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Research Article

Feasibility Study on Application of Various MADM Approaches for Selection of Kenaf/Saw Dust Composite

Vishwas Mahesh *

Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumakuru 572103, Karnataka, India

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ABSTRACT

This study focuses on the mechanical characterization and application of the various Multiple Attribute Decision Making (MADM) approaches for the selection of composites fabricated using two natural fibers, kenaf, and sawdust. Mechanical characterization involves testing the physical properties of these materials, such as tensile strength, flexural strength, and impact strength along with density and water absorption, to determine their mechanical behavior and suitability for various applications. The MADM approaches namely VIKOR and PSI are used to evaluate the mechanical properties of kenaf and sawdust reinforced composites for different applications based on multiple criteria or attributes. The study analyzes the trade-offs between different attributes to identify the optimal composite configuration for a given application. MADM technique offers a helpful framework for assessing the mechanical attributes of fiber-reinforced composites thereby determining their possible uses in a variety of sectors. However, it is essential to use the MADM approach in conjunction with other methods of material characterization and testing to ensure that the final decision is based on a comprehensive understanding of the material's properties and performance. The outcomes of this feasibility study will benefit researchers, manufacturers, and decision-makers involved in the selection and development of composite materials. It can assist in optimizing the material selection process, promoting sustainable and environmentally friendly choices, and enhancing the overall performance and cost-effectiveness of composite materials in various applications.

1. Introduction

Due to their sustainability and eco-friendliness, natural fibers are being used more frequently in composite materials. Many composite materials use natural fibers including kenaf, jute, flax, hemp, sisal, and bamboo to enhance their mechanical qualities [1-4]. The mechanical attributes of composites, such as their strength in tensile and flexural loads, toughness, and resistance against impact and fatigue, can be improved by the use of fibers available naturally. Natural fibers have high specific strength and stiffness, which means they can provide significant improvements in strength and stiffness while minimizing the overall weight of the composite material [5,6].

Furthermore, natural fibers have low density and are biodegradable, making them ideal for applications in industries such as automotive, construction, and aerospace. The use of natural fibers in composites can contribute to reducing the carbon footprint, as these fibers can be produced using sustainable farming practices

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* **Corresponding author.**
E-mail address: vishwasmahesh@gmail.com

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and do not require the use of fossil fuels for their production [7,8].

Kenaf is a natural fiber that has gained attention as a potential reinforcement material in composites since it exhibits enhanced specific strength, and stiffness along with low weight. Kenaf fibers are derived from the bast and core of the kenaf plant and have a relatively high cellulose content, making them an ideal candidate for composite reinforcement. Composites' mechanical attributes, including flexural as well as tensile strength, stiffness, and energy absorption due to impact load, can be enhanced by the inclusion of kenaf fibers [9-11]. Kenaf fiber is the most powerful natural fiber that can be used to replace glass in composites. In comparison to glass fibers, which had specific tensile strength and tensile modulus of about 28.5 and 34.9 GPa, respectively, they displayed specific tensile strength and modulus up to roughly 832 MPa and 36.5 GPa. It should be noted that kenaf possesses characteristics similar to glass fiber, making it an excellent candidate for FRPMC. Kenaf fiber and composites are three to two times less costly than glass fiber and have equal specific stiffness [12]. Thus, exhibiting the potential in reducing the use of synthetic fibers [13]. The high aspect ratio of kenaf fibers and their orientation within the composite matrix can also enhance the fracture toughness and fatigue resistance of the composite material. Kenaf fibers can be processed into different forms, such as chopped fibers, continuous fibers, or woven fabrics, to suit different applications. By adjusting the content and orientation of fibers, and by using appropriate matrix material, it is possible to customize the characteristics of the composites. The use of kenaf fibers as reinforcement in composites has several advantages [14]. Firstly, kenaf is a renewable and sustainable resource, making it an environmentally friendly alternative to synthetic fibers. Secondly, the use of kenaf fibers can reduce the weight of the composite material, leading to improved fuel efficiency in transportation applications. Lastly, the use of kenaf fibers can reduce the overall cost of the composite material compared to traditional reinforcement materials such as glass fibers [7,12]. Sawdust is a by-product of the woodworking industry and has been identified as a potential filler material in composite materials due to its low cost, abundance, and desirable properties. Sawdust can be incorporated into composite materials as a filler to enhance their mechanical properties, reduce their weight, and improve their environmental sustainability [15]. Saw dust is a waste material obtained after crafting wood products. This sawdust will be thrown into the environment. Waste management and disposal is a global issue for protecting the environment from pollution and depletion. There are various advantages to reusing waste material in the production of new commodities, including environmental and economic advantages. Researchers have not addressed the topic of wood dust disposal or reuse specifically. To improve the mechanical qualities of composite materials, various waste materials can be employed as fillers [16].

The addition of sawdust as a filler in composites can improve their mechanical properties such as tensile strength, flexural strength, and impact resistance. The sawdust particles can also reduce the weight of the composite material and increase its dimensional stability. In addition, the use of sawdust as filler can enhance the thermal insulation properties of the composite material [17]. Sawdust can be incorporated into composite materials using various techniques such as compression moulding, extrusion, and injection moulding. The amount of sawdust added to the composite material can be varied to optimize the mechanical and physical properties of the material. The use of sawdust as a filler in composites also has several environmental benefits. Firstly, the use of sawdust as a filler material can reduce the amount of waste generated by the woodworking industry, leading to more sustainable use of resources. Secondly, the use of sawdust as filler in composites can reduce the carbon footprint of the composite material as it is a renewable and locally available resource. Lastly, the use of sawdust as a filler in composites can reduce the overall cost of the material, making it more accessible to a wider range of applications [18,19].

The Multiple Attribute Decision Making (MADM) approach is a method used to evaluate and select the best composite material for a specific application based on multiple criteria or attributes. This approach involves the consideration of various factors, such as cost, mechanical properties, environmental impact, and manufacturing feasibility, to determine the most suitable composite material for a particular application. The MADM approach is useful in selecting composite materials as it allows for a systematic and objective evaluation of the different materials against multiple criteria. This approach can also take into account the trade-offs between different criteria, such as cost versus performance, and can help identify the most suitable composite material for a specific application [20-23].

Various natural fibers have been explored by different researchers for various engineering applications. However, the combination of kenaf along with natural saw dust as filler with varied percentages and application of various MADM approaches such as TOPSIS, VIKOR, and PSI to study the feasibility and consistency of these MADM approaches in the selection of composites have not been attempted. Keeping these gaps in mind, the present study aims at the mechanical characterization of the kenaf/sawdust composite and assessing the feasibility of TOPSIS, VIKOR, and PSI for composite selection.

2. Theoretical Principles and Model Building for MADM

2.1. Topsis

Every criterion has a benefit or cost idea attached to it. The greatest value of the criteria is favored when it comes to benefit criteria, while lesser values are preferred when it comes to cost criteria. The decision matrix is then normalized and by using the weights obtained from the entropy method, the weighted normalized matrix is generated. Determination of positive ideal solution (PIS) and negative ideal solution (NIS) is the next stage, which is followed by computing the separation measure from PIS and NIS. Depending on how the options were ranked, the proximity between PIS and NIS is determined [24]. Listed below are the steps in the TOPSIS methodology:

Step 1- Decision matrix normalization: Applying Eq. 1, the decision matrix is normalized by using the determined normalized vector "rij."

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

where, i = 1, 2,......, m and j = 1,2,.....,n

Step 2- Establishing weights: Weights are determined using the entropy approach, which is used to determine the weights for each criterion. Eq. 2 is used to compute the index's percentage "Pij," and Eq. 3 is used to determine the index's entropy "Ej."

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (2)$$

$$E_j = -k \sum_{i=1}^{m} P_{ij}\, x \, ln\, P_{ij} \qquad (3)$$

where k is given by Eq. 4

$$k = {}^{1}/_{\ln m} \qquad (4)$$

where m stands for the research's options (m=4 in the current study). Using Eq. 5, the weight "wj" for each criterion is computed.

$$w_j = \frac{[1 - E_j]}{\sum_{j=1}^{n}[1 - E_j]} \qquad (5)$$

Step 3- Eq. 6 is used to calculate the standardized value of weight (v_{ij}), which aids in the creation of a weighted normalized matrix.

$$v_{ij} = w_j r_{ij} \qquad (6)$$

where, i = 1, 2,......, m and j = 1, 2,.....,n

Step 4- Find the PIS and NIS: Equations 7 and 8 are used, respectively, to get the PIS and NIS.

$$A^+ = \{(\max_i v_{ij}, j\epsilon J_1), (min_i v_{ij}, j\epsilon J_2), i = 1,2,\dots,m\} = v_1^{\#}, v_2^{\#}, \dots, v_n^{\#} \qquad (7)$$

$$A^- = \{(\min_i v_{ij}, j\epsilon J_1), (max_i v_{ij}, j\epsilon J_2), i = 1,2,\dots,m\} = v_1^{\wedge}, v_2^{\wedge}, \dots, v_n^{\wedge} \qquad (8)$$

Step 5- Computation of separation measures: Eqs. 9, 10, and 11 are used, respectively, to compute the distance from PIS and NIS and the relative closeness.

$$S^{\#} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{\#}\right)^2} \qquad (9)$$

$$S^{\wedge} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{\wedge}\right)^2} \qquad (10)$$

$$Relative\ closeness\ C_i^* = \frac{S_i^{\wedge}}{(S_i^{\#} + S_i^{\wedge})} \qquad (11)$$

C_i^* will be in the range of 0 to 1. Evaluation objectives are sorted from largest to smallest and the objective with the largest C_i^* is the best objective of all the alternatives.

Step 6- Priorities are ranked in order of decreasing C_i^* value: The performance of the alternatives is better when the index value is higher.

2.2. VIKOR

Several scholars have presented the VIKOR approach to handle MADM issues with conflicting criteria and criteria that are not quantifiable by the same standard. It is utilized for the optimization of difficult problems with many criteria. The initial weights determined by the entropy method are given to each criterion [25].

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} \\ x_{21} & x_{22} & x_{23} & x_{24} \\ x_{31} & x_{32} & x_{33} & x_{34} \end{bmatrix} \qquad (12)$$

The current multi-criteria problem is represented by the decision matrix "D" in Eq. 12. The decision matrix is normalized by first identifying the normalized vector "r_{ij}" using Eq. 1 and then producing a normalized matrix by utilizing the normalized vector. Equation 2 is used to calculate the index's percentage ("P_{ij}"), while Equation 3 is used to determine the index's entropy ("E_j"). The entropy weight "w_j" of index "j" is calculated using Eq. 5.

The standardized value of weight "v_{ij}" is established using Eq. 6, and the standardized weighted normalized matrix is constructed. The positive and negative ideal solutions are derived, respectively, using equations 13 and 14.

$$\begin{aligned}&A^{+} = \{\max v_{ij}\} = v_1^{+}, v_2^{+}, v_3^{+}, \dots v_n^{+} \\ &\text{for maximization} \\ &A^{+} = \{\min v_{ij}\} = v_1^{+}, v_2^{+}, v_3^{+}, \dots v_n^{+} \\ &\text{for minimization}\end{aligned} \tag{13}$$

$$\begin{aligned}&A^{-} = \{\min v_{ij}\} = v_1^{-}, v_2^{-}, v_3^{-}, \dots v_n^{-} \\ &\text{for maximization} \\ &A^{-} = \{\max v_{ij}\} = v_1^{-}, v_2^{-}, v_3^{-}, \dots v_n^{-} \\ &\text{for minimization}\end{aligned} \tag{14}$$

Each non-dominated solution's utility and regret measures are determined using Eqs. 15 and 16, respectively.

$$S_i = \sum_{j=1}^{n} w_j \left(v_j^{+} - v_{ij}\right)/\left(v_j^{+} - v_j^{-}\right) \tag{15}$$

$$R_i = max\left[w_j\left(v_j^{+} - v_{ij}\right)/\left(v_j^{+} - v_j^{-}\right)\right] \tag{16}$$

where, $S_i, R_i \varepsilon$ [0,1]. The greatest and worst scenarios are represented by the numbers 0 and 1, respectively. The VIKOR index is calculated using Eq. 17, and the option with the lowest VIKOR index is considered to be the best choice.

$$Q_i = \alpha\left[\frac{S_i - S^{-}}{S^{+} - S^{-}}\right] + (1-\alpha)\left[\frac{R_i - R^{-}}{R^{+} - R^{-}}\right] \tag{17}$$

where α denotes a weighting factor with a range of 0 to 1. Typically, α is chosen to be 0.5.

2.3. PSI

A strategy for solving MADM issues called the PSI method was created by Maniya and Bhatt [26]. This is a straightforward method for choosing the best option because no weights for the traits need to be found or assigned, nor is it necessary to rank the attributes in order of significance. The PSI technique involves the following steps:

Step 1. Problem definition: Attributes and alternatives that will be considered in the decision-making process are identified in this stage together with the objectives.

Step 2. Formulation of the decision matrix: The qualities and alternatives are used to create the decision matrix. The qualities of each choice are represented by a row in the decision matrix, and each attribute has its column. As a result, for the ith choice, a member x_{ij} of the decision matrix reflects the x value of the jth attribute in real values that are not normalized. Hence, the matrix will be of order m x n and expressed as in Eq. 18 if there are m choices and n characteristics to consider.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{1m} \\ x_{21} & x_{22} & x_{23} \cdots & x_{2m} \\ x_{n1} & x_{n2} & x_{n3} & x_{nm} \end{bmatrix} \tag{18}$$

Step 3. Normalization: In MADM techniques, it's crucial to make the values of the attribute's dimensions dimensionless. By changing the attribute values to a number between 0 and 1, this is accomplished. Larger numbers are preferred for traits of a positive nature. As a result, normalization is performed using Eq. 19 for advantageous types of characteristics and Eq. 20 for nonbeneficial types of attributes to get lower values.

$$n_{ij} = {x_{ij}}\Big/{x_j^{max}} \tag{19}$$

$$n_{ij} = {x_j^{min}}\Big/{x_{ij}} \tag{20}$$

where, x_{ij} is the measure of attribute (i=1,2,3,...,m and j = 1,2,3,...,n)

Step 4. Determining the mean of the normalized value: Using Eq. 21, the mean value of the normalized data is determined for each attribute.

$$M = \frac{1}{m}\sum_{i=1}^{m} n_{ij} \tag{21}$$

Step 5. Determining the preference variation value: Using Eq. 22, the preference variation value is determined for each characteristic.

$$\varphi_j = \sum_{i-1}^{m}\left[n_{ij} - M\right]^2 \tag{22}$$

Step 6. Determining the deviation in preference value: In this case, Eq. 23 is used to determine the variance in preference value for each characteristic.

$$\Delta_j = \left[1 - \varphi_j\right] \tag{23}$$

Step 7. Compute overall preference value: Using Eq. 24, the overall preference value is determined for each characteristic. The total value of $\sum_{j=1}^{K} \Delta_j$ should be equal to 1.

$$\in_j = \frac{\Delta_j}{\sum_{j=1}^{n} \Delta_j} \tag{24}$$

Step 8. Compute the preference selection index: Using Eq. 25, the preference selection index (PSI) is determined for each choice.

$$PSI_i = \sum_{j=1}^{n} x_{ij}\,\epsilon_j \tag{25}$$

Step 9. The option with the greatest PSI will be ranked 1, and so on until an acceptable alternative has been chosen.

3. Materials and Methods

3.1. Materials

The kenaf fibers used in this study were obtained from Gogreen products, Chennai, India, and were cleaned and dried before use. The sawdust used in this study was obtained from a local supplier in Tumakuru, India and was sieved to obtain particles with a size range of 0.5 mm. The resin used in this study was L12-epoxy along with K6 hardner, obtained from CS marketing, Bengaluru, India. The materials used in the present study are presented in Figure 1.

Fig. 1. Raw material used in the present study

3.2. Methods

The kenaf fibers were cleaned and dried in an oven at 90^0 C for 4 hours. The sawdust was sieved to obtain particles with a size range of 0.5 mm. The kenaf fibers and sawdust were mixed in different weight ratios as shown in Table 1.

The dried kenaf and sawdust mixture was added to the resin at a weight ratio and mixed thoroughly. The hardener was added to the mixture at a weight ratio of 10:1 and stirred. The release agent was applied to the moulds, and the mixture was poured into the moulds and allowed to cure for 24 hours at room temperature.

The coupons for various characterizations are cut from the laminate prepared according to respective ASTM standards as tabulated in Table 2.

Table 2. Standards used: ASTM

Testing	Standard number
Tensile	ASTM D3039
Flexural	ASTM D7264/D7264M15
Charpy impact	ASTM D6110-18

The steps involved in the preparation of proposed composites are presented in Figure 2.

Table 1. Composite configurations used in the present study

Composite	Code	Saw dust (wt%)	Kenaf (wt%)	Epoxy (wt%)
Kenaf+Epoxy	KE	0	50	50
Kenaf+Epoxy+5wt% Sawdust	KESC5	5	45	50
Kenaf+Epoxy+10wt% Sawdust	KESC10	10	40	50
Kenaf+Epoxy+20wt% Sawdust	KESC20	20	30	50

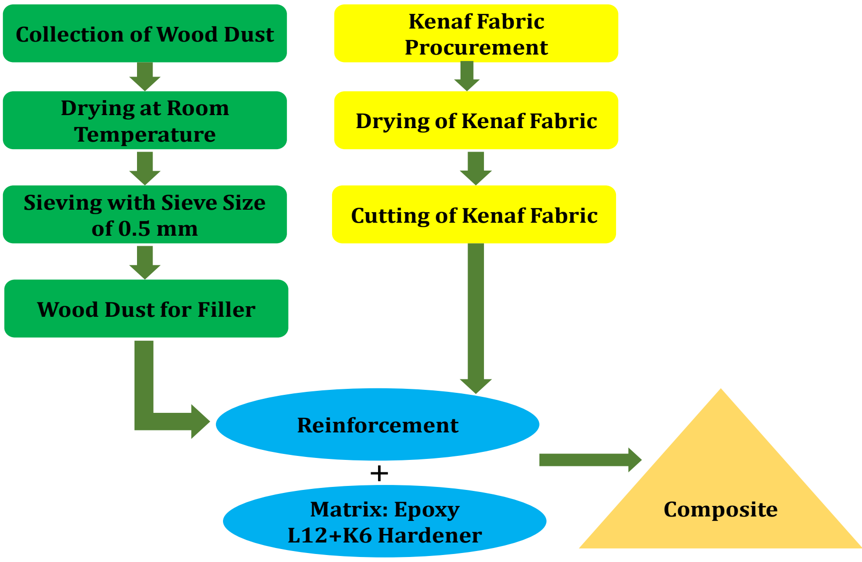

Fig. 2. Methodology for preparation of proposed composites

The specimen used for testing and their conditions are presented in Figure 3.

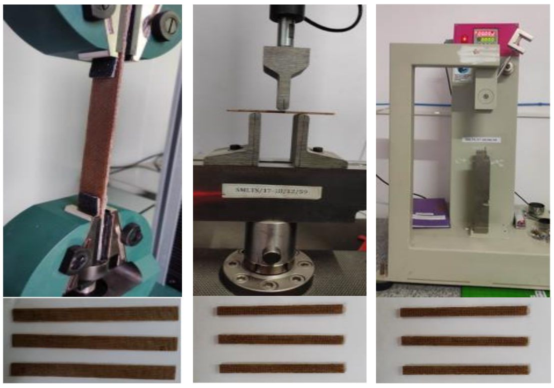
Tensile **Flexural** **Impact**

Fig. 3. Mechanical characterization of proposed composites

4. Results and Discussions

The physio-mechanical properties of this composite depend on several factors, such as the composition, processing method, and testing conditions. Here are some of the key physio-mechanical properties of kenaf sawdust composite. The density of the composite material depends on the amount of kenaf fibers and sawdust particles used in the composition. Generally, increasing the amount of sawdust particles decreases the density of the composite. Tensile strength is a measure of the maximum stress that the material can withstand under tension. The addition of sawdust particles to the kenaf fibers can improve the tensile strength of the composite, but the optimal amount and size of sawdust particles vary depending on the processing method and testing conditions. Flexural strength is a measure of the maximum stress that the material can withstand under bending. Similar to tensile strength, the addition of sawdust particles can improve the flexural strength of the composite, but the optimal amount and size of sawdust particles vary. The water absorption of the composite material depends on the hydrophilic nature of kenaf fibers and sawdust particles. Generally, increasing the amount of sawdust particles in the composite can increase water absorption. Charpy impact strength is a measure of the energy required to fracture a material under an impact load. In the case of composite materials, the Charpy impact strength can depend on several factors, such as the composition of the composite, the type and quality of the fibers, the processing method, and the testing conditions.

Table 3 provides a summary of the findings from the physio-mechanical assessment of the selected composites.

Table 3 demonstrates that the KE composite has a lower density, water absorption, and better impact strength. However, the tensile and flexural strengths of KESC5 and KESC10 are better respectively. Hence, choosing a winning design based on the physio-mechanical outcomes is difficult. With the aid of the MADM technique, which assists the designer or engineer in choosing a successful configuration of the suggested composite taking into account numerous features, this complexity is removed.

4.1. Physio-Mechanical Characterization

Figure 4 makes it clear that adding sawdust as filler affects the density and water absorption of the suggested composites since sawdust has a higher density than kenaf fiber. Kenaf and sawdust both aid in the absorption of water since they are hydrophilic by nature.

Table 3. Outline of the suggested composites' physio-mechanical characteristics

Composites	Density (kg/mm^3)	Water absorption (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Impact strength (kJ/m^2)
KE	275	4	13	68.53	9.84
KESC5	320	8	43.46	77.86	6.75
KESC10	345	10	35.5	90.56	6.57
KESC20	365	15	31.9	75.36	6.23

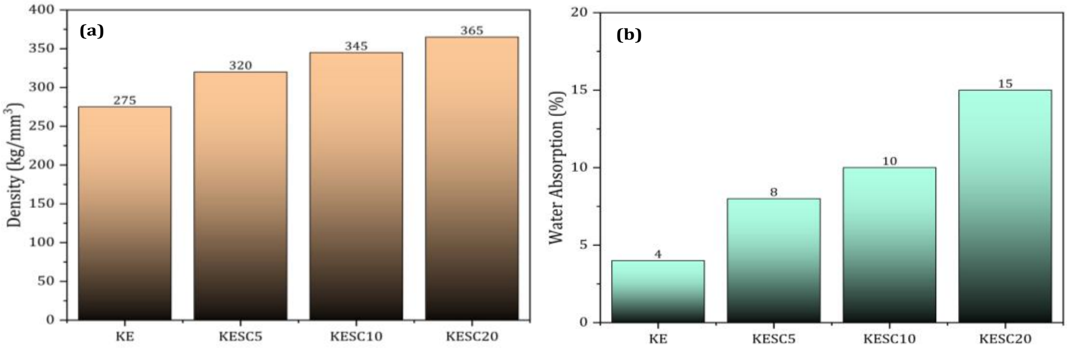

Fig. 4 Change in the suggested composites' (a) density and (b) water absorption

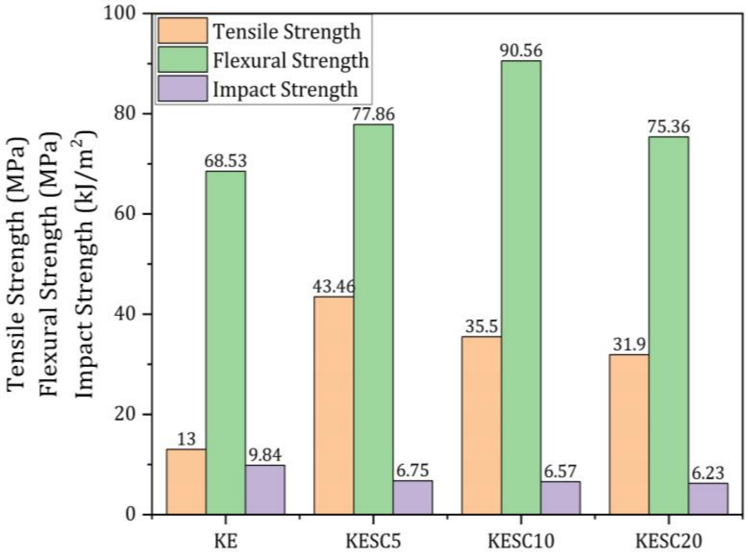

Fig. 5 Variation of Tensile, Flexural, and Impact strengths of proposed composites

Figure 5 displays the variance in the suggested composites' mechanical characteristics. The tensile strength of the suggested composites first improves noticeably when sawdust is added, with KESC5 showing a tensile strength of 43.46 MPa, which is 3.34 times more than the KE composite. This is because the sawdust and epoxy matrix have a strong interfacial connection that improves the load transmission from the matrix to the reinforcement (kenaf and sawdust) and increases the strength [27]. Nevertheless, as compared to the KESC5 composite, further dust addition causes a drop in tensile strength. The composite KESC10, which contains 10 wt% of sawdust particles, has the highest flexural strength of 90.56 MPa among the suggested composites, whereas the composite KE, which contains 0 wt% wood dust, has the lowest flexural strength of 68.53 MPa and is 1.32 times weaker than KE. It is noticeable how much the flexural strength has decreased. When sawdust is added, the composite's flexural strength is improved up to a 10% addition of sawdust particles.

This is because the mechanical tangling or interlocking of the polymer chain matrix with the sawdust allows for effective stress transfer from the matrix to the reinforcement [28]. The flexural strength, however, decreases when more wood dust particles are added than 10% by weight. This is because the reinforcement is unable to bear the pressures placed on it by the polymer matrix, and because there is insufficient interfacial bonding between the reinforcement and matrix materials, leaving certain regions between them largely open. This leads to a weak structure [29]. It is clear from the results that adding sawdust as a filler to epoxy composites reinforced with kenaf has a negative influence on the impact strength of the suggested composites. This is mostly caused by a loss of flexibility of material due to filler addition thereby reducing the deformability of the matrix [30]. Impact strength diminishes as filler concentration rises because it makes the matrix less able to absorb energy and hence less robust.

4.2. *Fractography Study*

SEM may be used to evaluate the various failure modes of the proposed composites. Figure 6 shows the many failure types identified in the recommended composites. The three main reasons why composite materials fail are demonstrated to be fiber breakage, fiber pull-out, and matrix cracking. The composite fails due to matrix cracking, followed by fiber withdrawal and fracture. Brittle composites have damage processes that are typical to them. Fiber pullout is caused by a lack of adhesion between the fibers and the matrix. Fracture mechanics of composites propose that the matrix and fibers in the composite system first bear the stress. As the matrix fractures, the fibers operate as crack-stoppers or arrestors to delay the material's catastrophic failure until the matrix has completely broken down.

The main cell wall, which is fragile, collapses as the applied stress rises, causing cell cohesion and fiber failure. One of the main failure modes is brittle failure, which is indicated by cracks in the matrix. In Figure 6, voids brought on by fiber withdrawal are seen. The distance between the fiber and the matrix may be used to determine how poorly the fibers adhere to the matrix. The outcomes are consistent with the trend found in the literature [31].

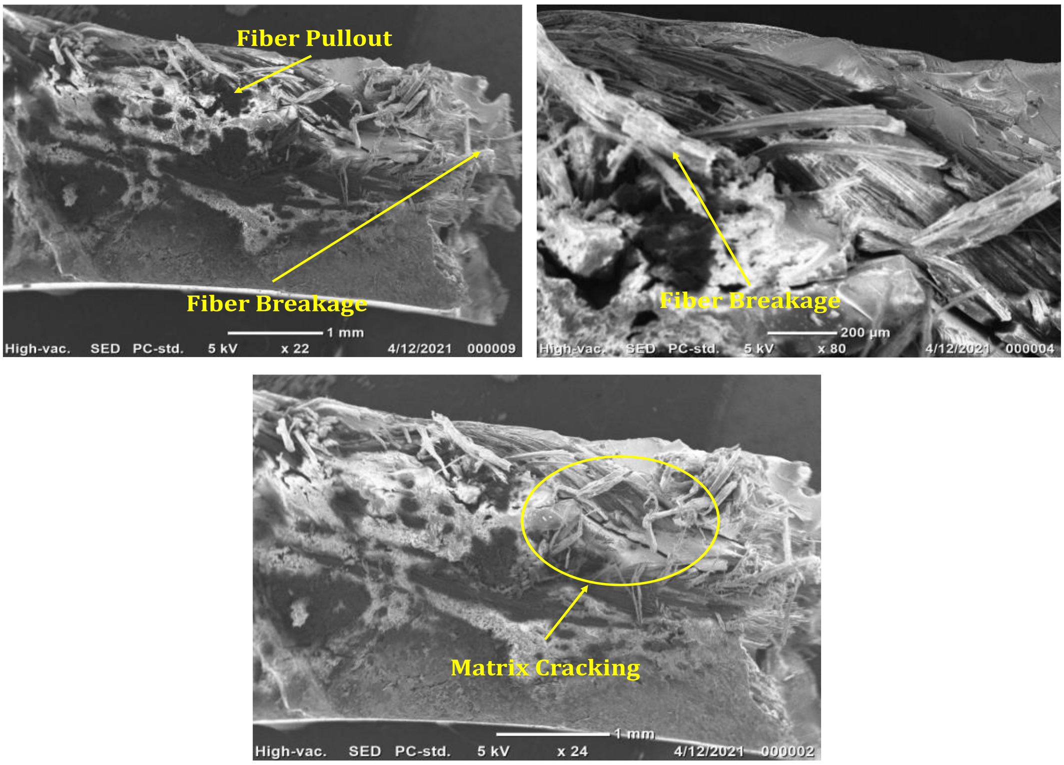

Fig. 6 Fractography of proposed composites

4.3. *MADM-TOPSIS, VIKOR and PSI*

The performance-defining attributes (PDAs) with their implication are provided in Table 4.

Table 4. PDAs and their implications considered

PDAs used in the present study	Implication of PDAs
Density	Least is preferable
Water absorption	Least is preferable
Tensile strength	Highest is preferable
Flexural strength	Highest is preferable
Impact strength	Highest is preferable

4.3.1. TOPSIS and VIKOR Approach

Tables 5 and 6 exhibit the decision and normalized matrix that were created based on the testing results.

The entropy method is used to determine the weights. The weights that were found are listed in Table 7. The weighted normalized matrix is shown in Table 8.

Table 5. The decision matrix used for the TOPSIS and VIKOR approach

Composites	Density (kg/mm^3)	Water absorption (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Impact strength (kJ/m^2)
KE	275	4	13	68.53	9.84
KESC5	320	8	43.46	77.86	6.75
KESC10	345	10	35.5	90.56	6.57
KESC20	365	15	31.9	75.36	6.23

Table 6. The normalized matrix used for the TOPSIS and VIKOR approach

Composites	Density	Water absorption	Tensile Strength	Flexural Strength	Impact strength
KE	0.42	0.20	0.20	0.44	0.66
KESC5	0.49	0.40	0.66	0.50	0.45
KESC10	0.53	0.50	0.54	0.58	0.44
KESC20	0.56	0.75	0.48	0.48	0.42

Table 7. Weights calculated by entropy method

Criteria	Weights (Calculated from Entropy Method)
Density	0.0272
Water absorption	0.4784
Tensile strength	0.3760
Flexural strength	0.0258
Impact strength	0.0923

Table 8. VIKOR's weighted normalized matrix

Composite Configuration	Density	Water absorption	Tensile Strength	Flexural Strength	Impact strength
KE	0.0114	0.095	0.074	0.0113	0.0606
KESC5	0.013	0.190	0.248	0.0128	0.0416
KESC10	0.014	0.237	0.202	0.0149	0.0405
KESC20	0.015	0.356	0.182	0.0124	0.0384

Table 9. PIS, NIS, and separation from PIS and NIS

Parameters	Positive Ideal Solution	Negative Ideal Solution	Separation from a positive ideal solution	Separation from a negative ideal solution
Density	0.0114	0.015	0.1739	0.2625
Water absorption	0.095	0.35	0.0970	0.2407
Tensile strength	0.248	0.074	0.1511	0.1751
Flexural strength	0.014	0.011	0.2707	0.1079
Impact strength	0.060	0.038	0.173992	0.26251

Table 10. Ranking for alternatives through TOPSIS and VIKOR

Alternative	Relative closeness (TOPSIS)	Ranking (TOPSIS)	$\boldsymbol{Q_i}$	Ranking (VIKOR)
KE	0.6014	2	0.457882	3
KESC5	0.7127	1	0.000000	1
KESC10	0.5367	3	0.334144	2
KESC20	0.2850	4	1.000000	4

Table 11. Values for preference variation, preference deviation, and total preference

Composite Configuration	Density	Water absorption	Tensile strength	Flexural strength	Impact strength
Preference variation value	0.0339	0.2788	0.2648	0.0302	0.086
Deviation in preference value	0.9660	0.7211	0.7351	0.9697	0.9130
Overall preference value	0.224	0.167	0.170	0.225	0.212

The PIS and NIS for TOPSIS are determined based upon which the separations from positive and negative ideal solution is found out are tabulated in Table 9.

Also, the TOPSIS and VIKOR Index relative proximity is calculated, and the alternatives are sorted with the option with the highest relative closeness receiving rank 1 for TOPSIS and the option with the lowest VIKOR Index receiving rank 1 for VIKOR. The same is presented in Table 10.

4.3.2. PSI Approach

Table 11 summarizes the preference variation value, preference value deviation, and total preference value.

The PSI values for each alternative are computed, and a ranking based on the PSI values is given, starting with the alternative with the highest PSI and moving down the list from there. The identical are listed in Table 12.

Table 12. PSI scores and alternative rankings

Composite alternatives	PSI score	Rank
KE	82.12527	3
KESC5	106.9497	1
KESC10	99.54116	2
KESC20	0	4

5. Conclusions

The current study examines the benefits of using leftover sawdust as fillers in Kenaf fiber-impregnated composites for a range of structural applications. Also, a feasibility analysis of the TOPSIS, VIKOR, and PSI MADM techniques for the choice of composite materials has been completed. The following findings are reached from the current investigation.

The current study examines the benefits of using leftover sawdust as fillers in Kenaf fiber-impregnated composites for a range of structural applications. Also, a feasibility analysis of the TOPSIS, VIKOR, and PSI MADM techniques for the choice of composite materials has been completed. The following findings are reached from the current investigation.

- Waste management may be made more efficient by using waste sawdust as fillers in polymer composites.

- The density of the suggested composites is found to rise with an increase in the weight % of the chosen filler because the density of the chosen wood dust is higher than the density of the fiber reinforcement utilized.

- Due to the -OH groups that the sawdust particles contain on their surfaces, the water uptake increases when more sawdust is added as a weight percentage to the composite.
- It is found that among proposed composites with different saw dust weight percentages, no single composite configuration provides better results under all the criteria considered. Hence, the physio-mechanical characterization is not definitive about the best composite design.
- The comparison of the results from Hybrid Entropy-VIKOR, TOPSIS, and PSI showed that these methods are effective for picking the right composite design.
- It is found that TOPSIS, VIKOR, and PSI show KESC5 as the winning configuration among all the composites considered in the present study. It is also clear that the MADM model is very helpful in choosing composite compositions and that it can be extended to incorporate the product designer's choice of acceptable composite compositions for any planned engineering application. These models may also be used by engineers and designers to select the best material from a range of possibilities since they are clear-cut, accurate, and very powerful tools.

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