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Research Article

A Comparative Analysis of the physical-mechanical behavior of glass-coir fiber reinforced epoxy composites using TOPSIS Method

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Abstract

Nowadays, because of highly competitive global market, the organizations are pressurized to focus more on increasing demand of productivity while decreasing cost, by right selection of machine tools and materials. Proper selection of machine tools and materials minimizes labour cost, improves product quality and increases production rate with better productivity. Evaluation and selection of machine tools and materials is based on certain techniques. Multiple criteria decision making tool (MCDM), is a quiet handy tool to evaluate and select machines and materials based on specific method which can be used to select the best option among the several alternatives. TOPSIS, a branch of MCDM which is based on an aggregating function signifying closeness to the ideal concept, is dominant in compromise programming method. This paper deals with logical procedure to evaluate the best composite materials item by optimizing the physical and mechanical properties of coir/glass fibre best hybrid composite by using TOPSIS method from ideal solution, the best performance value of composite materials is determined. Similarly, the least good performance for the same is obtained from negative ideal solution. The results highlight both robustness and effectiveness of the model.

Keywords: *MCDM, MADM, TOPSIS, Composites.*

Introduction

Multi-criteria decision making (MCDM) is a set of methods to select, compare, or rank multiple alternatives that involve multiple attributes. Multiple attributes decision making (MCDM) system is a well-established expert decision system when there exist conflicting criteria to evaluate a product/system among the available options. MADM is a tool geometry used to conciliate multiple evaluation criteria, taking into account the preference of a decision maker. This systematic technique requires the decision maker to decide between the alternatives (Rao *et al*, 2007). By the help of computers the decision making methods have initiated great acceptance in all areas of the decision making process. For solving the MADM problem a new classical MADM method has been developed which is known as technique for order preference by similarity to an ideal solution (TOPSIS) and both are user friendly for the ranking of the parameters (Singh *et al*, 2012). The idea for the choosing based on the shortest path from the positive ideal solution and the farthest distance from the negative ideal solution on the other side (Chen *et al*, 2011). Composite, the actuals and worth discovery of mankind, of the materials with the lightweight; high strength to weight ratio. Hybridisation of chopped coir/glass has been used to boost the properties of composite. The aim of the present paper is to find out the best alternatives from the mechanical and physical properties of coir glass epoxy based hybrid composite, and the proposed an idea based on technique for order preference by similarity to ideal solution (TOPSIS).

Materials and methods

Here randomly oriented short coir/glass fibre are taken as the reinforcement and epoxy is taken as matrix materials. The fabrication of composite materials is carried out by hand layup technique. The low temperature curing epoxy resin and their corresponding hardener are mixed in a ratio of 10:1 by weight as recommended by the manufacture. Composites with two different coir fibre loading (5wt% and 10wt%) and four different fibre length (5mm,10mm,15mm,20mm) were fabricated at room temperature for 24 hours. The detail designation and composition of composite are given in table 1.

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Table 1 Designation of Composites

Composites	Compositions
C1	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 5 mm) (5wt %)
C2	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 10 mm) (5wt %)
C3	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 15mm) (5wt %)
C4	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 20 mm) (5wt %)
C5	Epoxy (70wt %) +Glass Fibre (20wt %) +Coir Fibre (Fibre length 5 mm) (10wt %)
C6	Epoxy (70wt %) +Glass Fibre (20wt %) +Coir Fibre (Fibre length 10 mm) (10wt %)
C7	Epoxy (70wt %) +Glass Fibre (20wt %) +Coir Fibre (Fibre length 15 mm) (10wt %)
C8	Epoxy (70wt %) +Glass Fibre (20wt %) +Coir Fibre (Fibre length 20 mm) (10wt %)

Topsis procedure

The TOPSIS stand for technique for preference by similarity to the ideal solution (Chen *et al*, 2011). TOPSIS was in initially presented by many authors (Hwang *et al*, 2012; Lai *et al*. 1994; Yoon *et al*, 1995). According to this technique the best alternatives would be the one that is closeness to the positive-ideal solution (hypothetically best) solution and distance from the negative ideal solution (hypothetically worst) solution. In short, the positive ideal solution is composed of all the good values attainable from the criteria, whereas the negative ideal solution consist of all worst values possible of the criteria. The TOPSIS methods consist of the following steps (Shyur *et al*, 2016). The idea of the TOPSIS can be expressed in a series of steps.

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:

$$D = \begin{array}{c} A_1 \\ A_2 \\ . \\ A_i \\ . \\ A_j \end{array} \begin{bmatrix} x_{11} & x_{12} & . & x_{1j} & x_{1n} \\ x_{21} & x_{22} & . & x_{2j} & X_{2n} \\ . & . & . & . & . \\ x_{i1} & x_{i1} & . & x_{ij} & . \\ . & . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mj} & x_{mn} \end{bmatrix} \quad (1)$$

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

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2_{ij}}} \quad (2)$$

Here, r_{ij} represents the normalized performance of A_i with respect to attribute X_j.

STEP 3**:** obtain the weighted normalized decision matrix, $V = |v_{ij}|$ can be found as

$$v = w_j r_{ij} \quad (3)$$

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

STEP 4: Determine the ideal (best) and negative ideal (worst) solutions in this step. The ideal and negative ideal solution can be expressed as:

a) The ideal solution

$$A^+ = \left\{ \left(\max v_{ij} \mid \mathrm{j} \in \mathrm{j} \right), \left(\min v_{ij} \mid j \in J' \mid i = 1,2,....m \right) \right\} = \left\{ v_1^+, v_2^+, ...v_j^+, ...v_n^+ \right\} \quad (4)$$

b) The negative ideal solution

$$A^- = \left\{ \left(\max v_{ij} \mid \mathrm{j} \in \mathrm{j} \right), \left(\min v_{ij} \mid j \in J' \mid i = 1,2,....m \right) \right\} = \left\{ v_1^+, v_2^+, ...v_j^+, ...v_n^+ \right\} \quad (5)$$

Here, $J = \{ J = 1,2,....., n \mid J \}$ associated with beneficial attributes

$J' = \{ J = 1,2,....., n \mid J \}$ Associated with beneficial attributes

STEP 5: Determine the distance measures. The separation of each alternative from the ideal solution is given by n- dimensional Euclidean distance from the following equations:

$$s_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+ \right)^2} \quad (6)$$

$$s_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2} \quad (7)$$

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

$$c_i^+ = \frac{s_i^-}{s_i^+ + s_i^-}, i = 1, 2, ...m; 0 \le c_i^+ \le 1 \quad (8)$$

STEP 7: Rank the preference order: the alternative with the largest relative closeness is the best choice.
Thus, TOPSIS minimize the distance to the ideal alternatives while maximize the distance to the nadir.
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Result and discussion

All the composite materials are compared based on the TOPSIS method and ranking has been done. The normalization matrix and relative closeness ranking are tabulated in tables2, 3 respectively. Finally the ranking of different composite based on their properties is shown in the table 3.

Table 2 Normalization matrix (R)

Composites	Tensile strength (MPa)	Flexural strength (MPa)	Hardness(Hv)	Density (gm/cc)	Water absorption (%)
C1	0.339	0.265	0.285	0.361	0.246
C2	0.36	0.332	0.364	0.356	0.272
C3	0.382	0.373	0.384	0.355	0.321
C4	0.332	0.343	0.406	0.354	0.34
C5	0.33	0.336	0.208	0.355	0.375
C6	0.369	0.36	0.329	0.353	0.384
C7	0.4	0.419	0.376	0.347	0.401
C8	0.301	0.376	0.422	0.343	0.443

Table 3 Calculate the relative closeness (ci*)

Composites	Relative closeness (C*)	Ranking of composites
C1	0.49905	7 th
C2	0.68250	2nd
C3	0.72044	1st
C4	0.63021	3th
C5	0.27131	8th
C6	0.49712	6th
C7	0.60914	4th
C8	0.51901	5th

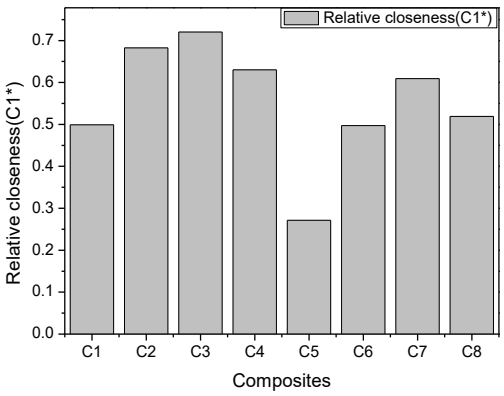

Figure 1 Ranking of the different composites

Conclusion

This paper deals with best fitted result of the physicals, mechanicals behaviour of composite materials which is obtained from the experiment by using TOPSIS. All the composite materials are compared based on the TOPSIS methods and ranking has been done. Finally the ranking of different composite based on their properties is shown in the figure 1. It has been observed that ranking of composite materials are as follows: rank 1(C3), rank 2(C2), rank3 (C4), rank4 (C7), rank5 (C8), rank6 (C6), rank7 (C1) and rank 8(C5).

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