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Optimization of Mechanical Properties on Hybrid Composites by Topsis Technique

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Abstract— 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. A great deal of work has already been done on the use of TOPSIS for selection of the best alternatives in many fields. In this connection the present work is undertaken to develop a new class of natural fibre based hybrid composites to study their mechanical and water absorption behaviour. All the composite materials are compared based on the TIOPSIS method and ranking has been done. Finally TOPSIS method is used for the selection of the best material among a set of alternatives.

Keywords — TOPSIS, Hybrid composite selection, Decision matrix, Normalization matrix, Weight normalized matrix, Positive and Negative Ideal solutions, Separation measure, Relative closeness, Ranking.

1. INTRODUCTION

The selection of best Hybrid composite is essential for the application due to the confusion created by unlike mechanical properties. Selecting just the right one becomes a critical decision making problem. Other important criteria‘s while selection include: Tensile strength, Flexural strength, Impact strength, Hardness and Water absorption. An appropriate decision-making method for selecting the best Hybrid composite is useful to end application.

2. 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. [1] 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. [2] 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. [3] 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. [4] 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 [5] studied the combined TOPSIS-AHP-method-based approach for non-traditional machining processes selection and also includes 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 [6] studied a multi-criteria decision making approach (ANP-TOPSIS) to evaluate suppliers in Iran’s auto industry. Lin et al. [7] 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 [8]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.

3. METHODOLOGY

The objective of this work is to develop TOPSIS method for Hybrid composite selection. In order to comply with collecting quantitative and qualitative data for TOPSIS Hybrid selection model that could be applied by a seven steps approach was performed to ensure successful implementation. Table 1 is showing the preparation of composites and Table 2 is presenting the outcome of mechanical properties of defined Hybrid composite preparation and method.

Table 1: Preparation of Composites

Composites	Compositions
S1	Epoxy (75wt %) +Glass Fibre (20wt. %) +banana Fibre (Fibre length 5 mm) (5wt %)
S2	Epoxy (75wt %) +Glass Fibre (20wt. %) + banana Fibre (Fibre length 10 mm) (5wt %)
S3	Epoxy (75wt %) +Glass Fibre (20wt. %) + banana Fibre (Fibre length 15mm) (5wt %)
S4	Epoxy (75wt %) +Glass Fibre (20wt. %) + banana Fibre (Fibre length 20 mm) (5wt%)
S5	Epoxy (70wt %) +Glass Fibre (20wt %) + banana Fibre (Fibre length 5 mm) (10wt %)
S6	Epoxy (70wt %) +Glass Fibre (20wt %) + banana Fibre (Fibre length 10 mm) (10wt %)
S7	Epoxy (70wt %) +Glass Fibre (20wt %) + banana Fibre (Fibre length 15 mm) (10wt %)
S8	Epoxy (70wt %) +Glass Fibre (20wt %) + banana Fibre (Fibre length 20 mm) (10wt %)

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 [9]:

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:

$$D = \begin{matrix} A_1 \\ A_2 \\ \cdot \\ A_i \\ \cdot \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \cdot & x_{1j} & x_{1n} \\ x_{21} & x_{22} & \cdot & x_{2j} & x_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ x_{i1} & x_{i2} & \cdot & x_{ij} & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ x_{m1} & x_{m2} & \cdot & x_{mj} & x_{mn} \end{bmatrix}$$

STEP 2: Then, the normalized decision matrix or R matrix is calculated with rij as the normalized value:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

STEP 3: obtain the weighted normalized decision matrix,

V = v i j can be found as:

$$V = w_j r_{ij}$$

Here, $\sum_{j=1}^{n} w_j = 1$

STEP4: Determine the ideal (best) and negative ideal (worst) solutions in this step. The ideal and negative ideal solution can be expressed as:

The ideal solution:

$$A^+ = \left\{ \left(\max_i v_{ij} \middle| j \in J \right), \left(\min_i v_{ij} \middle| j \in J' \middle| i = 1,2,.......m \right) \right\}$$

$$= \left\{ v_1^+, v_2^+, ...v_j^+, ...v_n^+ \right\}$$

The negative ideal solution:

$$A^- = \left\{ \left(\min_i v_{ij} \middle| j \in J \right), \left(\max_i v_{ij} \middle| j \in J' \middle| i = 1,2,.......m \right) \right\}$$

$$= \left\{ v_1^-, v_2^-, ...v_j^-, ...v_n^- \right\}$$

Here,

$j = \{ j = 1,2,......,n | j \}$ Associated with the beneficial attributes

$j' = \{ j = 1,2,......,n | j \}$ Associated with non- beneficial attributes

STEP 5: Determine the distance measures. The separation of each alternative from the ideal solution

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is given by n- dimensional Euclidean distance from the following equations:

STEP 6: Calculate the relative closeness (closeness coefficient, CC) to the ideal solution:

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-}, i = 1,2,\ldots\ldots.m; 0 \le C_i^+ \le 1$$

STEP 7: Rank the preference order: the alternative with the largest relative closeness is the best choice.

RESULTS

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.

Table 2: Decision matrix (D)

Composites	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness	Water Absorption (%)
S1	23.40	95.68	43.95	46	2.646
S2	25.76	101.71	67.91	51	2.924
S3	28.84	114.86	96.84	54	3.122
S4	26.92	108.3	87.15	57	3.312
S5	23.84	98.56	51.3	43	3.651
S6	26.54	104.24	72.56	47	3.741
S7	29.61	118.32	101.84	51	3.906
S8	27.70	112.47	92.1	53	4.310

Table 3: Normalization matrix (R)

Composites	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness	Water Absorption (%)
S1	0.310	0.316	0.196	0.322	0.268
S2	0.341	0.336	0.303	0.357	0.296
S3	0.382	0.379	0.432	0.379	0.316
S4	0.357	0.358	0.389	0.399	0.335
S5	0.316	0.325	0.229	0.301	0.370
S6	0.352	0.344	0.323	0.329	0.379
S7	0.392	0.390	0.454	0.357	0.396
S8	0.367	0.371	0.410	0.371	0.437

Table 4: Weight normalized matrix

Composites	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness	Water Absorption (%)
S1	0.062	0.0632	0.0392	0.0644	0.0536
S2	0.0682	0.0672	0.0606	0.0714	0.0592
S3	0.0764	0.0758	0.0864	0.0758	0.0632
S4	0.0714	0.0716	0.0778	0.0798	0.067
S5	0.0632	0.065	0.0458	0.0602	0.074
S6	0.0704	0.0688	0.0646	0.0658	0.0758
S7	0.0784	0.078	0.0908	0.0714	0.0792
S8	0.0734	0.0742	0.082	0.0742	0.0874
WEIGHTAGE	0.2	0.2	0.2	0.2	0.2

Table 5: Positive-ideal (best) and negative-ideal (worst) Solution

solution	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness	Water Absorption (%)
A+(Ideal solution)	0.0784	0.078	0.0908	0.0798	0.0536
A-(Negative Ideal solution)	0.062	0.0632	0.0392	0.0602	0.0874

Table 6: Separation measures of attributes

Composites	S+	S-
S1	0.0582	0.03405
S2	0.03514	0.03785
S3	0.01168	0.0585
S4	0.02094	0.04949
S5	0.05678	0.01509
S6	0.03903	0.03021
S7	0.02694	0.05782
S8	0.0360	0.04773

Table 7: Calculate the relative closeness (si*)

Composites	Relative closeness (S*)	Ranking of composites
S1	0.3691	7th
S2	0.5185	5th
S3	0.8335	1st
S4	0.7026	2nd
S5	0.2030	8th
S6	0.4363	6th
S7	0.6821	3rd
S8	0.5700	4th

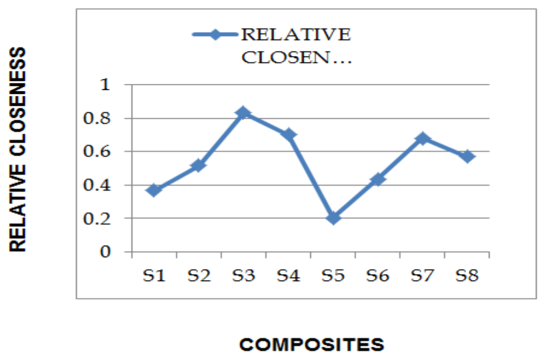

Fig. 1.Ranking of the different composites

CONCLUSIONS

TOPSIS method is used to select a best alternative from a set of alternatives.The proposed new procedure for hybrid composite selection is to find the best composite among available ones in results using of decision making method.It has been perceived that ranking of composite materials are as follows: Rank 1(S3), Rank 2 (S4), Rank 3 (S7), Rank 4 (S8), Rank 5 (S2), Rank 6 (S6), Rank 7 (S7) and Rank 8 (S5). It is observed sample S3 is identified as the best hybrid composite among the considered ones which has the best relative closeness value 0.8335.

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