Fabrication of a hybrid composite of glass and kenaf fibers and investigation of its mechanical properties

Fabricação de um composto híbrido de fibras de vidro e kenaf e investigação de suas propriedades mecânicas

Fabricación de un compuesto híbrido de fibras de vidrio y kenaf e investigación de sus propiedades mecánicas

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Ansari Faiyaz Ahmed
PhD in Mechanical Engineering Sciences
Institution: University of Technology and Applied Sciences
Address: Salalah, Oman
E-mail: ansari.ansari@utas.edu.om

Zeeshan Ali
PhD in Mechanical Engineering Sciences
Institution: Navodaya Institute of Technology
Address: Raichur, Karnataka, India
E-mail: azeeshan51@gmail.com

Madeva Nagaral
PhD in Mechanical Engineering Sciences
Institution: Aircraft Research and Design Centre, HAL
Address: Bangalore, Karnataka, India
E-mail: madev.nagaral@gmail.com

Samuel Dayanand
PhD in Mechanical Engineering Sciences
Institution: Government Engineering College
Address: Gangavathi, Karnataka, India
E-mail: samueldayanand@gmail.com

Nagaraj Namdev
PhD in Mechanical Engineering Sciences
Institution: Department of Mechanical Engineering, APS Polytechnic
Address: Bangalore, Karnataka, India
E-mail: n.nagaraj.namdev@gmail.com
ABSTRACT
In this research, agriculture residues as reinforcement and filler were utilized for an epoxy-based matrix material. Glass fibre was incorporated in this composite throughout the production process in addition to the kenaf fibre. Rice husk ash filler in the matrix was maintained at 10 wt %, while the kenaf/glass hybrid fibre varied from 0 to 40%. Compression moulding was used to create the hybrid to study its mechanical attributes, which includes tensile strength, flexural strength, and impact strength. The results showed that due to the wettability of the given hybrid matrix, it exhibits superior mechanical characteristics. For 30% hybrid fibre and 10% filler material, the mechanical properties like tensile strength, flexural strength, and impact strength were raised by 41.26%, 14.42%, and 63.15%, respectively.

Keywords: reinforcement, epoxy resin: rice husk, kenaf fibre, glass fibre.

RESUMO
Nesta pesquisa, foram utilizados resíduos agrícolas como reforço e enchimento para um material de matriz à base de epóxi. A fibra de vidro foi incorporada a esse compósito durante todo o processo de produção, além da fibra de kenaf. O enchimento de cinzas de casca de arroz na matriz foi mantido em 10% em peso, enquanto a fibra híbrida de kenaf/vidro variou de 0 a 40%. A moldagem por compressão foi usada para criar o híbrido e estudar seus atributos mecânicos, que incluem resistência à tração, resistência à flexão e resistência ao impacto. Os resultados mostraram que, devido à molhabilidade da matriz híbrida em questão, ela apresenta características mecânicas superiores. Para 30% de fibra híbrida e 10% de material de enchimento, as propriedades mecânicas, como resistência à tração, resistência à flexão e resistência ao impacto, foram aumentadas em 41,26%, 14,42% e 63,15%, respectivamente.

Palavras-chave: reforço, resina epóxi: casca de arroz, fibra de kenaf, fibra de vidro.

RESUMEN
En esta investigación se utilizaron residuos agrícolas como refuerzo y relleno para un material de matriz a base de epoxi. La fibra de vidrio se incorporó a este material compuesto durante todo el proceso de producción, además de la fibra de kenaf. El relleno de ceniza de cáscara de arroz en la matriz se mantuvo en el 10% en peso, mientras que la fibra híbrida de kenaf/vidrio varió del 0 al 40%. Se utilizó el moldeo por compresión para crear el híbrido y estudiar sus atributos mecánicos, que incluyen la resistencia a la tracción, la resistencia a la flexión y la resistencia al impacto. Los resultados mostraron que, debido a la humectabilidad de la matriz híbrida dada, presenta características mecánicas superiores. Para un 30% de fibra híbrida y un 10% de material de relleno, las propiedades mecánicas como la resistencia a la tracción, la resistencia a la flexión y la resistencia al impacto aumentaron en un 41,26%, 14,42% y 63,15%, respectivamente.

Palabras clave: refuerzo, resina epoxi: cáscara de arroz, fibra de kenaf, fibra de vidrio.
1 INTRODUCTION

Trash wastage is one of the major concerns nowadays, which has prompted modern manufacturers and researchers to concentrate on efficient use of wastages in a reproducing way to address environmental challenges [1-2]. Depending on this concept, waste from the agriculture is included into the matrix as filler or reinforcement to create an environmentally acceptable hybrid composite. A composite, in general, is a material that combines two or more components and is composed of a matrix and reinforcement that combines two or more elements [3, 4]. A green material for many purposes without harming the environment might result from matrix change in the hybrid composite form and reinforcement with natural fibre [5].

Since India is primarily an agricultural nation, rice is the plant that is most frequently grown there. India is fourth in the world for rice plantation output. In addition to other agricultural trash, a lot of rice husk is produced and dumped in landfills. Since rice husk is naturally fibrous, its characteristics make it excellent for filler or fibre material [6, 7].

Modern materials with enhanced characteristics are increasingly in demand. This growth has made a significant contribution to the development of new polymer matrix composite materials, allowing for the enhancement of a material's properties for use in a variety of engineering applications, such as composites for automobiles, aircraft, and buildings, biomedical and sporting goods, etc. Researchers' interest in finding superior substitutes for synthetic fibres (such glass, carbon, and aramids) has recently grown due to rising environmental concerns and sustainability demands around the globe. In terms of environmental concerns, these synthetic fibres do have certain drawbacks, but thankfully, nature is always on hand to provide a number of excellent substitute materials. Plants that produce high-quality fibres and are cost-effective without sacrificing mechanical qualities are able to solve these challenges. Natural fibres are being used more often in a variety of industries, including the packaging, aerospace, automotive, and construction sectors [8]. This is partly because they have better qualities than synthetic fibres, such as lower costs, lower densities, cost-effectiveness, higher toughness, and non-toxic, renewable, recyclable, non-abrasive, and biodegradable qualities.

Several researchers have developed the fillers reinforced epoxy composites. The commonly used fillers in the case of metal composites are B₄C [9], graphite [10], SiC [11], TiC [12], Al₂O₃ [13], Graphene [14], Red mud [15], TiO₂ [16], Si₃N₄ [17], ZrO₂ [18], mica
[19], AlB₂ [20] and WC [21]. These particles act as a filler in the case of polymer composites to increase the wear resistance.

The necessity to ensure our condition has made the concept of sustainable materials of utmost relevance. Natural fibres including coconut fibre, bamboo, jute, hemp, and Calotropis gigantea are now finding uses in a variety of industries. The present study aimed to present another regular bio-based basic fibre as one of the natural products and fortification channels in the assembly of a new composite material for lightweight structures. Different basic biological characteristic filaments and their compounds have been the subject of numerous research studies.

For the hybridization of fibre in epoxy composites, a wide range of fibre (both natural and synthetic) were accessible. Due to its minimum cost, no negative environmental effect, and appealing mechanical qualities, kenaf fibre has recently emerged for its usage as reinforcement in polymer composites. Recent studies have demonstrated that kenaf fibre, when mixed with other natural or synthetic fibre had been effectively employed as reinforcing material for polymer matrix composites [22]. Glass fibre, which are made up of incredibly tiny glass fibre, have mechanical characteristics that are similar to those of synthetic and carbon fibre. To use glass fibres as reinforcement in polymer composites, much research was done [23, 24]. The use of rice husk as a filler and kenaf and glass fibre as reinforcement to create an epoxy hybrid composite is explained in this article. In order to close a research gap, this study provides a brief overview of the mechanical and impact characteristics of kenaf/glass hybrid composites. Based on their strength and impact qualities, the goal is to increase the possibility for kenaf/glass hybrid composites to be employed in automotive applications [25, 26]. The chosen ratio optimises the composite's mechanical characteristics. While Kenaf fibres provide excellent specific strength and stiffness, glass fibres are renowned for their great rigidity and tensile strength. A composite with a larger percentage of glass fibres may have better overall strength and stiffness.

2 MATERIALS AND METHODS

2.1 MATERIALS

The two major components of composites are the matrix and the reinforcement. The matrix serves to lessen fracture propagation while also enhancing the composite's mechanical and durability qualities. Epoxy resin (Araldite AW106) was utilized as the
matrix in this project, coupled with a hardener (Araldite HV953U). Since this work focuses on hybrid composites, the filler and reinforcing components employed here come from the agriculture sector. One of the more affordable materials, rice husk, was employed as filler and was purchased from Tamil Nadu, India, local business. Kenaf and glass fibre was bought from vruksha composites located in Andhra Pradesh of India. Figure 1 depicts the photographic images of fibres. Table 1 represents the characteristic of fibres used in experimental investigation. The mixing ratio between resin and hardener is 10.1.

![Figure 1. Photographic images of fibres: (a) Kenaf fibre and (b) Glass fibre](image)

Table 1. Properties of kenaf and glass fibres

<table>
<thead>
<tr>
<th>Details of fibre</th>
<th>Units</th>
<th>Kenaf fibre</th>
<th>Glass fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness</td>
<td>μm</td>
<td>81</td>
<td>150</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>1.45</td>
<td>2.51</td>
</tr>
<tr>
<td>Length</td>
<td>mm</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>MPa</td>
<td>930</td>
<td>2025</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>GPa</td>
<td>20</td>
<td>76</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>8.3</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: from author

2.2 FABRICATION METHOD

Kenaf fibre was submerged in 5% sodium hydroxide solution for 4 hours to eliminate the chemical precipitation. Then, it was repeatedly rinsed with distilled water. The fibres were washed and air dried for a period of 48 hours, later dried in an oven at a temperature of about 70°C for nearly about 2 hours respectively. The chemically treated kenaf fibres were then chopped into 5 mm long pieces. The glass fibres had previously been purchased and were 5 mm long. In a steel mould with a 3 mm thickness, glass and kenaf fibres were equally distributed, and epoxy resin was then applied. Here in this research compression moulding technique had been introduced to make the epoxy-based composite.
at a temperature of about 120°C along with a pressure of nearly 10 MPa. Table 2 represents
the different weight proportions of the components utilized to create hybrid composite.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Epoxy resin + Hardener (%)</th>
<th>Filler (%)</th>
<th>Reinforcement (%)</th>
<th>Total percentage of reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>KG0</td>
<td>90</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>KG10</td>
<td>80</td>
<td>10</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>KG20</td>
<td>70</td>
<td>10</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>KG30</td>
<td>60</td>
<td>10</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>KG40</td>
<td>50</td>
<td>10</td>
<td>8</td>
<td>32</td>
</tr>
</tbody>
</table>

Source: from Author

2.3 TESTING METHODS

2.3.1 Tensile strength

The specimen's tensile strength is determined by testing a dog-bone-shaped sample
with dimensions of 175 x 10 x 3.2 mm that was made in accordance with ASTM D-638
requirements. With a gauge length of 125 mm, however a Universal Testing Machine
(UTM) was used to find the ultimate tensile strength, displacement, break load, and strain
rate for the tensile test specimens [27].

2.3.2 Flexural strength

For the flexural strength of composite test specimens with dimensions of 125 x 12.5
x 3.2 mm and length of span about 75 mm was assessed in accordance with ASTM D 790
by applying a three-point load with a UTM. The specimen's flexural strength was calculated
using the formula, Flexural Strength = 3PL/2bd², where, L = Span's length, P = Applied
force, b = Width of the specimen, d = depth of the specimen.

2.3.3 Impact strength

To find the specimen's impact resistance, an Izod impact test in accordance with
ASTM D256 was performed on a notched specimen measuring size for about 65 x 12.5 x
3.2 mm. When a descending pendulum strikes a specimen, the Izod impact testing apparatus
counts the energy absorbed in J.
3 RESULTS AND DISCUSSION

3.1 TENSILE STRENGTH

Tensile strength tests were conducted on epoxy composite test specimens, and its output were displayed in below Table 3. However, Figure 2 represents the tensile strength for several epoxy-based composite specimens incorporating fibre. This combination of kenaf with the glass fibre has made a major contribution to the specimen's increased tensile strength. The maximum tensile stress from the experiment had been evaluated for given composite material. Table 3 compares the tensile strength of epoxy-based composites made with various proportion of kenaf and glass fibres. Tensile strength of epoxy-based composite material for 10%, 20%, 30%, and 40% fibres rose by 7.94%, 20.63%, 33.33%, and 41.26%, respectively, compared to the epoxy resin specimen with only 10% filler, which had a tensile strength of 63 MPa. In comparison to composites with different fibre percentages, the 40% hybrid composite has a higher tensile strength (Figure 2).

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Epoxy resin + Hardener + filler (%)</th>
<th>Reinforcement (%)</th>
<th>Tensile Strength MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>KG0</td>
<td>100</td>
<td>-</td>
<td>63</td>
</tr>
<tr>
<td>KG10</td>
<td>90</td>
<td>2</td>
<td>68</td>
</tr>
<tr>
<td>KG20</td>
<td>80</td>
<td>4</td>
<td>76</td>
</tr>
<tr>
<td>KG30</td>
<td>70</td>
<td>6</td>
<td>84</td>
</tr>
<tr>
<td>KG40</td>
<td>60</td>
<td>8</td>
<td>89</td>
</tr>
</tbody>
</table>

Source: from Author

Figure 2. Effect of reinforcement on tensile strength for hybrid composite

Source: from Author
3.2 FLEXURAL STRENGTH

Table 4 shows the flexural strength of epoxy-based composite reinforced with varying quantities of hybrid fibres. Flexural strength of epoxy-based composite material for 10%, 20%, 30%, and 40% fibres rose by 3.73%, 7.46%, 10.7%, and 14.42%, respectively, compared to the epoxy resin specimen with only 10% filler, which had a flexural strength of 40.2 MPa. In this case, similar to tensile strength, 40% hybrid fibre (8% kenaf fibre + 32% glass fibre) exhibits the greatest percentage gain in flexural strength (Figure 3).

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Epoxy resin + Hardener + filler (%)</th>
<th>Reinforcement (%)</th>
<th>Flexural strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KG0</td>
<td>100</td>
<td>-</td>
<td>40.2</td>
</tr>
<tr>
<td>KG10</td>
<td>90</td>
<td>2</td>
<td>41.7</td>
</tr>
<tr>
<td>KG20</td>
<td>80</td>
<td>4</td>
<td>43.2</td>
</tr>
<tr>
<td>KG30</td>
<td>70</td>
<td>6</td>
<td>44.5</td>
</tr>
<tr>
<td>KG40</td>
<td>60</td>
<td>8</td>
<td>46</td>
</tr>
</tbody>
</table>

Source: from Author

Figure 3. Effect of reinforcement on flexural strength for hybrid composite

3.3 IMPACT STRENGTH

As shown in Table 5, an epoxy composite sample's impact strength grows as the proportion of hybrid fibres does, too. Impact strength of epoxy-based composite material for 10%, 20%, 30%, and 40% fibres rose by 13.15 %, 36.84 %, 52.63%, and 63.15%, respectively. Epoxy composites are becoming more impact resistant to a 40% hybrid fibre content. However, the composite with sample of 40% hybrid reinforced fibre indicates 63.15 % increase in strength as compared to the sample KG0 (Figure 4).
4 CONCLUSION

In order to create a hybrid composite reinforced with kenaf and glass fibre for the investigation of its mechanical characteristics like tensile strength, flexural strength, and impact strength, rice husk with natural hybrid fibres such kenaf fibre and glass fibre were employed as reinforcement to the epoxy-based resin. The analysis of the report using the experimental findings leads to the following conclusions.

- for all hybrid reinforcement percentages, the filler material proportion of rice husk (10%) was maintained;
- for all hybrid reinforcement percentages, the mechanical characteristics displayed an upward trend;
- for flexural strength, the value of flexural strength is 46 Mpa. The increase in strength of the specimen is restricted due to the presence of strong adhesion between the fibers and the matrix which does not allow the penetration due to load into the composite specimen. For tensile strength, the value of maximum stress is 89 Mpa. For impact, the maximum amount of energy absorbed is recorded as 5.9 J. This is due to the presence of kenaf and glass fibre which resist the force to
minimum, thereby reduce the damage of the composite specimen. The load on the specimen is restricted due to the presence of strong adhesion between the fibers and the matrix which does not allow the penetration due to load into the composite specimen. Hence, due to high value of impact, hardness and tensile properties, this hybrid composite can be implemented in various engineering applications where high impact is in demand;

- the mixture KG40, which contains 32% glass fibre and 8% kenaf fibre, has exhibited the greatest percentage gain in all strengths. Based on this, 8% kenaf fibre and 32% glass fibre may be assumed to be the ideal hybrid fibre inclusion percentage for epoxy composites.
REFERENCES


