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Characterizations of Hybrid Composites of Linen /Glass Fibers for Automotive and Transportation Applications

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ABSTRACT

Recently, the sustainability issue has become crucial to operation, which motivates researchers to search for naturally generated, sustainable materials, especially in automotive applications outside of reduced prices and enhanced performance. Glass-linen/Polyvinyl Butyral hybrid composites' mechanical characteristics were examined in relation to the effect of linen fiber loading. The composite and hybrid composite samples of linen/glass fiber reinforced PVB film were created using a hot press with various layering patterns. The results were high impact values with increased both tensile and flexural strength values. Compared to other hybrid composites, the mechanical behaviors of the H1 (Glass / Linen) hybrid have a greater tensile strength measuring 401.30 MPa, while, H2 (Glass / Linen/ Glass) hybrids are found to have the highest flexural strength, measuring 160.80 MPa. An optical and scanning electron microscope morphological analysis on linen hybrid composites revealed good results. This indicated decreased rates of delamination between the fibers and matrix layers. The loading of the fibers was shown to have varying effects on the composite's mechanical behaviors. The linen/glass composites also demonstrated strong interfacial adhesion, which enabled the PVB-phenolic resin to penetrate the fiber bundles and produce a matrix with the good interlocking of the fibers.

1. Introduction

Owing to the sustainability concept and environmental issues, and the need to discover environmentally friendly alternatives, especially, for automotive and transportation applications, the production of new materials should rapidly address environmental and economic issues [1, 2]. Starting in 2015, all new automobiles must be 85% recyclable and reusable by weight; according to European Union legislation on end-of-life vehicles, in terms of performance and potential rivalry on the global market [3]. As an alternative to materials like steel and aluminum, composite materials have enormous potential to reduce weight by a sizable percentage while improving performance [4,5]. As

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a result, these new materials should be biodegradable and produced naturally [6, 7]. A natural fiber composite combines fibers produced from plants with a plastic binder. In automotive industries, natural fibers are now viewed as a serious substitute for synthetic fibers. Regarding ultimate disposalability and improved raw material usage, the use of natural fibers as reinforcing materials in thermoplastic and thermosetting matrix composites benefits the environment [8]. Natural fibers are increasingly being considered for use in polymeric-based composites as reinforcement because of their renewable source, relatively high specific strength and modulus, light weight, and affordable price [9]. Recent advancements in natural fibers like jute, sisal, coir, flax, banana, etc. have demonstrated that it is possible to create materials with high performance utilizing reinforcement that is favorable to the environment [10].

Numerous studies conducted on individual fibers have ultimately produced beneficial outcomes for a range of applications. For body parts, such as the underfloor protection trim on the Mercedes A class, which is made of a composite material reinforced with banana fibers, banana fibers have been used in the automotive industry [11].

The utilization of more homogenous color, strength, length, and fineness to lower fiber production costs is one of the new technologies and separation processes that make linen more appropriate for composites. Many countries' environmental law demands the use of recyclable or biodegradable components [12].

Linen is a promising bio-fiber option to take the place of glass fiber. Up to 1500 MPa of tensile strength for its fibers has been recorded. The failure mechanism is a complex sequence consisting of axial splitting of the technical fiber along its elementary constituents, radial cracking of the elementary fibres, and multiple fractures of the elementary fibres, according to Wang's investigation [13] of tensile fracture and failure behavior. The woven linen fabric's ability to manage fiber orientation and quality control, as well as its high repeatability and productivity, is credited with the successful construction [14]. It is proven that the linen fabric-reinforced polymer composites have tensile stresses and strains at the failure of 300 MPa and 1.8%, respectively [15]. This places them on the same level as glass fiber-reinforced polymer composites [16]. It is possible to conclude that fiber volume fraction, not fiber microstructure, primarily determines toughness [17, 18].

Polyvinyl Butyral (PVB) film was used as the matrix material in the composite structures generated in this study, and two distinct fabrics, reinforcement materials linen and glass fiber, were preferred. The products were made using a hot press technique. It was investigated whether these structures' utilization in the automotive industry is more advantageous for our ecosystem by examining their mechanical and microscopic-macroscopic characteristics.

2. Experimental Details

2.1 Materials

Two kinds of woven fabrics were utilized: linen and glass fibres reinforced with PVB film as a binder, were supplied by ZKK Sdn Bhd. Malaysia. Physical /mechanical properties of linen fibers are given in Tables 1 and 2 illustrate the mechanical and physical properties of PVB (technical sheet). Between the fiber layers, PVB thin film layers were utilized. A new thin film layer matrix fabrication technique has recently been created using a straightforward and affordable method [19]. PVB interlayers that are ductile and robust are typically employed for applications that require strong bonding, many surface adhesions, stiffness, and flexibility. Due to its low cost, durability, ease of production, and good chemical- mechanical, and chemical properties, PVB is a common interlayer in the architectural and automotive industries [5].

Table 1. Chemical, mechanical and physical properties of fibres (technical sheet).

Material	Linen fibres

Density (g/cm3)	1.5
Tensile strength (MPa)	500 - 1500
Young's modulus (GPa)	27.6
Elongation at break (%)	2.7 - 3.2
Cellulose content (%)	58 - 60
Hemicellulose content (%)	16
Lignin content (%)	2.5

Table 2. Mechanical and physical properties of PVB (technical sheet).

Materials	PVB film
Thickness (mm)	0.38
Areal density (g/m2)	410
Density (g/cm3)	1.078
Average breaking strength (MPa)	20
Average maximum strain (%)	200

2.2 Hybrid Composites Panel Preparation

As shown in Figure 1, a laminated hybrid with various content of linen fibers and glass fibers that reinforced PVB was created using the hot press. Linen fibers were dried inside the oven at 105 oC to remove the moisture and then stored in a dry container. Fabricated at dimensions of (300×300 mm), linen-glass/ PVB composites were used to examine how the loading of fibers affected mechanical behavior.

By changing the weight content % of the fibers, laminated composites with different layering patterns of fibers were fabricated. Sheets of linen, glass fibers, and PVB layers were cut to size (300×300 mm) and then stacked in various configurations. To keep the sample from sticking and to provide a smooth sample surface, the mold release agent has been sprayed prior to any molding operation. The two plates of compression mold were centered on the stack of varied laminates (stainless steel made). As a consequence, plates were sealed and heated for 20 minutes at 165 °C under 5 MPa of compression. The compression pressure was set at 5 MPa when the plate temperature reached 165 °C and remained there for fifteen minutes. When the temperature was lowered to laboratory temperature (25 °C), the pressure was kept constant at 5 MPa. Once the plate temperature reached 25 °C, the constructed laminates were taken out from the compression mold.

Figure 1. Hybrid composite samples preparation.

Table 3. Laminated composites designation.

Specimens descriptions	Abbreviation	Specimens thickness (mm)	Weight percentage (wt %)*	
			Glass	Linen
Glass/Linen	H1	2.3	50	50
Glass/Linen/Glass	H2	2.8	70	30
Linen/Glass/Linen	H3	3.8	30	70

* The total fibres weight (wf) was kept at 40% ± 2.

2.3 Testing of Composites

In accordance with ASTM D3039-76 [20], the tensile tests were conducted using an Instron Universal Testing Machine at a cross speed of 2 mm/min until tensile failure was noted.

Each laminated sequence arrangement had five test samples replicated. Following ASTM D7264 [21], the flexural strengths were conducted using an Instron Universal Testing Machine at a cross speed of 2 mm/min until flexural failure was noted. Each laminated sequence arrangement had five test samples replicated. According to ASTM D256 [22], the three-point bending test was carried out using an Impact Pendulum Tester (Ceast Model 9050) on rectangular specimens with a 2 mm notch. Striking energy of 0.5 J hammer was used for the Izod method. Each laminated sequence arrangement had five test samples replicated.

2.4 Morphological Analysis of Hybrid Composites

The morphologies of the samples, which were mounted on aluminum studs and coated with gold in a vacuum before being viewed using an SEM, were clarified by scanning electron microscope (SEM) photographs.

3. Rrsults and Discussion

3.1 Tensile Properties

The bar graph of the tensile strength measured for each composite type is shown in Figure 2. The fiber properties affect how the hybrid composites are characterized. In this chart, five specimens with various linen fiber glass-linen fibers weight content are used to illustrate how linen fiber loading affects the tensile properties of composite materials. The H1 hybrids are found to have a maximum tensile strength of 401.30 MPa, followed by the H3 hybrids and the H2 hybrids at 383.73 MPa and 352.80 MPa, respectively. According to the results provided, compared to other hybrid composites, the mechanical behaviors of the H2 hybrid have a greater tensile strength. The findings were in agreement with those of Cicala et al. [23] who investigated the characteristics and performance of different glass/natural fiber composites for use in curved pipes. In their investigation on flax/glass fabric-reinforced epoxy composites, Assarar et al. [24] noticed a similar pattern. Ductile fracture with linear behavior up to fracture was experienced by all tensile specimens. Due to the usage of the PVB-phenolic as a matrix, the present hybrid results, however, demonstrated higher tensile properties than those of the earlier studies.

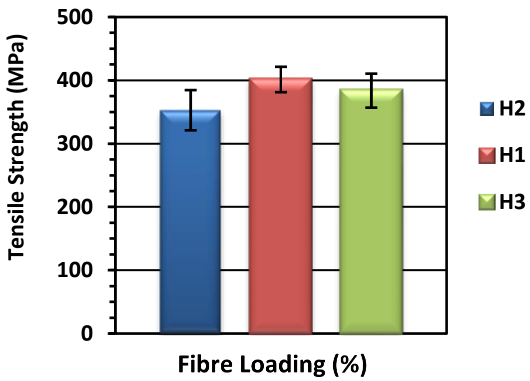

Figure 2. Hybrid composites tensile strength based glass-linen fibers weight content (%).

3.2 Flexural Test

The bar chart of the flexural strength measured for configurations on an average of five specimens is shown in Figure 3. The fiber properties affect how the hybrid composites are characterized. In this figure, five specimens with various linen fiber loadings (%) are used to illustrate how linen fiber loading affects the flexural properties of composites. The H2 hybrids are found to have the highest flexural strength, measuring 160.80 MPa, followed by the H1 hybrids and the H3 hybrids, measuring 144.10 MPa and 130.08 MPa, respectively. For glass-linen (H1) samples, the flexure tests were done while the linen layer was at the upper side and the glass layer was at the lower side. This research confirms the findings of Vinod B., et al. [25] and Dicker et al. [26]. The increase in flexural strength of the H2 hybrid composites is explained by variations in the load distribution properties across configuration sequences, in contrast to the tensile trend. Because the flexural effect may result in an interlocking structure that places restrictions on how far the linen fibers can extend in each direction. In addition, it is well known that the composition, degree of adhesion, and interfacial bonding of the polymers all affect the flexural properties of composites. This is consistent with Sezgin et al.'s findings [27] who discovered comparable patterns in juts's plant fibers. Additionally, the H1 samples were found to have somewhat greater flexure strength than the H3 samples, despite the fact that there was not a significant difference between the flexure strength values of H2 and H3 hybrid composites. When the components are subjected to bending stress conditions, the results produced from these tested composite parts describe the mechanical performance of the gap fractions and the sliding behavior.

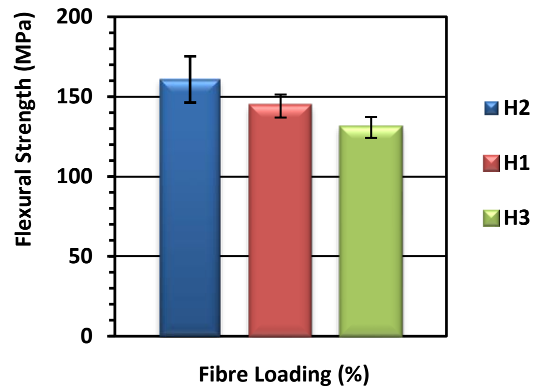

Figure 3. Hybrid composites flexural strength based glass-linen fibers weight content (%).

3.3 Impact Test

The ability of a material to withstand fracture at short period of loading is known as impact strength. The interfacial bond strength, matrix, and fiber characteristics have a significant effect on how an impact behaves in a composite. The energy from the impact load damage process is dispersed through matrix fracture, fiber pull-out, and fiber fracture. Figure 4 displays a bar graph of the impact strength measured on an average of five specimens for different hybridizations of glass-linen fibers. The fiber properties affect how the hybrid composites are characterized. This figure illustrates how glass-linen affects the impact characteristics of hybrid composites using five samples with varying linen fiber contents (%). The H3 hybrid composites, with an impact strength of 3566 J/m, are found to have the highest impact strength, followed by the H2 hybrid composites and the H1 hybrid composites, with impact strengths of 2807 J/m and 2508 J/m. For glass-linen (H1) samples, the impact tests were done while the linen layer was at the front of the striker. According to Dicker et al. [26], stacking sequence plays a larger role in toughness than composition, and different lay-ups maximize different toughness parameters like total energy, initiation energy, or propagation energy. Additionally, the H2 samples were found to have somewhat greater flexure strength than the H1 samples, despite the fact that there was not a significant difference between the impact resistance values of H1 and H2 hybrid composites. When the components are subjected to sudden impact conditions, the results produced from these tested composite parts describe the mechanical performance of the gap fractions and the sliding behavior.

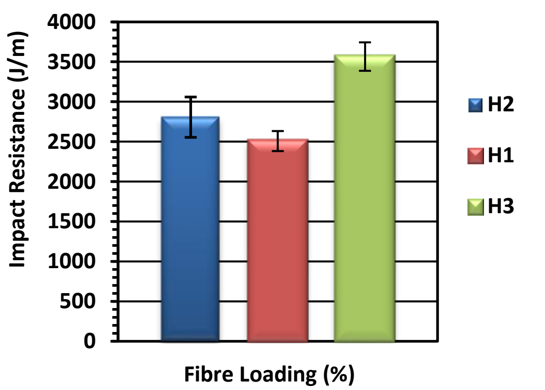

Figure 4. Hybrid composites impact strength glass-linen fibers weight content (%).

3.4 Morphological Characterization

As illustrated in Figures 5, 6, and 7, scanning electron microscopy (SEM) analysis was utilized to determine the mode of failure mechanism that occurred on the tensile, flexural, and impact composite specimens. The composite laminates exhibited a variety of failure modes, including glass fiber fracture and linen fiber pullout. Additionally, cracks had started and spread to the point that the specimen failed. Additionally, fibers incur deformation (become curled) prior to the fracture and fail as a result.

In general, it is possible to observe clear fiber degradation, breakage, and debonding of some of the linen fibers, which shows that the linen fibers have a strong interfacial adhesion with the PVB resin. According to Kumar et al. [28], failure by delamination will be more difficult when the fibers are mixed more closely because it takes more energy to create new surfaces in a rich mixing than it does to generate delamination in a layered hybrid. Additionally, Figure 6 depicts a dense region of PVB resin that was present both inside and outside the bundle of linen fibers. This suggests that some fibers have strong matrix adhesion. As demonstrated in Figure 7, the amount of incorporation between the fibers and resin was enhanced as a result of the high degree of resin penetration, which decreased the defragmentation of linen fiber from PVB resin. Transverse and longitudinal fissures are the first signs of hybrid degradation (at the failure surface) before delamination between the laminated layers leads to catastrophic collapse. Other studies [29, 30] have documented failure processes for kenaf-glass hybrid reinforced composites that are similar to these. The hot press technique greatly reduced the composites' voids.

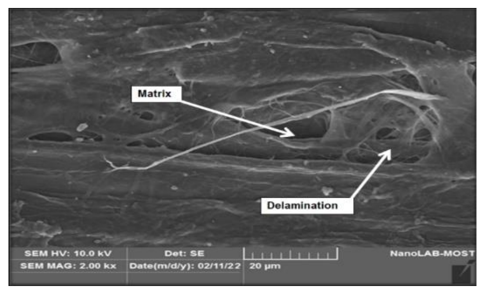

Figure 5. H1 Specimen after tensile test.

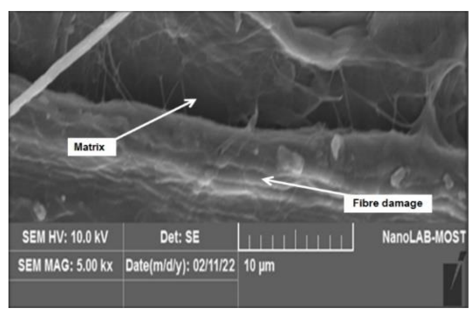

Figure 6. H2 Specimen after flexural test.

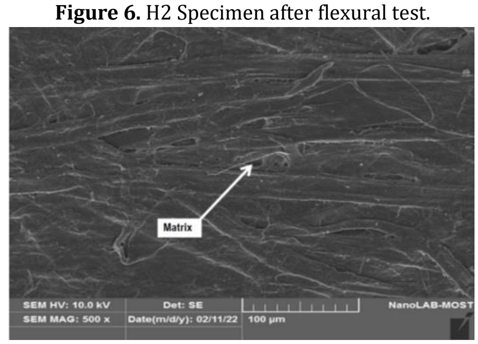

Figure 7. H3 Specimen after impact test.

4. Conclusion

According to the experiments, the tensile and flexural properties indicated that as the fibers loading was increased, the strength increased. Enhanced linen fiber loading results in increased impact strength but will also add a ductility factor to hybrid composites' impact performance. The linen/glass fibers composite material reinforced PVB resin, to investigate the tensile, flexural, impact, and failure surface properties. Compared to other hybrid composites, the mechanical behaviors of the H1 (Glass / Linen) hybrid have a greater tensile strength measuring 401.30 MPa, while, H2 (Glass / Linen/ Glass) hybrids are found to have the highest flexural strength, measuring 160.80 MPa. The loading of the fibers was shown to have varying effects on the composite's mechanical behaviors. An increment in the impact strength of the linen-glass/PVB (H3) composite was observed compared to the H1 hybrid composites. The linen/glass composites also demonstrated strong interfacial adhesion, which enabled the PVB resin to penetrate the fiber bundles and produce a matrix with the good interlocking of the fibers. Due to the influence of the sandwich structure, higher tensile performance was achieved in comparison to compression properties for all laminated hybrids. The hybrids of linen are lightweight, economical, and environmentally friendly materials with a good balance of mechanical properties. According to the results, the hybrid of linen, glass, and polyvinyl butyral exhibit acceptable mechanical characteristics that make it suitable for use in various industrial fields.

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