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Technique for Order of Preference by Similarity to Ideal Solution- A Strategic Decision for Material Selection

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ABSTRACT — *The electroplating industry has been playing a vital role in development and growth of numerous metal manufacturing sectors and other engineering industries. In India, there are more numbers of independent tiny to small scale units operating throughout the country working in electroplating process. Strategic decision for outsourcing of material for electroplating is one of the major parameter to make the efficiency and production rate high. At time of selecting metal for the electroplating process, it is necessary to compare their characteristics in a critical way and should be taken into account other conflicting criteria that can influence the process. In this paper, in the paper various MADM techniques discuss with their strength and weakness. Then implication of TOPSIS method adopted and replace with AHP and VIKOR Hybrid Methodology as input data. Solve with TOPSIS methodology to select the appropriate metal for the electroplating process. Finally the proposed model has been compared with AHP and VIKOR methods for the selection of appropriate electroplating material.*

Keywords*- Multi Attribute Decision Making (MADM), Technique for Order of Preference by Similarity to ideal Solution (TOPSIS), Electroplating Process, Material Selection, Ranking Methodology*

I. INTRODUCTION

The selection of electroplating metal depends on many criteria like type of process tank, breadth of electrode, distance between electrodes, length of electrode, electrolytic concentration, layer thickness, surface cleaning, current value, voltage value, corrosion resistance, environmental factor, adhesions, cohesion, hardness of plating, dullness, roughness, coefficient of friction, surface tension, deposition rate, deposition time, wear resistance, part geometry, part irregularity, friction of plating parts, heat resistance, colour of plating, impurities impingement, etc. These all parameters will decide the life, durability, capability, grad ability and operating economy of the electroplating. The primary objective is to control the wear or erosion so that the user adaptability of product does not exceed the certain level. There is a number of research works carried out in concerning the selection of electroplating for manufacturing application.

[1] worked for optimized surface pre-treatment for copper electroplating in the area of electroplating. [2] implemented taguchi orthogonal array design approach for finding the optimum parameter which influences the lithography quality of SU-8photoresist. [3] has identified different alternative electrodes for different applications and their effect on environment. [4] designed the electroplating experiment apparatus for improvement of efficiency by Cathode Rotating (CR) and anode. [5] investigated an electroplating bath, for toxicity. In the paper Attribute based specification, comparison and selection of electroplating system using multi attribute decision making (MADM) approach. [6] implemented TOPSIS method to select the process metal. [7] worked for selecting a Material for an electroplating process Using AHP and VIKOR MADM technique.

II. CONCEPT OF ANALYTICAL HIERARCHY PROCESS (AHP) & VIKOR

2.1 Analytic hierarchy process (AHP)

Analytic hierarchy process (AHP) which was developed by Saaty and initiate; it is one of the most accepted techniques for variety of alternatives and attributes and complex decision-making problems. A number of functional characteristics make AHP a useful methodology. An AHP can have as many levels as needed to fully distinguish a particular decision situation. These include the ability to handle decision situations involving multiple decision makers, subjective judgments and the ability to provide measures of ranking reliability. Designed to reflect the way people actually think, AHP continues to be the most highly regarded and widely used decision-making method.

Weaknesses:

- *This approach has the disadvantage that the number of pair wise comparisons to be made, may become very large (n (n−1)/2), and thus become a lengthy task.*
- *The AHP method is the artificial limitation of the use of the 9−point scale.*

2.2 Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

It determines the compromise ranking list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the input weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi criteria ranking index based on the particular measure of "nearness" to the "ideal" solution

Weaknesses:

- *The performance rating is quantified as crisp values.*
- *Under many circumstances, crisp data are inadequate to model real-life situation.*
- *In addition, in case of conflicting situations or criteria, a decision maker must also consider imprecise or ambiguous data.*

The aim of this paper is to implement and validate TOPSIS established by Kumar and Agrawal [6] and comparing the same to result with the AHP and VIKOR approach which was developed for material selection for an electroplating process [7].

III. TECHNIQUE FOR ORDER OF PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS) METHOD

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon [8] with further developments by Yoon [9] and Hwang, Lai and Liu [10]. TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution [6]. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion.
In MADM TOPSIS method gives a positive ideal solution maximizes the benefit criteria or attributes and minimizes the cost criteria or attributes, whereas a negative ideal solution maximizes the cost criteria or attributes and minimizes the benefit criteria or attributes. The TOPSIS method is expressed in a succession of six steps as follows:

Step 1: Calculate the normalized decision matrix. The normalized value r_{ij} is calculated as follows:

Normalization Rule for Beneficial Attributes $r_{ij} = \frac{x_{ij}}{x_{\max}}$ ……………………………………………………….(1)

Normalization Rule for Non- Beneficial Attributes $r_{ij} = \frac{x_{\min}}{x_{ij}}$ ……………………………………………………….(2)

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as follows:

$v_{ij} = r_{ij} \times w_j$ ………………………………………………………………………………………….(3)

for i =1, 2,..., m and j = 1, 2, ..., n. w_j is the weight of the j^{th} criterion or attribute and always $\sum_{j=1}^{n} w_j = 1$.

Step 3: Determine the ideal (A^*) and negative ideal (A^-) solutions.

$A^* = \{(\max_i v_{ij} \mid j \in C_b), (\min_i v_{ij} \mid j \in C_c)\} = \{v_j^* \mid j = 1,2,..., m\}$ ………………………………………….(4)

$A^- = \{(\min_i v_{ij} \mid j \in C_b), (\max_i v_{ij} \mid j \in C_c)\} = \{v_j^- \mid j = 1,2,..., m\}$ ………………………………………….(5)

Step 4: Calculate the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

$D_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^*)^2}, \; j = 1,2,\ldots,m$ ……………………………………………………….(6)

$D_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2}, \; j = 1,2,\ldots,m$ ……………………………………………………….(7)

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defined as follows:

$RC_i^* = \frac{D_i^-}{D_i^* + D_i^-}, \; i = 1,2,\ldots,m$ ……………………………………………………….(8)

Step 6: Rank the preference order.
The alternatives rank according to ascending order, i.e. highest alternative Correlation Coefficient RC_i^+ is consider as first rank, while lowest alternative score RC_i^+ is consider as last rank.

IV. CASE EXAMPLE

The purposed MADM is compared with the work on the selection of electroplating system for ornamental purposes conducted and comparing the result with TOPSIS method. Input Decision matrix shown in Table 2. [7]

Where Hardness, Thickness, Aesthetic and Adhesion are considered as the Beneficial Attributes and Cost is considered as non-beneficial attribute. Where given weight of the attributes Hardness, Thickness, Aesthetic, Adhesion and cost are respectively 0.198, 0.060, 0.1, 0.166 and 0.475 [7].

Table: 2 Input Set of Matrix with Alternatives and Attributes [7]

Alternatives	Hardness(HV) (+)	Thickness(µm) (+)	Aesthetic (+)	Adhesion (+)	Cost (-)
	C1 (+)	C2 (+)	C3 (+)	C4 (+)	C5 (-)
A1: Silver	350	20	3.2	3.6	1.8
A2: Gold	250	25	4.6	2.8	2.8
A3: Lead	150	30	2.6	1.4	1.2
A4: Rhodium	400	20	2.2	2.6	1.6
A5: Nickel	550	30	1.4	1.6	1.4
A6: Chromium	600	35	1.2	4.6	1.2
A7: Platinum	580	30	1.4	4.4	3

Normalized decision matrix shown in the Table 3 with considering Beneficial and non-beneficial attributes. In the Input set matrix +ve sign indicate Beneficial and –ve sign indicate Non Beneficial attributes by equations (1) and (2).

Table: 3 Normalized Decision Matrix

Alternatives	C1 (+)	C2 (+)	C3 (+)	C4 (+)	C5 (-)
A1: Silver	0.5833	0.5714	0.6957	0.7826	0.6667
A2: Gold	0.4167	0.7143	1.0000	0.6087	0.4286
A3: Lead	0.2500	0.8571	0.5652	0.3043	1.0000
A4: Rhodium	0.6667	0.5714	0.4783	0.5652	0.7500
A5: Nickel	0.9167	0.8571	0.3043	0.3478	0.8571
A6: Chromium	1.0000	1.0000	0.2609	1.0000	1.0000
A7: Platinum	0.9667	0.8571	0.3043	0.9565	0.4000

Weighted normalized decision matrix carried out with the equation (3). Positive Ideal Solution and Negative Ideal Solution (PIS/NIS) as shown in table 4.

Table: 4 Weighted Normalized Decision Matrix

Alternatives	C1 (+)	C2 (+)	C3 (+)	C4 (+)	C5 (-)	D+	D-
A1: Silver	0.1155	0.0343	0.0696	0.1299	0.3167	0.1864	0.1691
A2: Gold	0.0825	0.0428	0.1000	0.1010	0.2036	0.3025	0.0967
A3: Lead	0.0495	0.0514	0.0565	0.0505	0.4750	0.1933	0.2871
A4: Rhodium	0.1320	0.0343	0.0478	0.0938	0.3562	0.1645	0.1918
A5: Nickel	0.1815	0.0514	0.0304	0.0577	0.4071	0.1467	0.2548
A6: Chromium	0.1980	0.0600	0.0261	0.1660	0.4750	0.0739	0.3425
A7: Platinum	0.1914	0.0514	0.0304	0.1588	0.1900	0.2937	0.1794
D+ (PIS)	0.1980	0.060	0.1000	0.1660	0.4750		
D- (NIS)	0.0495	0.0343	0.0261	0.0505	0.1900		

Table 5 shows closeness value by equation 8 for each alternative.

Table: 5 Relative Closeness value for each alternatives

Alternatives	Relative Closeness Value (RC_I^+)
A1: Silver	0.4757
A2: Gold	0.2422
A3: Lead	0.5976
A4: Rhodium	0.5383
A5: Nickel	0.6346
A6: Chromium	0.8225
A7: Platinum	0.3792

Table 6 shows Ranking of each Alternative as per TOPSIS and comparison with AHP + VIKOR result

Table: 6 Comparative Result Analyses with AHP and VIKOR

Alternatives	Ranking by TOPSIS (Series 2)	Ranking by AHP+VIKOR [7] (Series 1)
A1: Silver	5	6
A2: Gold	7	5
A3: Lead	3	2
A4: Rhodium	4	7
A5: Nickel	2	4
A6: Chromium	1	1
A7: Platinum	6	3

V. CONCLUSION

This study proposes a Multi Attribute Decision Making (MADM) method adopted and validate in the selecting material for electroplating process. The calculations and rank comparison shows that from increasing order of ranking compared with the given input matrix show that ranking by TOPSIS method is easier as compared to AHP and VIKOR with more reliable result. TOPSIS method is also overcome the limitation of AHP and VIKOR simultaneously. Comparing with input matrix alternatively with ranking with two different methodologies indicate that ranking with TOPSIS is better as compared to AHP & VIKOR. This method can considered as one of the critical decision making process for effective ranking and selection.

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