TOPSIS RANKING OF HYBRID COMPOSITES

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Abstract— In This Research Article Epoxy and polyester based composites reinforced with Glass Fiber/Fillers are fabricated by manual hand layup process and mechanical properties like Tensile Strength, Tensile modulus, Flexural Strength, ILSS, Hardness and impact strength are determined. Selection of a composite with respect to above mechanical characterization parameters is a difficult task; some selection procedure techniques are required to overcome from this confusion state. TOPSIS is one of the selection procedure technique adopted for this problem. This technique provides a base for decision-making processes where there are limited numbers of choices but each has large number of attributes. In this paper some composites are considered with different compositions and various mechanical properties. Selection of the best composite is done using TOPSIS technique

Index Terms— TOPSIS, Normalized decision matrix, Positive and Negative Ideal solutions, Relative closeness, Ranking.

I. INTRODUCTION

The TOPSIS (technique for order performance by similarity to ideal solution) was first developed by Hwang & Yoon (1981). It is one of the best grading methods of multi criteria decision making (MCDM) that is taken place in compromising subgroup of compensating models of decision making [1]. TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point [2]. TOPSIS has also been used to compare company performances [3] and financial ratio performance within a specific industry [4]. A great deal of work has already been done on the use of TOPSIS for selection of the best alternatives in many fields. However, the use of TOPSIS for selection of the material is hardly been reported.

II. LITERATURE REVIEW

TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point. TOPSIS has been applied to a number of applications many researchers. Singh et al. [5] studied the selection of material for bicycle chain in Indian scenario using MADM Approach. They concluded that both MADM and TOPSIS methods User friendly for the ranking of the parameters. Huang et al. [6] studied the multi-criteria decision making and uncertainty analysis for materials selection in environmentally conscious design. It was reported that TOPSIS method demonstrates a reasonable performance in obtaining a solution; and entropy method presents designers' or decision makers' preference on cost or environmental impact and effectively demonstrates the uncertainties of their weights. Khorshid et al. [7] studied the selection of an optimal refinement condition to achieve maximum tensile properties of Al-15%Mg2Si composite based on TOPSIS method and observed that the TOPSIS method is considered to be a suitable approach in solving material selection problem when precise performance ratings are available. Ghaseminejad et al. [8] used data envelopment analysis and TOPSIS method for solving flexible bay structure layout, and found that this method is useful for creating, initial layout, generating initial layout alternatives and evaluating them. Chakladar and Chakraborty [9] studied the combined TOPSIS-AHP-method-based approach for non-traditional machining processes selection and also include the design and development of a TOPSISAHP- method-based expert system that can automate the decision-making process with the help of a graphical user interface and visual aids. Shahroudi and Rouydel [10] studied a multi-criteria decision making approach (ANP TOPSIS) to evaluate suppliers in Iran's auto industry. Lin et al. [11] studied on customer-driven product design process using AHP and TOPSIS approaches and results shows that the proposed approach is capable of helping designers to systematically consider relevant design information and effectively determine the key design objectives and optimal conceptual alternatives. Isiklar and Buyukozkan [12] studied a multi-criteria decision making (MCDM) approach to assess the mobile phone options in respect to the users preferences order by using TOPSIS method.

III. METHODOLOGY

The objective of this work is to develop TOPSIS method for composite selection. In order to comply with collecting quantitative and qualitative data for TOPSIS composite selection model that could be applied by a seven steps approach was performed to ensure successful implementation.

IV. TOPSIS METHOD

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is implemented to measure the proximity to the ideal solution. The basic concept of this method is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Positive ideal solution is composition of the best performance values demonstrated (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values. The steps involved for calculating the TOPSIS values are as follows [13]:

Step 1

This step involves the development of matrix format. The row of this matrix is allocated to one alternative and each column to one attribute. This matrix is called as a decision matrix (D). The matrix can be expressed as:

$$\begin{matrix} A1 \\ A2 \\ A3 \\ Ai \\ A5 \end{matrix}\begin{bmatrix} X11 & X12 & . & X1j & X1n \\ X21 & X22 & . & X2j & X2n \\ . & . & . & . & . \\ Xi1 & Xi2 & . & Xij & Xin \\ . & . & . & . & . \\ Xm1 & Xm2 & . & Xmj & Xmn \end{bmatrix}$$

Step 2

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

$$r_{ij} = x_{ij} \sqrt{\sum_{i-1}^{m} x_{ij}^2}$$ i =1, 2, ..., m and j = 1, 2, ..., n.

Step 3

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

$$v_{ij} = r_{ij} \times w_j$$ i =1, 2,..., m and j = 1, 2, ..., n.

Where w_j is the weight of the j^{th} criterion or attribute and $\sum_{j=1}^{n} w_j = 1$.

Step 4

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

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

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

Step 5

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:

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

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

Step 6

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

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, i = 1,2,...,m$$

Step 7

Rank the preference order.

V. RANKING OF COMPOSITES BY TOPSIS METHOD

All the composite materials are compared based on the TIOPSIS method and ranking has been done. The decision matrix, normalization matrix, weight normalized matrix, ideal positive and ideal negative solution, separation measure, relative closeness value and ranking are tabulated in Tables 1,2, 3, 4, 5,6 respectively. Finally the ranking of different composite based on their properties is being shown in the Figure 1. It has been observed that ranking of composite materials are as follows: Rank 1(C7), Rank 2 (C8), Rank 3 (C9), Rank 4 (C10), Rank 5 (C5), Rank 6 (C3), Rank 7 (C1), Rank 8 (C6), Rank 9 (C2) and Rank 10 (C4).

STEP-1: This step involves the development of matrix format. The row of this matrix is allocated to one alternative and each column to one attribute. This matrix is called as a decision matrix (D).

Table-1: Decision Matrix (D) Of Fabricated Composites						
Composite Designation	Decision Matrix(D)					
	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Impact Strength (J)	Hardness (Hs)	ILSS (GPa)
C1	223.11	8.118	203.27	4	86.66	5.959
C2	175.71	9.562	214.43	3.6	89	6.542
C3	159.91	5.688	189.58	4	85.66	7.84
C4	213.81	10.61	213.2	4	84.66	7.082
C5	205.76	7.338	192.26	3.2	91	5.641
C6	256.832	18.041	93.96	2	88	2.584
C7	208.913	7.54	67.315	2	89	2.191
C8	150.9155	4.103	80.76	4	93	2.631
C9	208.137	8.784	92.545	2	91	3.107
C10	194.582	10.947	102.065	2	89	4.0978

STEP-2: Calculate the normalized decision matrix. The normalized value r_{ij} is calculated as follows:

Table-2: Normalized Matrix						
Composite Designation	Normalized Matrix(N)					
	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Impact Strength (J)	Hardness (Hs)	ILSS (GPa)
C1	0.349355	0.263069	0.411069	0.39375	0.308845	0.364963
C2	0.275134	0.309863	0.433638	0.354375	0.317184	0.400669
C3	0.250394	0.184324	0.383384	0.39375	0.305281	0.480166
C4	0.334793	0.343824	0.43115	0.39375	0.301717	0.433741
C5	0.322188	0.237793	0.388804	0.315	0.324312	0.345487
C6	0.402158	0.584631	0.190014	0.196875	0.313621	0.158259
C7	0.327172	0.244339	0.13613	0.196875	0.317184	0.134189
C8	0.23631	0.132961	0.163319	0.39375	0.33144	0.161137
C9	0.32591	0.284651	0.187152	0.196875	0.324312	0.19029
C10	0.304685	0.354745	0.206404	0.196875	0.317184	0.250972

STEP-3: Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as follows:

Table-3: Weight Normalized Matrix (W)						
Composite Designation	Weight Normalized Matrix(W)					
	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Impact Strength (J)	Hardness (Hs)	ILSS (GPa)
C1	0.058226	0.043845	0.068512	0.065625	0.051474	0.060827
C2	0.045856	0.051644	0.072273	0.059062	0.052864	0.066778
C3	0.041732	0.030721	0.063897	0.065625	0.05088	0.080028
C4	0.055799	0.057304	0.071858	0.065625	0.050286	0.07229
C5	0.053698	0.039632	0.064801	0.0525	0.054052	0.057581
C6	0.067026	0.097438	0.031669	0.032812	0.05227	0.026376
C7	0.054529	0.040723	0.022688	0.032812	0.052864	0.022365
C8	0.039385	0.02216	0.02722	0.065625	0.05524	0.026856
C9	0.054318	0.047442	0.031192	0.032812	0.054052	0.031715
C10	0.050781	0.059124	0.034401	0.032812	0.052864	0.041829

STEP-4: Determination of ideal (A^*) and negative ideal (A^-) solutions.

Table-4: Best & Worst Solutions						
Ideal Solution	Best & Worst Solutions					
	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Impact Strength (J)	Hardness (Hs)	ILSS (GPa)
Positive Ideal Solution(A^*)	0.067026	0.097438	0.072273	0.065625	0.05524	0.080028
Negative Ideal Solution(A^-)	0.039385	0.02216	0.022688	0.032812	0.050286	0.022365

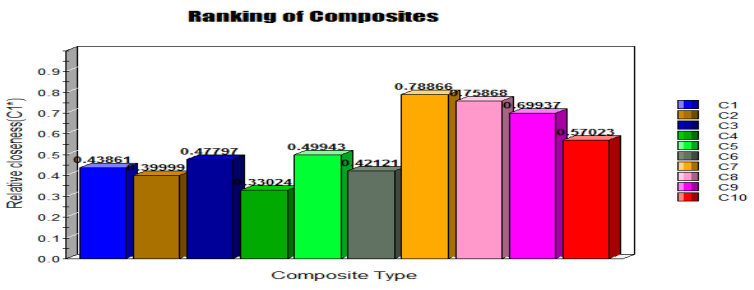
STEP-5: Calculate the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

Table-5: Separation Measures Of Attributes		
Composite Designation	Separation Measures Of Attributes	
	S^*	S^-
C1	0.05785041	0.074043493
C2	0.051801773	0.077705172
C3	0.071973226	0.078606749
C4	0.042677514	0.086553226
C5	0.06251399	0.06265445
C6	0.058816142	0.080818189
C7	0.08991898	0.024094922
C8	0.106244121	0.0337926
C9	0.074884155	0.032188528
C10	0.059618271	0.044931975

STEP6&7: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defined as follows & Rank the preference order.

Table-6: Relative Closeness & Composite Ranking		
Composite Designation	Relative closeness & Composite Ranking	
	$C1^*$	R
C1	0.438613226	7TH
C2	0.399992243	9TH
C3	0.477973421	6TH
C4	0.330242743	10TH
C5	0.499438915	5TH
C6	0.421215483	8TH
C7	0.788666807	1ST
C8	0.758687584	2ND
C9	0.699376841	3RD
C10	0.570235591	4TH

CONCLUSION



Ranking of composite materials are as follows:

Rank 1⟶(C7)	Rank 6⟶(C3)
Rank 2⟶(C8)	Rank 7⟶(C1)
Rank 3⟶(C9)	Rank 8⟶(C6)
Rank 4⟶(C10)	Rank 9⟶(C2)
Rank 5⟶(C5)	Rank 10 ⟶(C4)

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