with required weight. The material is getting expelled by a progression of discrete sparkles occurring at the zone to be machined through electro-warm system. Test set up of the wire electrical release machine is appeared in Figure 2. Amid machining process little hole kept up between the work and wire material. The machined small minute particles were flushed & carried away by the persistent stream of dielectric medium. The electrode is held by a stick direct at the upper & lower parts of the work piece.
The work example measure utilized a part of this examination is 100 x 100 x 10 mm rectangular plate. Zinc covered metal cathode wire of 0.25 mm diameter was utilized to a part of this investigation. Deionized water was preferred as dielectric liquid at room temperature. In the wake of machining, the examples were cleaned with acid after machining. The kerf was measured utilizing profile projector measuring framework. The kerf esteems were measured at six spots spread over the entire length of cut. The kerf esteems considered as a part of this examination are the numerical normal of three estimations produced using the example in each cut.

2.4. Methodology

Procedure for Order Preference by Similarity to Ideal Solution Method (TOPSIS) is one of the MCDM which is utilized to comprehend the sort of basic leadership issue. This technique depends on the idea that the picked option ought to have the most limited Euclidean separation from the perfect arrangement, and the most remote from the negative perfect arrangement. The perfect arrangement is a speculative answer for which all ascribe esteems compare to the most extreme trait esteems in the database containing the fantastic arrangements; the negative perfect arrangement is the theoretical answer for which all credit esteems relate to the base property estimations in the database. TOPSIS along these lines gives an answer that is not just nearest to the speculatively best, that is additionally the most distant from the theoretically most noticeably awful.

**Step 1**: Initial step to be followed in TOPSIS strategy is the standardization of execution of various model and the standardized grid is appeared in Table 4. This stage give way to contrasting distinctive foundation by changing over different properties measurement into non dimensional property. Standardize scores or information as takes after:

$$R_{ij} = \frac{x_{ij}}{\sum x_{ij}}$$ for $i = 1 \ldots m; j = 1 \ldots n$;

**Step 2**: Apportioning weights for the whole model which are considered for streamlining. The weights considered for this exploration were: surface unpleasantness = 0.522, kerf width = 0.478. The aggregate of weight ought to be equivalent to one.

**Step 3**: Develop the weighted standardized choice grid as in Table 5. Assume we have weights for every basis $w_j$ for $j = 1 \ldots n$.

On duplicating every section of standardized choice lattice by its particular weight the component acquired is:

$$V_{ij} = W_j R_{ij}$$

**Step 4**: The next step is determination of ideal and negative ideal solution Ideal solution.

Positive ideal solution

$$A^+ = \{ V^+ \} \text{ where } V^+ = \{ \max (V_{ij}) \text{ if } j \in J; \min (V_{ij}) \text{ if } j \in J' \}$$

Negative ideal solution

$$A^- = \{ V^\prime \} \text{ where } V^\prime = \{ \min (V_{ij}) \text{ if } j \in J; \max (V_{ij}) \text{ if } j \in J' \}$$

**Step 5**: Separation measure determination is the fifth step in TOPSIS method. The value obtained is given below:

The separation from the ideal alternative is:

$$S^+_i = \left[ \sum (V^+_j - V_{ij})^2 \right]^{1/2}$$ for $i = 1, \ldots, m$

Similarly, the separation from the negative ideal alternative as shown below Table 6:

$$S^-_i = \left[ \sum (V^\prime_j - V_{ij})^2 \right]^{1/2}$$ for $i = 1, \ldots, m$

**Step 6**: The relative closeness of a particular alternative

$$P_i = \frac{S^-_i}{(S^+_i + S^-_i)} \cdot 0 < P_i < 1$$

Select the option with $P_i$ closest to 1

3. Result and discussion

Table 4 shows the square of Xi and normalized matrix for Xi calculated by TOPSIS method. The normalized CS & KW are multiplied with their corresponding weights given in table 5. The parameters, higher the better (maximum) and smaller the better (minimum) respectively added for rank calculation. The surface roughness observed in the experiment is in the range of from 2.252 to 4.256. Similarly, the kerf width observed in the experiment is in the range of from 292 to 327. From these observations, experiment number 4 has the best rank. The parameters corresponding to experiment run number 2 are pulse on time 106 units (Level1), pulse off time 60 units (Level 3), peak current 70 units (Level 1), gap set voltage 40 units (Level 3), wire feed 4 units (Level1) and wire tension 4 units (Level1). Figure 2 shows the effect of process parameters on closeness values of coefficient.
Table 3: Cutting speed & Kerf width

| Ex. No. | Pulse on Time | Pulse off Time | Current | Gap voltage | Wire Feed | Wire Tension | CS | KW |
|---------|---------------|----------------|---------|-------------|-----------|--------------|----|----|
| 1       | 106           | 40             | 70      | 20          | 4         | 4            | 6.32 | 0.323 |
| 2       | 106           | 40             | 150     | 30          | 6         | 8            | 7.52 | 0.32 |
| 3       | 106           | 40             | 230     | 40          | 8         | 12           | 6.89 | 0.321 |
| 4       | 106           | 50             | 70      | 30          | 6         | 12           | 3.47 | 0.33 |
| 5       | 106           | 50             | 150     | 40          | 8         | 4            | 3.49 | 0.332 |
| 6       | 106           | 50             | 230     | 20          | 4         | 8            | 5.51 | 0.337 |
| 7       | 106           | 60             | 70      | 40          | 8         | 8            | 1.92 | 0.327 |
| 8       | 106           | 60             | 150     | 20          | 4         | 12           | 3.06 | 0.33 |
| 9       | 106           | 60             | 230     | 30          | 6         | 4            | 2.83 | 0.341 |
| 10      | 116           | 40             | 70      | 30          | 8         | 8            | 6.12 | 0.346 |
| 11      | 116           | 40             | 150     | 40          | 4         | 12           | 6.25 | 0.341 |
| 12      | 116           | 40             | 230     | 20          | 6         | 4            | 5.98 | 0.358 |
| 13      | 116           | 50             | 70      | 40          | 4         | 4            | 4.03 | 0.374 |
| 14      | 116           | 50             | 150     | 20          | 6         | 8            | 6.01 | 0.371 |
| 15      | 116           | 50             | 230     | 30          | 8         | 12           | 5.98 | 0.365 |
| 16      | 116           | 60             | 70      | 20          | 6         | 12           | 3.08 | 0.337 |
| 17      | 116           | 60             | 150     | 30          | 8         | 4            | 3.79 | 0.348 |
| 18      | 116           | 60             | 230     | 40          | 4         | 8            | 3.68 | 0.358 |
| 19      | 126           | 40             | 70      | 40          | 6         | 12           | 5.78 | 0.356 |
| 20      | 126           | 40             | 150     | 20          | 8         | 4            | 5.92 | 0.351 |
| 21      | 126           | 40             | 230     | 30          | 4         | 8            | 5.97 | 0.352 |
| 22      | 126           | 50             | 70      | 20          | 8         | 8            | 5.17 | 0.347 |
| 23      | 126           | 50             | 150     | 30          | 4         | 12           | 5.99 | 0.364 |
| 24      | 126           | 50             | 230     | 40          | 6         | 4            | 5.97 | 0.364 |
| 25      | 126           | 60             | 70      | 30          | 4         | 4            | 3.14 | 0.361 |
| 26      | 126           | 60             | 150     | 40          | 6         | 8            | 4.92 | 0.372 |
| 27      | 126           | 60             | 230     | 20          | 8         | 12           | 5.98 | 0.349 |

Fig. 2 Effect of process parameters on closeness coefficient
### Table 4: Normalized Cutting speed & Kerf width

| Ex.No. | Pulse on Time | Pulse off Time | Peak Current | Gap set Voltage | Wire Feed | Wire Tension | CS   | KW   |
|--------|---------------|----------------|--------------|-----------------|-----------|--------------|------|------|
| 1      | 108           | 40             | 90           | 10              | 3         | 4            | 0.13921 | 0.08859 |
| 2      | 108           | 40             | 90           | 10              | 4         | 8            | 0.12754 | 0.08887 |
| 3      | 108           | 40             | 90           | 10              | 5         | 12           | 0.06423 | 0.09136 |
| 4      | 108           | 50             | 160          | 30              | 3         | 4            | 0.0646  | 0.09191 |
| 5      | 108           | 50             | 160          | 30              | 4         | 8            | 0.05664 | 0.09136 |
| 6      | 108           | 50             | 160          | 30              | 5         | 12           | 0.05239 | 0.0944  |
| 7      | 108           | 60             | 230          | 50              | 3         | 4            | 0.03554 | 0.09053 |
| 8      | 108           | 60             | 230          | 50              | 4         | 8            | 0.0957  | 0.10105 |
| 9      | 108           | 60             | 230          | 50              | 5         | 12           | 0.0746  | 0.10354 |
| 10     | 117           | 40             | 160          | 50              | 3         | 8            | 0.11329 | 0.09579 |
| 11     | 117           | 40             | 160          | 50              | 4         | 12           | 0.11125 | 0.10271 |
| 12     | 117           | 40             | 160          | 50              | 5         | 4            | 0.1107  | 0.09911 |
| 13     | 117           | 50             | 230          | 10              | 3         | 8            | 0.05701 | 0.09329 |
| 14     | 117           | 50             | 230          | 10              | 4         | 12           | 0.07016 | 0.09634 |
| 15     | 117           | 50             | 230          | 10              | 5         | 4            | 0.06812 | 0.09911 |
| 16     | 117           | 60             | 90           | 30              | 3         | 8            | 0.05813 | 0.09855 |
| 17     | 117           | 60             | 90           | 30              | 4         | 12           | 0.07016 | 0.09634 |
| 18     | 117           | 60             | 90           | 30              | 5         | 4            | 0.06812 | 0.09911 |
| 19     | 126           | 40             | 230          | 30              | 3         | 12           | 0.1107  | 0.09855 |
| 20     | 126           | 40             | 230          | 30              | 4         | 4            | 0.10959 | 0.09717 |
| 21     | 126           | 40             | 230          | 30              | 5         | 8            | 0.11051 | 0.09745 |
| 22     | 126           | 50             | 90           | 50              | 3         | 12           | 0.0957  | 0.09606 |
| 23     | 126           | 50             | 90           | 50              | 4         | 4            | 0.11088 | 0.10077 |
| 24     | 126           | 50             | 90           | 50              | 5         | 8            | 0.11051 | 0.10077 |
| 25     | 126           | 60             | 160          | 10              | 3         | 12           | 0.05813 | 0.09994 |
| 26     | 126           | 60             | 160          | 10              | 4         | 4            | 0.09108 | 0.10298 |
| 27     | 126           | 60             | 160          | 10              | 5         | 8            | 0.1107  | 0.09662 |

### Table 5: Closeness coefficient values and ranking of alternatives

| Ex.no. | S⁺  | S⁻  | Pᵢ  | Rank |
|--------|-----|-----|-----|------|
| 1      | 0.022235 | 0.082665 | 0.788032 | 3    |
| 2      | 0    | 0.104742 | 1    | 1    |
| 3      | 0.011673 | 0.093162 | 0.888651 | 2    |
| 4      | 0.075031 | 0.031168 | 0.293489 | 22   |
| 5      | 0.074684 | 0.031301 | 0.295333 | 21   |
| 6      | 0.037506 | 0.067246 | 0.641956 | 15   |
| 7      | 0.103688 | 0.01301  | 0.11484  | 27   |
| 8      | 0.082616 | 0.024363 | 0.227736 | 23   |
| 9      | 0.087014 | 0.019169 | 0.18053  | 26   |
| 10     | 0.026901 | 0.078135 | 0.743886 | 5    |
Conclusions

In this experimental study, the TOPSIS method is applied for the estimation of optimum machining parameters to minimize cutting speed and kerf width. The conclusions drawn from this study are as follows:

1. TOPSIS method is employed to select the optimum machining parameters in WEDM machining of AZ91 Magnesium alloy with zinc coated brass wire electrode.

2. From these observations, experiment number 4 has the best rank. The parameters corresponding to experiment run number 2 are pulse on time 106 units (Level1), pulse off time 60 units (Level 3), peak current 70 units (Level 1), gap set voltage 40 units (Level 3), wire feed 4 units (Level 1) and wire tension 4 units (Level1).

3. The optimum results are adopted in validation study and the results based on WEDM process responses can be effectively improved.

4. As compared to many other MADAM methods, this method is found to be simple, logical and robust. This method can simultaneously consider any number of quantitative and qualitative selections of attributes and is able to provide optimum solution quickly as computational time required to obtain the solution is reasonably low. This technique can be effectively considered to take care of a few multi objective optimization problems with different environment.

REFERENCES

[1] Tatar, C., Ozdemir, N. (2010). “Investigation of thermal conductivity and microstructure of the a-Al2O3 particulate reinforced aluminium composites (Al/Al2O3-MMC) by powder metallurgy method”. Physica B Condensed Matter. Vol.405, pp.896-899.

[2] Manna, A., Bains, H.S., Mahapatra. P.B. (2011).“Experimental study on fabrication of Al–Al2O3/Grp metal matrix composites”. Journal of Composite Materials, Vol.45, No.19, pp.2003-2010.

[3] Tosun N., Cogun C. and Tosun G. 2004. A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method. Journal of Materials Processing Technology. 152,316-322.

[4] Hung, N.P., Loh, N.L., Xu, Z.M . (1996). “Cumulative tool wear in machining metal matrix composites part II: machinability”. Journal of Material Processing Technology, Vol.58, pp.114–120.

[5] Singaravel Balasubramaniyan &Thangiah Selvaraj (2017), Application of integrated Taguchi and TOPSIS method for optimization of process parameters for dimensional accuracy in turning of EN25 steel, Journal of the Chinese Institute of Engineers, pp. 1-8.

[6] R. Manivannan & M. Pradeep Kumar (2016), Multi-attribute decision making of cryogenically cooled Micro-EDM drilling process parameters using TOPSIS method, Materials and Manufacturing Processes, pp. 1-31

[7] Arun Kumar Srirangan &Paulraj Sathiya (2017), Optimization of Process Parameters for Gas Tungsten Arc Welding of Incoloy 800HT Using TOPSIS, Materials Today: Proceedings 4 (2017) 2031–2039
[8] K.D. Mohapatraa and S.K. Sahoo (2018), A multi objective optimization of gear cutting in WEDM of Inconel 718 using TOPSIS method, Decision Science Letters, pp.157-170.

[9] Arun Kumar Parida and Bharat Chandra Routara (2014), Multiresponse Optimization of Process Parameters in Turning of GFRP Using TOPSIS Method, International Scholarly Research Notices, Hindawi Publishing Corporation, pp. 1-10.

[10] Gadakh, V. S (2012), parametric optimization of wire electrical discharge machining using TOPSIS method, Advances in Production Engineering & Management, pp. 157-164.

[11] P.C.Padhi, VikasUpadhyay, Raj Kumar (2016), Optimization of Process Parameters in WEDM of EN-31 Alloy Steel using Taguchi Technique and TOPSIS, Advanced Materials Manufacturing & Characterization, Vol 6 Issue 1, pp. 39-45.

[12] Muniappan .A, Thiagarajan .C and Somasundaram .S (2017) Parametric Optimization of kerf width and surface roughness in Wire Electrical Discharge Machining (WEDM) of hybrid Aluminium (Al6061/SiC/Graphite) composite using Taguchi-based Gray Relational Analysis” International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol:16 No:05, pp. 95-103.