Shielded Metal Arc Welding Electrode Selection Using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method

R. Bansode[1*], S. Gangurde[2]

[1]PG Student, K.K Wagh Institute of Engineering Education and Research, Nasik, India
[2]Associate Professor, K.K Wagh Institute of Engineering Education and Research, Nasik, India
{rjfrncs01@gmail.com}

Abstract: An important factor in welding process is selection of appropriate welding electrode. If a wrong welding electrode is selected then it may give rise to various welding defects and ultimately lead to failure of weld.In this paper, best welding electrode is selected from available alternatives of general purpose electrodes for mild steel for Shielded Metal Arc Welding process (SMAW). The selection is done by using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The results are then compared with other Multi Attribute Decision Making (MADM) methods; Simple Additive Weighing (SAW), Weighted Product Method (WPM), Modified TOPSIS. The best ranked electrode by all the methods is then selected as the best welding electrode from available alternatives.

Keywords: *Shielded Metal Arc Welding, welding electrodes, TOPSIS*
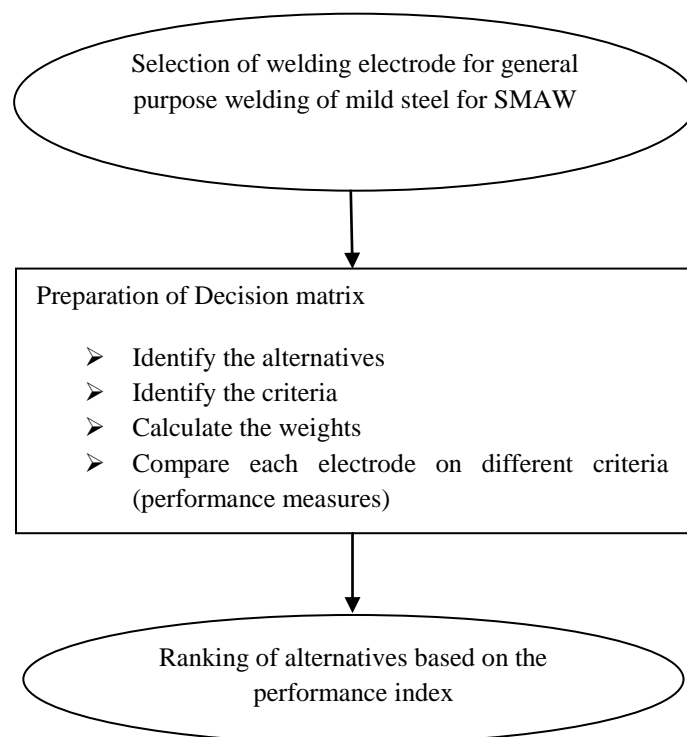
1 Introduction

Shielded metal arc welding (SMAW), also known as stick welding, is a process in which the joining occurs by melting the electrode by the arc established between a sticklike covered electrode and the metals [1]. There are many electrodes available for SMAW process. Each welding electrode comes with a set of parameters on the material of electrode and the diameter of electrode.This makes it very important to select appropriate electrode for welding process. If the appropriate electrode for the welding operation is not selected then it may give rise to various defects viz. undercutting, porosity, incomplete penetration, incomplete fusion, longitudinal cracking, spatter and arc instability [2]. This problem of selecting the appropriate electrode is solved by using multi attribute decision making (MADM) methods. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method is one of the MADM methods which is widely used. The results of TOPSIS are then compared with other MADM methods like Simple Additive Weighing (SAW) Method, Weighted Product Method (WPM) and Modified TOPSIS. In this work, six different alternatives are considered for general purpose welding of mild steel for SMAW. These electrodes are evaluated on the basis of seven criteria such as tensile strength (TS), yield strength (YS), elongation (E), reduction in area (RA), Charpy V-Notch impact test (CVN), deposition rate (DR), cost.

2 Methodology

The initial step for the methodology (Fig. 1) is to prepare the decision matrix. To prepare the decision matrix we have to identify the alternatives, criteria and calculate the weights of the criteria. Then we compare each electrode on different criteria (performance measures). The ranking of the criteria is done on the basis of the performance index calculated by the MADM methods.

The decision matrix for the problem is shown in Table 1. All the criteria, except for cost, are beneficial. There are six alternative selected for the problem.The weights of the criteria are calculated by Analytical Hierarchy Process (AHP) [3]. The elements of the decision table are to be normalized; as the criteria have different units,

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so that all the possible attributes in the decision problem can be considered.The values of criteria were taken from the product catalogue of a leading welding electrode manufacturer ESAB.

Selection of welding electrode for general
purpose welding of mild steel for SMAW

Preparation of Decision matrix

> Identify the alternatives
> Identify the criteria
> Calculate the weights
> Compare each electrode on different criteria
(performance measures)

Ranking of alternatives based on the
performance index

Fig. 1. Methodology

Table 1 Decision matrix

Alternatives	Criteria						
	TS (MPa)	YS (MPa)	E (%)	RA (%)	CVN (J)	DR (kg/hr)	Cost (₹)
Weights	**0.16**	**0.07**	**0.15**	**0.18**	**0.06**	**0.25**	**0.14**
E6010	427	490	28	65	37	1.40	369.36
E6011	562	524	22	56	50	1.70	254.28
E6013	482	558	27	55	47	1.45	294.42
E7010-P1	480	560	22	56	39	1.30	397.48
E7014	420	490	28	64	60	1.70	262.30
E7024	490	550	26	63	34	3.30	262.30

2.1 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method

TOPSIS method was first proposed by Hwang and Yoon [4]. In this method, we choose the best alternative having the shortest distance to the ideal solution and the farthest distance from the negative-ideal solution. We calculate the normalized values (R_{ij}) by Eq. (1).

$$R_{ij} = \frac{y_{ij}}{\sqrt{\sum_{j=1}^{m} y_{ij}^2}} \quad (1)$$

where, y_{ij} are the performance measures of the criteria.

The quantitative values of the welding electrode selection attributes are normalized by Eq. (1) and are shown in Table 2.

Table 2 Normalized matrix for TOPSIS and modified TOPSIS

Alternatives	Criteria						
	TS	**YS**	**E**	**RA**	**CVN**	**DR**	**Cost**
Weight	**0.16**	**0.07**	**0.15**	**0.18**	**0.06**	**0.25**	**0.14**
E6010	0.3638	0.3778	0.4460	0.4424	0.3329	0.2957	0.4836
E6011	0.4789	0.4040	0.3504	0.3811	0.4498	0.3590	0.3329
E6013	0.4107	0.4302	0.4301	0.3743	0.4228	0.3062	0.3855
E7010-P1	0.4090	0.4318	0.3504	0.3811	0.3509	0.2745	0.5204
E7014	0.3579	0.3778	0.4460	0.4356	0.5398	0.3590	0.3434
E7024	0.4175	0.4241	0.4142	0.4288	0.3059	0.6969	0.3434

Then the separation measures of each alternative are calculated using Eq. (2) and Eq. (3).

$$S_i^+ = \sqrt{\sum_{j=1}^{m} \left(V_{ij} - V_j^+\right)^2}$$

(2)

$$S_i^- = \sqrt{\sum_{j=1}^{m} \left(V_{ij} - V_j^-\right)^2}$$

(3)

The separation measures calculated by Eq. (2) and Eq. (3) are given below.

$$S_1^+ = 0.1050 \qquad S_1^- = 0.0203$$
$$S_2^+ = 0.0866 \qquad S_2^- = 0.0399$$
$$S_3^+ = 0.0996 \qquad S_3^- = 0.0264$$
$$S_4^+ = 0.1114 \qquad S_4^- = 0.0095$$
$$S_5^+ = 0.0868 \qquad S_5^- = 0.0389$$
$$S_6^+ = 0.0180 \qquad S_6^- = 0.1098$$

The composite or overall scores are termed as Electrode Selection Index (ESI), P_i and are calculated by Eq. (4).

$$P_i = \frac{S_i^-}{(S_i^+ + S_i^-)}$$

(4)

The overall scores (P_i) are shown in Table 4 and the alternatives are ranked in descending order of their scores in Table 5.

2.2 Modified TOPSIS

This method was presented by Deng et al. [5]. In this method, the positive ideal solution and the negative ideal solution are not dependent on the weighted decision matrix. The normalized is same as that of calculated in TOPSIS and is shown in Table 2. Using Eq. (5) and Eq. (6) we calculate the weighted Euclidean distances.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} w_j \left(R_{ij} - R_j^+ \right)^2}$$

(5)

$$D_i^- = \sqrt{\sum_{j=1}^{m} w_j \left(R_{ij} - R_j^- \right)^2}$$

(6)

The values of weighted Euclidean distances are given below

$D_1^+ = 0.2198$	$D_1^- = 0.0505$
$D_2^+ = 0.1764$	$D_2^- = 0.1017$
$D_3^+ = 0.2024$	$D_3^- = 0.0722$
$D_4^+ = 0.2334$	$D_4^- = 0.0274$
$D_5^+ = 0.1764$	$D_5^- = 0.1072$
$D_6^+ = 0.0640$	$D_6^- = 0.2255$

The overall scores (P_i) are calculated by Eq. (7) and is shown in Table 4 and the alternatives are ranked in descending order of their scores in Table 5.

$$P_i = \frac{D_i^-}{\left(D_i^+ + D_i^- \right)}$$

(7)

2.3 Simple Additive Weighing (SAW) Method

This method was developed by Fishburn in 1967 [6] and is also called Weighted Sum Method. The decision matrix is normalized before calculating the overall scores.

$$P_i = \sum_{j=1}^{m} w_j \left(y_{ij} \right)_{normal}$$

(8)

Where $(z_{ij})_{normal}$ is the normalized value of z_{ij} i.e. normalized values of performance measures. The overall scores are calculated by Eq. (8). The alternative having the highest composite score P_i is the best option from the given set of alternatives. The normalized matrix is shown in Table 3.

Table 3 Normalized matrix for SAW and WPM

Alternatives	Criteria						
	TS	YS	E	RA	CVN	DR	Cost
Weights	0.16	0.07	0.15	0.18	0.06	0.25	0.14
E6010	0.7598	0.8750	1.0000	1.0000	0.6167	0.4242	0.6884
E6011	1.0000	0.9357	0.7857	0.8615	0.8333	0.5152	1.0000
E6013	0.8577	0.9964	0.9643	0.8462	0.7833	0.4394	0.8637
E7010-P1	0.8541	1.0000	0.7857	0.8615	0.6500	0.3939	0.6397
E7014	0.7473	0.8750	1.0000	0.9846	1.0000	0.5152	0.9694
E7024	0.8719	0.9821	0.9286	0.9692	0.5667	1.0000	0.9694

The ranking of alternatives is shown in Table 5.

2.4 Weighted Product Method (WPM)

This method is similar to SPM and was developed by Miller and Starr in1969 [7]. WPM uses multiplication instead of addition. The normalized matrix is same as that of calculated in SPM. The overall scores (ESI) is calculated by Eq. (9).

$$P_i = \prod_{j=1}^{m} \left[\left(y_{ij} \right)_{normal} \right]^{w_j}$$

(9)

The overall scores (P_i) are shown in Table 4 and the ranking of alternatives is given in Table 5.

3 Results and Discussion

The results of MADM methods applied for the selection of welding electrode for general purpose electrodes for mild steel for SMAW process is shown in Table 4.

Table 4 Electrode Selection Index (ESI)

Electrode Selection Index (ESI)				
	TOPSIS	**MOD. TOPSIS**	**SAW**	**WPM**
E6010	0.1623	0.1870	0.7523	0.7054
E6011	0.3153	0.3657	0.8172	0.7832
E6013	0.2095	0.2629	0.7817	0.7400
E7010-P1	0.0784	0.1051	0.7066	0.6640
E7014	0.3145	0.3781	0.8326	0.7954
E7024	0.8590	0.7790	0.9417	0.9246

Based upon the Electrode Selection Index (ESI), the alternatives are ranked as shown in Table 5.

Table 5 Ranking of electrodes

Rankings				
	TOPSIS	**MOD. TOPSIS**	**SAW**	**WPM**
E6010	5	5	5	5
E6011	2	3	3	3
E6013	4	4	4	4
E7010-P1	6	6	6	6
E7014	3	2	2	2
E7024	1	1	1	1

The results of TOPSIS are compared with other three MADM methods viz. modified TOPSIS, SPM and WPM. TOPSIS ranks electrode E7024 as the best electrode. This result is then compared to other methods. Modified TOPSIS, SPM and WPM also ranks electrode E7024 as the best electrode. Hence, from the rankings shown in Table 5, electrode E7024 is the best option from the available electrodes.

4 Conclusions

In this paper, we identified the important criteria for selection of SMAW electrodes for general purpose welding of mild steel. TOPSIS method was applied for selection for of best alternative. The results of TOPSIS were then compared with Modified TOPSIS, SPM and WPM. The results by all the methods showed that electrode E7024 is the best welding electrode from the available set electrodes. A close look at the attributes of the alternatives will show that E7024 is having the highest deposition rate which is a very important criterion. Also, the cost of E7024 is quite lower when compared to other electrodes. Hence, we can say that the E7024 is the best electrode from the given set of alternatives.

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