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ORIGINAL PAPER

Physio-mechanical characterization of kenaf/saw dust reinforced polymer matrix composite and selection of optimal configuration using MADM-VIKOR approach

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Abstract

The current study focuses on development and mechaincal charactetization of kena and waste saw dust reinforced hybrid composites for various structural/ semi structural applications in automobiles. The proposed composites are developed and tested in four different configurations namely kenaf + epoxy (KE), kenaf + epoxy + 5 wt% saw dust (KESC5), kenaf + epoxy + 10 wt% saw dust (KESC10) and kenaf + epoxy + 20 wt% saw dust (KESC20). It is found from the physical characterization that addition of selected saw dust results in enhenced density of the composites and the proposed composites are also sussceptible to water absorption due to the hydrophillic nature of reinforcements used. The brightest side of the proposed hybrid composites is seen in their tensile and flexural strengths, where the tensile strength of the KESC5 composites enhanced appreciably by 3.34 times compared with KE composite. Also, tensile strength of hybrid composites are better than non hybrid composite. The flexural strength of the saw dust reinforced kenaf/epoxy composite showed a promising behavior with KESC10 exhibiting 90.56 MPa which is 1.32 times more than the non hybrid composite KE. But, it is found that addition of saw dust results in adverse effects on the impact strength of proposed composites due to reduction of elasticity of material and thereby reducing the deformability of matrix. Based on the outcome of the VIKOR, it is concluded that KESC5 composite is the better composite among all its counterparts considered in the present study.

Keywords Kenaf · Saw dust · Hybrid composite · MADM · Mechanical characterization

1 Introduction

In comparison to their traditional isotropic equivalents, recent innovations have elevated the use of composite materials. Their major features, including enhanced ratio of strength to weight, reduced weight have fuelled this change, allowing for large weight reductions while maintaining appreciable properties. Composites are often made up of a polymer foundation induced with various synthetic and natural fibers.

To minimize the final product's density, composites are extensively using synthetic fibres [1, 2]. Artificial fibres have recently lost favour with businesses and engineers owing to environmental and energy concerns [3–13]. Natural fibres provide several advantages, including environmental friendliness, reduced cost, reduced weight and acceptable mechanical and physical properties [14]. The benefits provided by naturally available fibers have resulted in them being emerged as potential substitutes for artificial fibers [6, 8, 10, 12, 15–25], and are commonly utilised in interiors of automobiles [26, 27]. They do, however, have significant disadvantages, like lower resistance against absorbing water and mechanical properties compared to artificial fibres [28, 29]. As a result, academics are experimenting with a range of approaches to overcome these issues [30, 31]. One method is to treat the natural fibres [32]. Alkali treated fibers exhibit better properties compared to untreated fibers [33]. Alternatives to synthetic fibres, such as natural fibres, may be practical in sacrificial structural applications [34–37]. Natural fibre reinforced PMC is most typically made using plant-based natural fibres. Plant-based fibres are collected from many sections of the plant.

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Bast and core of the kenaf plant, also known as Hibiscus cannabimus L., are separated. The long fibers are extracted from bast region, which takes around 35 percent of the weight of the dried stalk, whereas the short fibers come from the kenaf plant's centre [38]. The height of the plant varies from 1 to 5 m, and yearly yield per acre of agricultural land can range from 600 to 10,000 kg of dry fibre. The kenaf plant's stem is divided into three sections: central, outer, and inner. Pith are polygonal parenchymatous cells that make up the core component [39]. The fibres from the stem's outer section have outstanding mechanical qualities and might be used in composites. Furthermore, kenaf has the advantage of being able to employ nearly 40 percent of yield from stalk for production of fiber, which is nearly, double that of other natural fibers. As a result, it is quite inexpensive [40]. Natural fibre has a well-defined structure and components [41]. Plant-based natural fibres are made up of cellulose, hemicelluloses, lignin, pectin, and other components, and their characterisation is done on the basis of their contents.

Kenaf's external walls mainly comprise of bast fibres called a macrofibrilm which consists of tube hollow in nature having four layers: one major cell wall layer and three secondary wall layers. The lumen is an open channel in the macrofibril's centre. In each wall layer, hemicellulose and lignin serve as a matrix for cellulose. The crystalline and amorphous parts of the microfibril are separated. Kenaf fibre is the most powerful natural fibre 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, it displayed specific tensile strength and modulus up to roughly 832 MPa and 36.5 GPa. However, the physical and mechanical qualities of kenaf plant fibre are largely dependent on environmental conditions and processing procedure. It should be noted that kenaf possesses characteristics similar to glass fibre, making it an excellent candidate for FRPMC. Kenaf fibre and composites are three to two times less costly than glass fibre and have equal specific stiffness [42]. Thus, exhibiting potential in reducing the use of synthetic fibers [43]. Over 95% of the world's kenaf fibre is produced in India, China, and Thailand, making them the principal producers [44]. Kenaf production is estimated to be over 300.000 tonnes globally [45].

Several research on the addition of various types of fillers to kenaf fiber-based composites have been conducted. The major purpose of using nanofiller is aimed towards improve the interface between the nanosized building pieces and the polymer matrix, thereby boosting the composite's performance [46]. These fillers are essential for improving the physical and mechanical properties of composites [47]. Furthermore, by utilising these filler materials, water absorption may be reduced, improving the mechanical performance of natural fibre reinforced polymer composites [48]. The spaces between the fibres and the resin are filled with fillers, improving the interaction between the fibre and the matrix in most cases at a substantially cheaper cost/amount than fibre. As a result, it might also be used to reduce composite costs. However, homogeneous dispersion is a common issue with these fillers.

For filler, the maximum quantity is crucial; too much might produce clustering in the matrix during mixing, which has a negative impact on composite performance. Filler materials are accessible in both natural and synthetic forms. Before being applied to the fibre surface, these filler components are usually mixed with resin.

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 in specifically. To improve the mechanical qualities of composite materials, various waste materials can be employed as fillers [49]. Fibers are employed as major reinforcing components to increase the composite's strength. However, using waste materials as filler, such as wood dust, can help to reduce weight and reduce dependency on natural fibres. To prevent pollution and resource depletion, wood waste is gathered and used to create a natural composite instead of synthetic fibres [50, 51]. Agricultural byproducts such as bagasse, rice husks, and wood chips are the principal natural resources. Natural fillers are lighter, less costly, and substantially stronger than synthetic fillers.

The present study aims at developing a sustainable saw dust and kenaf reinforced polymer matrix composite and selection of the appropriate composite using MADM VIKOR approach.

2 Materials and methods

2.1 Materials

Utilizing naturally occurring kenaf, the suggested hybrid composites are created along with saw dust and epoxy L12 resin along with K6 hardener. Table 1 presents the constituents in various propositions used in preparation of the proposed composites.

Wood dust having a density of 1650 kg/m^3 is collected from saw mill (Tumkur, Karnataka, India), dried at room temperature for 48 h in order to remove any moisture and further sieved using 1.2 mm sieve in order to remove any unwanted particles such as plastics, wood and metal particles etc. Thus obtained wood dust after sieving is used as filler in the proposed composites. Kenaf is obtained from local supplier of Chennai from India and is used as fiber reinforcement in

Table 1 Proposed composites configuration

Sample Number	Saw dust (wt%)	Kenaf (wt%)	Epoxy (wt%)
KE	0	50	50
KESC5	5	45	50
KESC10	10	40	50
KESC20	20	30	50

Table 2 Mechanical properties of uncured resin system [52]

Parameter	Strength
Tensile strength (MPa)	50–60
Flexural strength (MPa)	130–150
Impact strength (KJ/m^2)	17–20

the proposed composite and epoxy L12 along with K6 hardener obtained from CS Marketing, Bangalore, Karnataka, India in the ratio 10:1 is used as a matrix owing to excellent versatility and better properties. The matrix composes of Diglycidyl Ether Bisephinol and Hardener K6 is a low viscosity room temperature curing liquid aliphatic polyamine hardener. Table 2 provides the mechanical properties of cured unreinforced resin system [52]

2.2 Processing techniques

The steps involved in preparation of the proposed composites are presented in Fig. 1. The wood dust, kenaf fiber and epoxy resin along with K6 hardener are mixed together in the proportions mentioned in Table 1. The epoxy, hardener, kenaf and saw dust are mixed using a mechanical stirrer to get a homogeneous mixture. Thus obtained mixture is carefully applied using mould method. It is further compacted manually with the help of roller. The top cover plate smeared with wax is placed on the arrangement and a load of 10 kg is placed on it for 24 h for the purpose of curing. The required samples are cut from these laminates of 300 × 300 × 10 mm^3 based on the ASTM standard used for testing. For a composite without saw dust, the entire procedure remains same except that the addition of wood dust is avoided.

The final cured laminated obtained are presented in Fig. 2.

2.3 Testing methods

The proposed composites are physically characterized to determine their density and water absorption ability. One of the most important factors in selecting a material for a certain technical application is density which is calculated using standard relation between density, mass and volume as shown in Eq. 1.

$$Density = \frac{Mass}{Volume} \tag{1}$$

The composite's response with regards to water absorption is evaluated using the ASTM D 570-98 standard. Equation 2 is used to compute the percentage of water absorption.

$$Water\ absorption(\%) = \left(\frac{w_f - w_i}{w_i}\right) \times 100 \tag{2}$$

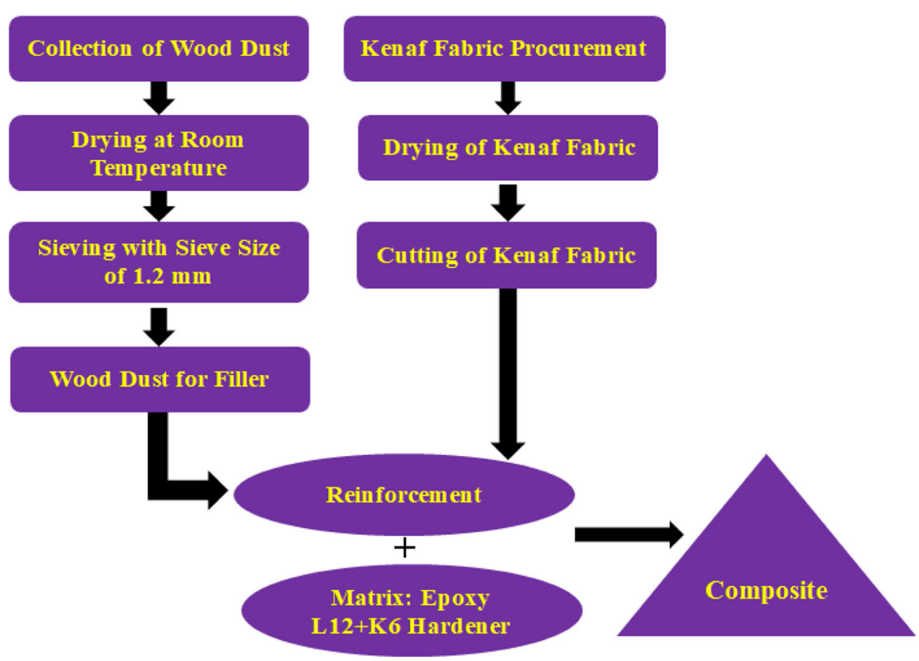
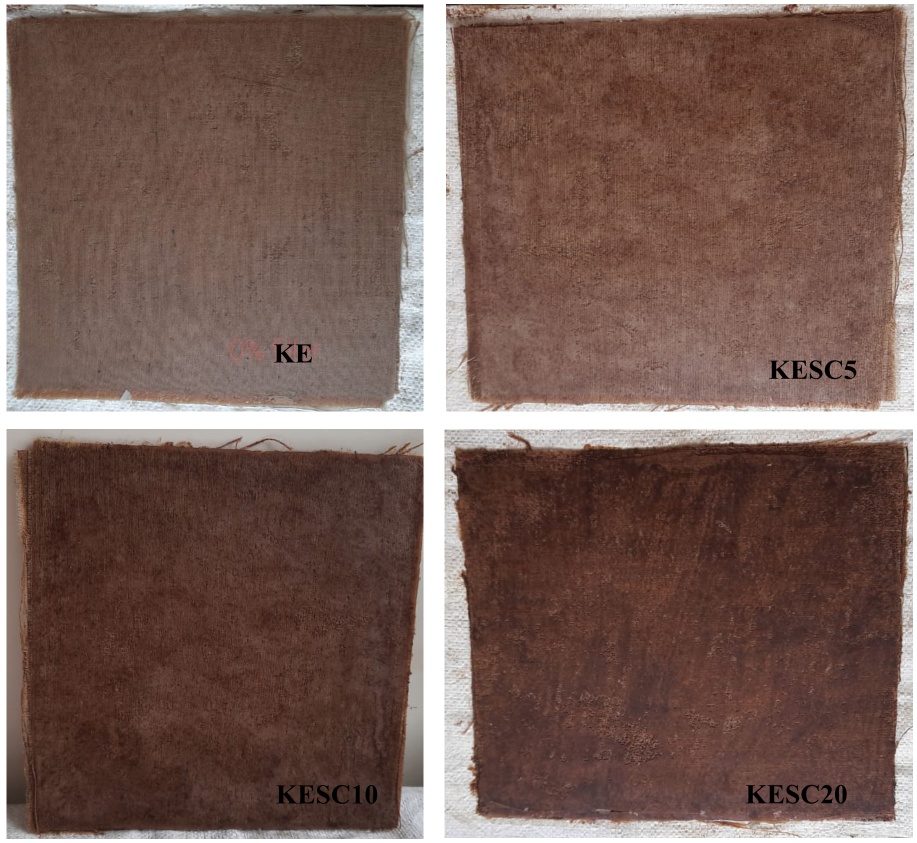


Fig. 1 Steps involved in preparation of the proposed composites

Fig. 2 Cured laminates



where w_f is the sample's final weight following the test and w_i is the sample's starting weight. Before being submerged in water, the 76 mm × 25 mm samples are first weighed using a sophisticated weighing scale equipment. They are submerged in water thereafter, and the same sophisticated weighing scale equipment measures their weights at 2, 6, 12, 24, 36, 48, and 72 h.

The proposed composites are mechanically characterized by determining their tensile, flexural and impact strength. According to ASTM D3039, four specimens (250 mm × 25 mm) are tested under tensile force in each of the configurations. The average values are then taken into account. A cross head speed of 2 mm/min is used for the test. ASTM D7264/D7264M15 standard was utilised for carrying out three point flexural test. Four specimens (125 mm × 12.7 mm) of each composition were tested and their average value is reported as the flexural strength of the proposed composites. The Charpy Impact test may be used to quantify the energy absorbed by a standard notched specimen when it breaks under the effect of an impact force and is carried out according to ASTM D6110-18. Four specimens (125 mm × 12.7 mm) of each composition were tested and their average value is reported as the impact strength of the proposed composites.

2.4 MADM approach

The ideal composition of the suggested composites with density, water absorption, tensile strength, flexural strength, and impact strength of the hybrid composites is determined using the MADM methodology, specifically the VIKOR method. The entropy approach is employed to determine the weights of the various criteria to be used in the VIKOR method.

$$D = \begin{pmatrix} x_{11} & \cdots & x_{15} \\ \vdots & \ddots & \vdots \\ x_{41} & \cdots & x_{45} \end{pmatrix} \tag{3}$$

Equation 3 shows decision matrix 'D' of the present multi-criteria problem with 4 alternatives (KE, KESC5, KESC10 and KESC20) and 5 criteria (density, water absorption, tensile strength, flexural strength and impact strength). It is further normalized using Eq. 4 and normalized matrix is built.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{4}$$

where i = 1, 2, 3, 4….., m and j = 1,2, 3, 4, ….,n

The weight to be assigned to each criterion is found using "Entropy method" using Eqs. 5 and 6.

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{5}$$

$$E_j = -k \sum_{i=1}^{m} P_{ij} ln P_{ij} \tag{6}$$

where k is calculated using Eq. 7

$$k = \frac{1}{\ln m} \tag{7}$$

where m is the number of alternatives (m = 4 in the present study).

The entropy weight "w_j" of index "j" is calculated using Eq. 8

$$w_j = \frac{[1 - E_j]}{\sum_{j=1}^{n} [1 - E_j]} \tag{8}$$

Using Eq. 9, the standardised weighted normalised matrix is created when the standardised value of weight "v_{ij}" has been determined.

$$v_{ij} = w_j r_{ij} \tag{9}$$

where i = 1, 2, 3, 4, ….., m and j = 1, 2, 3, 4, ….,n

Equations 10 and 11 are used, respectively, to derive the positive and negative ideal solutions.

$$\begin{aligned} A^+ &= \{\max v_{ij}\} = v_1^+, v_2^+, v_3^+, \ldots v_n^+ \text{ for maximization problems} \\ A^+ &= \{\min v_{ij}\} = v_1^+, v_2^+, v_3^+, \ldots v_n^+ \text{ for minimization problems} \end{aligned} \tag{10}$$

$$\begin{aligned} A^- &= \{\min v_{ij}\} = v_1^-, v_2^-, v_3^-, \ldots v_n^- \text{ for maximization problems} \\ A^- &= \{\max v_{ij}\} = v_1^-, v_2^-, v_3^-, \ldots v_n^- \text{ for minimization problems} \end{aligned} \tag{11}$$

According to Eqs. 12 and 13, the utility and regret measures for every non-dominated solution are determined..

$$S_i = \sum_{j=1}^{n} w_j \left(v_j^+ - v_{ij}\right) / \left(v_j^+ - v_j^-\right) \tag{12}$$

$$R_i = max\left[w_j \left(v_j^+ - v_{ij}\right) / \left(v_j^+ - v_j^-\right)\right] \tag{13}$$

where S_i, $R_i \varepsilon$ [0,1]. The numbers 0 and 1 represent the best and worst cases, respectively. Equation 14 is used to determine the VIKOR index, and the alternative with the lowest VIKOR index is ranked as the best option.

$$Q_i = \alpha \left[\frac{S_i - S^-}{S^+ - S^-}\right] + (1 - \alpha) \left[\frac{R_i - R^-}{R^+ - R^-}\right] \tag{14}$$

where α is a weighing factor ranging from 0 to 1. Usually, α is selected to be 0.5

3 Results and discussions

3.1 Physio-mechanical characterization

The overview of the obtained results are presented in Table 3.

The different densities of the proposed composites are exhibited in Fig. 3.

It is found that with an increase in the filler weight percentage, the density of the proposed composites increases. This is due to the fact that the density of kenaf fiber is lower compared to the density of the wood dust used in the present study." The density of kenaf fibers is around 1400 kg/m^3, the density of the wood dust obtained from tamarind wood has a density of 1650 kg/m^3.

It is evident from the Fig. 4 that with increase in filler weight percentage, the water absorption percentage of the proposed composites increases.

Both the kenaf fiber and saw dust are hydrophilic in nature. The saw dust particles contain –OH groups on their surface which results in enhanced water absorption as more weight percentage of saw dust is added into the composite [53]. Also, kenaf being natural fiber cellulosic in nature contributes more for water absorption.

It is found that with an increase in the filler weight percentage, the density of the proposed composites increases. The weight percentage of the epoxy resin is kept constant for all the proposed composites since it does not influence

Table 3 Overview of physio-mechanical properties of proposed composites

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

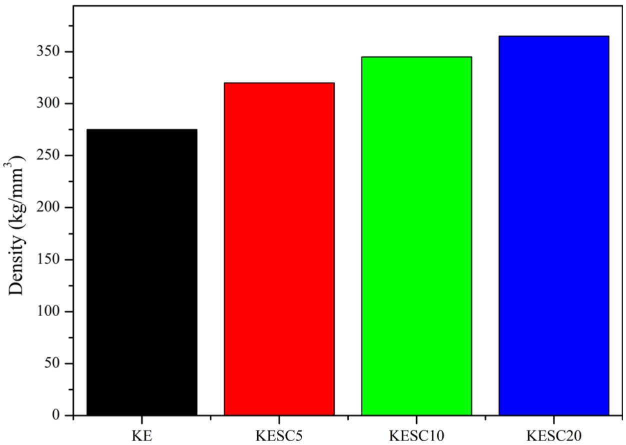


Fig. 3 Density of proposed composites

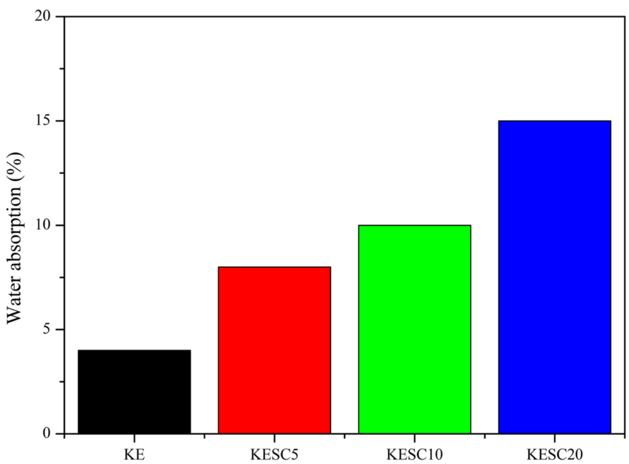


Fig. 4 Water absorption of proposed composites

the density of the composite to appreciable extent compared to kenaf fiber and wood dust used in the present study. The proposed composite without saw dust exhibits a density of 275 kg/mm^3. The addition of 5 wt% of saw dust results in significant enhancement of the density of the proposed composite with KESC5 having density of 16.36% more compared to KE composite. Further addition of saw dust by 10 wt% for KESC10 results in 7.8% enhancement in density compared to KESC5. The last composition KESC20 shows an increment of 5.8% in density compared to KESC10. This is due to the fact that saw dust being denser than kenaf fiber results in enhancement of density of the proposed composites. The composite KESC20 and KE exhibit higher and lower densities of 365 kg/m^3 and 275 kg/m^3 respectively. This shows that addition of saw dust as filler material increases the density of the composites which is in accordance with the trends observed in literature [54].

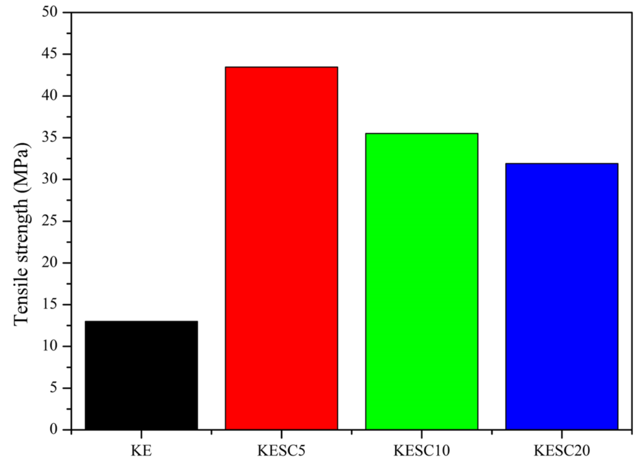


Fig. 5 Tensile strength of proposed composites

The tensile strength obtained for the composites considered in the present study are in the order of KESC5 > KESC10 > KESC20 > KE as shown in Fig. 5.

Adding saw dust, initially the tensile strength of the proposed composites gets enhanced appreciably with KESC5 exhibiting tensile strength of 43.46 MPa which is 3.34 times more compared to KE composite. This is due to the fact that there exists a strong interfacial bonding between saw dust and epoxy matrix resulting in better transfer of load from matrix to reinforcement (jute and wood dust) and thereby enhancing the strength [55]. However, further addition of saw dust results in reduction in tensile strength compared to KESC5 composite. But, the tensile strength of hybrid composites are still better than the KE composite. The tensile strength of KESC10 and KESC20 composites are 2.7 times and 2.45 times higher than KE composite. Further addition of saw dust particles beyond 5 wt% results in agglomeration and thus resulting in reduced strength. Thus the optimal weight percentage of saw dust that can be used along with kenaf fiber to obtain better tensile strength is found to be 5 wt%. It is also found that hybrid composites exhibit better tensile strength compared to non-hybrid composite. Thus, it is proved that addition of saw dust as filler proves to be beneficial in enhancing the tensile strength of the Kenaf based composites.

The flexural strength obtained for the composites considered in the present study are in the order KESC10 > KESC5 > KESC20 > KE. The effect of saw dust on the flexural strength of the proposed composites can be analysed using Fig. 6.

Among the proposed composites considered, the composite KESC10 having 10 wt% of saw dust particles exhibit higher flexural strength of 90.56 MPa and the composite KE with 0 wt% wood dust exhibits lowest flexural strength of 68.53 MPa which is 1.32 times less than KE. This reduction in the flexural strength is appreciable. The addition of saw dust results in enhanced flexural strength of the composite up

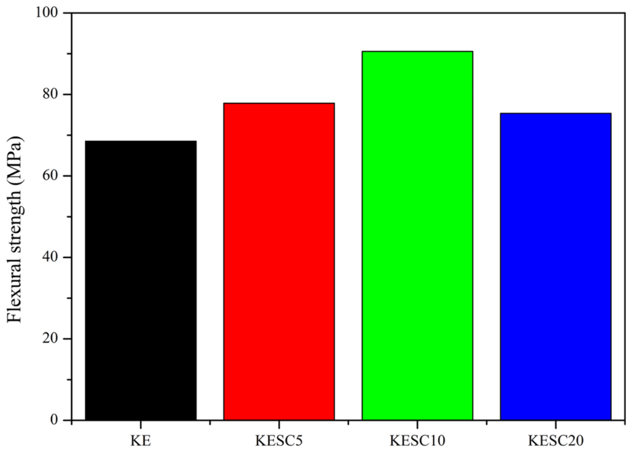


Fig. 6 Flexural strength of proposed composites

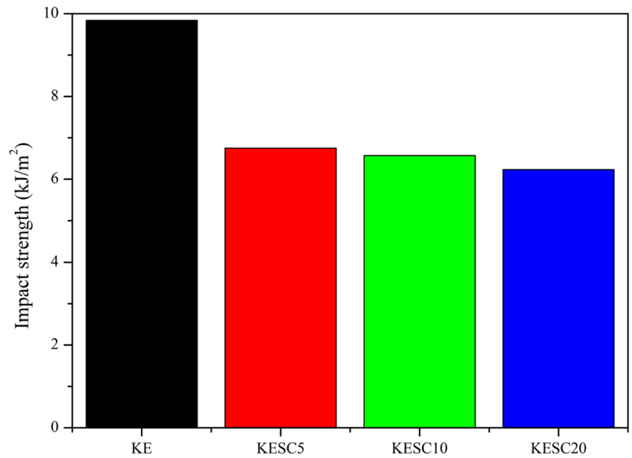


Fig. 7 Impact strength of proposed composites

to addition of 10 wt% of saw dust particles. This is due to the polymer chain matrix's mechanical interlocking or tangling with sawdust, which results in efficient stress transmission from the matrix to the reinforcement [56]. However, with further addition of wood dust particles beyond 10 wt%, the flexural strength reduces. This is owing to the reinforcement's inability to withstand stresses imparted from the polymer matrix, as well as inadequate interfacial bonding, which results in partially open areas between reinforcement and matrix materials, resulting in a weak structure [57]. With a large amount of saw dust exceeding 10%, it is also impossible to produce a high flexural strength because the higher amount of saw dust may form clusters at various sites in the composite, resulting in poor bonding. This might cause cracks to develop in the composite material during the flexural test, reducing the composites' flexural load-bearing capacity [58] and also more amount of filler weight percentage may result in improper wetting of the filler [55]. The minimum surface area of the sawdust in KESC10 composite, which may have an excellent interface contact with the matrix, and the composite's high stiffness value are what give it its maximum flexural strength. The impact strength of the proposed composites vary in the order KE > KESC5 > KESC10 > KESC20 as shown in Fig. 7.

It is evident from the obtained results that addition of saw dust as a filler in Kenaf reinforced epoxy composites has an adverse effect on the impact strength of the proposed composites. The non hybrid composite KE exhibits impact strength of 9.84 kJ/m^2 which is the highest among all the composites considered in the study. Addition of saw dust by 5 wt% in KESC5 composite resulted in drastic reduction in impact strength by 45.77% by exhibiting impact strength of 6.75 kJ/m^2. This is mainly due to the reduction of elasticity [59] of material due to filler addition and there by reducing the deformability of matrix. An increase in concentration of filler reduces the ability of matrix to absorb energy and thereby reducing the toughness, so impact strength decreases.

3.2 MADM-VIKOR

Table 4 contains a description of the performance-defining characteristics, and the VIKOR technique is used to carry out the optimization.

The four composite configurations KE, KESC5, KESC10 and KESC20 are evaluated and ranked in accordance with the VIKOR method comparison. The choice matrix, which was created based on the experimental findings, is shown in Table 5. Normalization is done to make it easier to compare the various values of the attributes acquired experimentally, and the results are shown in Table 6.

Using Eqs. 4 to 8, the weights are determined using the entropy approach. Table 7 lists the weights that were discovered. Table 8 contains the weighted normalised matrix.

Table 9 lists the derived positive and negative ideal solutions. Table 10 lists the S_i and R_i values that were determined by applying Eqs. 12 and 13, respectively. The VIKOR index is determined as a last step to rate the options using Eq. 14. The VIKOR index and rating for each alternative are shown in Table 11.

Table 4 Description of performance defining attributes utilized in MADM

Performance defining attributes (PDA's)	PDA's Implication
Density	Lower is best
Water absorption	Lower is best
Tensile strength	Higher is best
Flexural strength	Higher is best
Impact strength	Higher is best

Table 5 Decision matrix for VIKOR

Composite configuration	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 Normalized matrix for VIKOR

Composite configuration	Density (kg/mm^3)	Water absorption (%)	Tensile strength (Mpa)	Flexural strength (MPa)	Impact strength (kJ/m^2)
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 The weights determined by the entropy approach

Parameters	Weights (calculated from entropy method)
Density	0.027234
Water absorption	0.478497
Tensile strength	0.376036
Flexural strength	0.025888
Impact strength	0.092344

Table 9 Positive and negative aspects of the optimum VIKOR solution

Parameters	PIS	NIS
Density	0.011418	0.015154
Water absorption	0.095107	0.356651
Tensile strength	0.248195	0.074242
Flexural strength	0.014936	0.011302
Impact strength	0.060663	0.038408

According to the findings, KESC5 has a lower VIKOR index than KE, KESC10, and KESC20. Accordingly, using the VIKOR approach with KESC10, KE, and KESC20 as the reference points, KESC5 is shown to be the best composite composition for the parameters taken into account in the current study.

4 Results and discussions

The present study explores the benefits of using the waste saw dust as a filler in natural Kenaf fiber reinforced composites for various structural/semi-structural applications. Based on the present study, following conclusions are drawn upon:

- Waste material saw dust can be utilised as filler for polymer-based composites, resulting in efficient waste management.
- It is found that with an increase in the selected filler weight percentage, the density of the proposed composites increases due to the fact that the density of choosen wood dust is greater than the fiber reinforcement used.

Table 8 Weighted normalized matrix for VIKOR

Composite configuration	Density (kg/mm^3)	Water absorption (%)	Tensile strength (Mpa)	Flexural strength (MPa)	Impact strength (kJ/m^2)
KE	0.011417	0.095106	0.074241	0.01130247	0.0606633
KESC5	0.013285	0.190213	0.248195	0.01284124	0.0416135
KESC10	0.014323	0.237767	0.202736	0.01493582	0.0405038
KESC20	0.015154	0.356650	0.182177	0.01242892	0.0384077

Table 10 S_i and R_i measures for VIKOR

Alternative	S_i	R_i
KE	0.402	0.376
KESC5	0.282	0.174
KESC10	0.464	0.261
KESC20	0.759	0.478

Table 11 Q_i for $\alpha = 0.5$

Alternative	Q_i	Ranking
KE	0.457882	3
KESC5	0.000000	1
KESC10	0.334144	2
KESC20	1.000000	4

- The saw dust particles contain –OH groups on their surface which results in enhanced water absorption as more weight percentage of saw dust is added into the composite.
- It is found that the optimal weight percentage of saw dust that can be used to enhance the tensile strength of proposed hybrid composites is found to be 5 wt%. Addition of saw dust particles beyond 5 wt% results in agglomeration and thus resulting in reduced strength.
- It is also found that hybrid composites exhibit better tensile strength compared to non-hybrid composite. Thus, it is proved that addition of saw dust as filler proves to be beneficial in enhancing the tensile strength of the Kenaf based composites.
- It is found that the optimal weight percentage of saw dust that can be used to enhance the flexural strength of proposed hybrid composites is found to be 10 wt%. Addition of saw dust particles beyond 10 wt% owing to the polymer chain matrix's mechanical interlocking or tangling with sawdust, which results in efficient stress transmission from the matrix to the reinforcement.
- The impact strength of the proposed composites vary in the order KE > KESC5 > KESC10 > KESC20. It is found that addition of fillers does not enhance the impact strength of the composites mainly due to the reduction of elasticity of material due to filler addition and thereby reducing the deformability of matrix. An increase in concentration of filler reduces the ability of matrix to absorb energy and thereby reducing the toughness, resulting in reduced impact strength.
- Successful use of MADM techniques like VIKOR has demonstrated that KESC5 has outperformed its competitors. Additionally, it is evident that the Hybrid Entropy-VIKOR model greatly aids in the selection of composite composition and may be expanded to include the selection of acceptable composite compositions by the product designer for any intended engineering application. These models are also simple to comprehend, precise, and extremely effective tools that can be used to help engineers and designers choose the best material from the available options.

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