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Implementation of Multi-Criteria Decision Making for selection of Coating material on AISI 4140 steel

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Abstract - *In this investigation, Selection of various kinds of Nitriding procedure and coatings utilized on AISI 4140 steel to enhance tribological properties by Multi Criteria Decision Making strategies (MCDM) .The MCDM strategy is utilized for determination best in particular TOPSIS method . Entropy Method is utilized to discover weightage for the material criteria resembles young's modulus(E), Hardness (H),H/E ,H^3/E^2 and basic load for grip of covering for AISI 4140 steel. The investigation based on five different alternative gives the best material nitrided and WCC coated AISI 4140 steel*

Key Words: MCDM, TOPSIS

1. INTRODUCTION

In the ongoing research of advancement is done in the field of Tribology and surface designing. The majority of the examination is engaged to enhance the wear opposition of mechanical materials and applications. Metal affidavit and covering systems are utilized for enhancing the erosion misfortune in the modern application, in this way expanding the life expectancy of materials. Henceforth, to enhance wear obstruction, surface harshness, and surface research, broad research is completed which incorporates the expansion of a covering or metal statement on the surface of materials [1-2].

To the extent the coating material is concerned, it relies upon the properties viz. Modulus of Elasticity (E), hardness (H), Adhesion, wear rate and coefficient of Friction(COF) [3]. Each covering material will include distinctive properties, a few properties will enhance one part of material in the meantime it can adverse effect the other. It is fundamental to choose the best covering material which gives the best execution by thinking about various material properties and parameters. Multi-criteria basic leadership strategies (MCDM) are used for the determination of coating relying on the material properties, parameters and its applications [4].

MCDM techniques are developed amid the only remaining century for different groups of utilizations. According to the applications, analysts had created diverse MCDM techniques. Some of MCDM techniques depend on a graphical methodology for instance ASHBY strategy [5], on scientific methodologies viz. The direct task strategy [6], COPRAS (complex relative appraisal) [7], PROMETHEE [8], ELECTRE [9], the straight task strategy [10-11], and, VIKOR (VlseKriterijumska Optimizacija Kompromisno Resenje) [12].

The choice of coating materials is completed based on properties like modulus of elasticity (E), hardness (H), COF and Bonding between covering substrate and materials, Moreover, some analyst discovered variables like H/E and H^3/E^2 are viable in the choice procedure [13-15].

In the present work, five materials with various coating and nitriding are considered. Following are the materials used to recognize the most appropriate covering materials as AISI 4140 combination steel, Nitrided AISI 4140 amalgam steel, Nitrided and TiN coat AISI 4140 composite steel, Nitride and TiAlN coat AISI 4140 compound steel and Nitride and WC/C coat AISI 4140 combination steel are chosen to analyze the mechanical properties. The exploratory testing is done to discover mechanical properties. The choice of best materials depends on four elements viz. Young's modulus, Hardness, H/E and H^3/E^2.The weightage of the each factor is determined with the assistance of Analytical Hierarchy Process (AHP) [16], Entropy strategy (16), and bargained weighting technique. The TOPSIS technique is utilized to distinguish and choose the best covering material among the five unique options.

2. DECISION-MAKING PROBLEM

Numerous utilizations of AISI 4140 compound steel are having a high frictional power which prompts wear resistance. Subsequently it is fundamental to enhance the wear opposition. Consequently, AISI 4140 composite steel is for the most part being covered with various covering materials. In any case, choosing a proper covering for specific tribological application is as yet mind boggling and troublesome in light of the fact that the tribological reaction of covering relies upon no. of elements. Young's Modulus, Hardness, H/E and H^3/E^2 proportion properties are considered for determination of covering materials[17].

Five option AISI 4140 steel with the diverse blend of Nitriding affidavit and coatings are utilized for the investigation. The properties are outlined in Table 1. E, H, H/E, and H^3/E^2 are the criteria's chosen for this examination.

Table -1: Tribological and Mechanical characteristics of coatings

Sr. No.	Coating Material	E (GPA)	H (GPA)	H/E	H^3/E^2
1	AISI 4140 Alloy Steel	210.00	7.0632	0.6862	3.3260
2	Nitride AISI 4140 Alloy Steel	225.00	12.5274	1.1210	15.7421
3	Nitride and TiN Coat AISI 4140 Alloy Steel	250.00	22.5630	2.0767	97.3069
4	Nitride and TiAlN Coat AISI 4140 Alloy Steel	280.00	29.4300	2.4078	170.6157
5	Nitride and WCC Coat AISI 4140 Alloy Steel	280.00	29.4300	2.5583	192.6091

2.1. Entropy Method

Entropy method is objective weighting method which uses probability theory which measures uncertainty in output responses of each criteria to determine weightage of each criteria. The steps required in the entropy method are shown in Figure 4

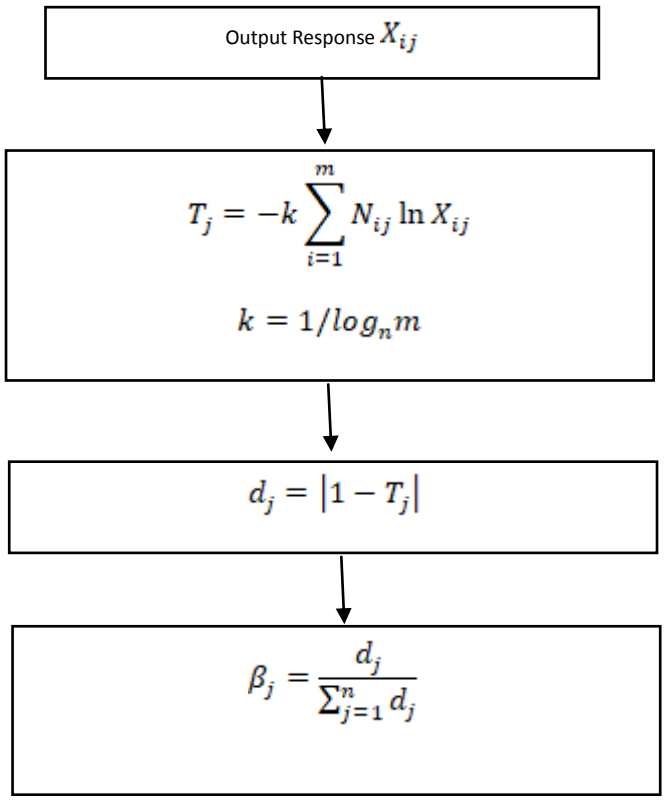

Figure No 1 Flow chart of Entropy methods

Where i=Experiment Number; j=output response number,

m=Total number of Experiments and n=total number of output response

β=weightage of corresponding jth response

The β values of weight responses each output responses are calculated with the help of flowchart explain in Figure No 1

2.2. TOPSIS method

TOPSIS is generally used to find the preference ranking of all alternate by using the output response of each criteria and to convert the multi-criteria system into a preferential index. The value which is close from the ideal solution, according to benefit and cost situation of all criteria will be used. The TOPSIS index is calculated as follows

Decision matrix is normalized with the help of Eq. (1) which based on root mean square value

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}; \quad (1)$$

$$where \ \ i = 1,2,\ldots..,m; alternatives$$

$$j = \ 1,2,\ldots.,n; Criterias$$

Weighted normalization is carried out with the help of weights obtained for each criteria by Eq. (1) .So the normalized decision matrix is multiplied with weights as given in Eq. (2)

$$V_{ij} = w_{j\times} N_{ij} \quad (2)$$

The Ideal solution for each criteria's are depends on their condition of maximization and minimization. Positive Ideal solution (PIS) is determined by Eq. (3) and Negative ideal solution (NIS) is determined by Eq. 3

$$V_j^+ = \begin{cases} \underset{j}{\text{Max}} V_{ij} & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{For Benifit criteria} \\ \underset{j}{\text{Min}} V_{ij} & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{for Cost Criteria} \end{cases} \quad (3)$$

$$V_j^- = \begin{cases} \underset{j}{\text{Min}} V_{ij} & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{For Benifit criteria} \\ \underset{j}{\text{Max}} V_{ij} & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{for Cost Criteria} \end{cases}$$

Separation Measure of each weighted, normalized decision matrix value from PIS and NIS is calculated by Eq. (4) and Eq. (5)

$$S_i^* = \left(\sum_{j=1}^{n} (V_{ij} - V^*)^2 \right)^{1/2} \quad (4)$$

$$S_i^- = \left(\sum_{j=1}^{n} (V_{ij} - V^-)^2 \right)^{1/2} \quad (5)$$

In TOPSIS method, the Final relative closeness index is found to be between 0 to 1, The closeness relative index is determined to help of Eq.

$$C_i = \frac{S_i^-}{S_i^* - S_i^-} \quad (6)$$

The ranking should be done as per the descending values of C_i, Greater values mean higher rating.

3. RESULTS AND DISCUSSION

Table- 2: Weightages of Criteria

	E (GPA)	H	H/E	H^3/E^2
Weights	0.2848	0.2138	0.2714	0.2298

The entropy method gives the weights of each criteria based on upon the interdependence of the alternatives. According to the section 3.1.3 weights were determined which is represented in the form En for respective criteria. The Corresponding values show the highest weight to E (0.2848) and least important criteria H (0.2138) and these weights were shown in Table 2.

3.1. TOPSIS method

In TOPSIS,

Normalizing of a decision matrix for each criteria is carried out by Eq. (1),

Then weight normalization of weights obtains by the criteria weighting method is carried out which is shown in Table 3,

PIS and NIS are calculated according to the criteria of each alternative by Eq. (3) ,

Distance from PIS (S_j^*) and NIS (S_j^-) of each criteria were represented by Eq.(4) (5),

Eq. (6) shows of relative closeness.

The highest value of C shows the best results. Hence the values of the C corresponding to it alternatives are arranged in descending order so as to get their ranks. The Table 4 shows us the best rank to Nitride and WCC Coated AISI 4140 Alloy Steel material.

Table- 3: Weightage normalization of Alternatives,

Sr No	Coating Material	E (GPA)	H	H/E	H^3/E^2
1	AISI 4140 Alloy Steel	0.3747	0.1428	0.1601	0.0121
2	Nitride AISI 4140 Alloy Steel	0.4015	0.2532	0.2615	0.0571
3	Nitride and TiN Coat AISI 4140 Alloy Steel	0.4461	0.4560	0.4844	0.3531
4	Nitride and TiAlN Coat AISI 4140 Alloy Steel	0.4997	0.5948	0.5616	0.6192
5	Nitride and WCC Coat AISI 4140 Alloy Steel	0.4997	0.5948	0.5967	0.6990

Table-4: TOPSIS Analysis

SR NO	S_j^*	S_j^-	C_j	RANK
1	0.1508	0.0123	0.0753	5
2	0.1344	0.0286	0.1754	4
3	0.0629	0.0955	0.6029	3
4	0.0133	0.1453	0.9162	2
5	0.0000	0.1550	1.0000	1

4. CONCLUSIONS

This study proposes better way to select material for tribological applications with help of different mechanical properties by using MCDM methods.

Nitride deposited and WCC coated AISI 4140 is selected among the alternatives taken for considerations.

The weights of each criteria for material selection are conducted out through a compromised weighting method which yields the most important measures to be ratio of Hardness and modulus of elasticity (H/E).

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