Flexural properties of hybrid synthetic/Napier fibres reinforced epoxy composites

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Abstract. This paper present the flexural properties of hybrid synthetic/Napier fibres reinforced epoxy composites. The synthetic materials used were carbon and glass fibres. The composites were fabricated using the vacuum infusion method. Napier grass and synthetic fibres were used as reinforcement materials would be mixed with the epoxy resin. The samples were differed by volume fractions. The flexural tests has been conducted using a universal testing machine according with ASTM standard D790. The flexural strength and modulus of the hybrid synthetic/Napier fibre reinforced epoxy composites increased as the content of the synthetic fibre content increased. The flexural properties of the hybrid carbon/Napier reinforced epoxy composites were observed higher than the hybrid glass/Napier reinforced epoxy composites.

Introduction

Hybrid composite is a fabricated material where it is a combination of common matrix with two different type of fibres. Thus, it also have more extensive scope of potential application to be compared with other composite reinforcement. As resulted in previous researched, the hybrid composites which contained 5% sodium hydroxide with Napier grass fibre exhibited great stiffness and flexural strength which lower percentages of void contents of the composite [1]. The properties of the hybrid composites are dependent on the fibre content, fibre orientation, and fibre length, bonding between the matrix and fibre, and the arrangement of the fibres within the laminates. Previous studies on natural-synthetic fibre hybrid composites have primarily focused on reducing the use of synthetic fibres [2–4]. The study has described the potential advantages associated with natural-synthetic fibre hybridisation [5]. The goal of this composite where there is an adequate viewpoint proportion which is providing reinforcement function at least in one directions. Regular substance used to fabricate the composite is using the epoxy resin which have great flexural properties of material [6]. Recently, we have examined the potential use of Napier fibre in polymer composites [7–9]. Therefore, in this work, we have compared the flexural properties of hybrid carbon/Napier fibres reinforced epoxy composites and hybrid glass/Napier fibres reinforced epoxy composites.
Materials and Method

1.1. Extraction of Napier Grass Fibre

Initially, the stems are cleaned and crushed with a mallet before immersed under tap water for approximately three to four weeks, for separation and decomposition process as shown in Figure 1(a). The fibres are then manually extracted from the stem internodes as illustrates in Figure 1(b) up to the removing the excessive cellulose from the fibre in Figure 1(e). Next, the fibres were cleaned with a distilled water and sun-dried for a couple of days to remove the excess moisture as shown in Figure 1(f). Meanwhile, the fibres extracted are measured within 170-200 mm in length. Finally, the extracted raw fibres are sun-dried for a few days to remove excess moisture and the fibres are further dried in an oven at 55°C about 10 minutes before for the vacuum infusion specimen preparation.

![Figure 1. Extraction process.](https://example.com/figure1)

1.2. Hybrid Composite Fabrication

The composites are the combining of Napier fibre and synthetic fibre which being prepared as a sandwich structure in dimensions of 320 x 300 x 0.1 mm per layer, thus fabricated using the vacuum infusion method [10]. There are two types of structural composite which are laminar composite and sandwich panel [11], where the special part of making this composite material in this experiment is the arrangement of the composite laminate which is clearly known as sandwich composite. Where some of the middle layers of the laminate are replaced by a very lightweight core material or fibre, typically being foam, or natural fibre which is low in density, such as Napier grass fibre, which is prepared and sorted unidirectional direction and formed as a mat or ply in Figure 2. In addition, sandwich panel is also a kind of layered composite which consist of two faces at the outer sheets and one core at the middle of the two faces. Figure 1 shows the schematic structure for the sandwich panels of the structural composites. Besides, sandwich composites are very attractive
because of the mechanical properties of the structures, which are very lightweight with a very high bending stiffness thus usually have great impact and fatigue resistance.

![Schematic sandwich structure of hybrid carbon/Napier epoxy composites.](image)

**Figure 2.** The schematic sandwich structure of hybrid carbon/Napier epoxy composites.

1.3. Flexural Test

Three point flexural tests are conducted on the composite specimens, according to ASTM D790 standards using a universal micro tester (INSTRON 5848), with a load cell of 2kN. Thus, the span length to depth ratio is set as 16:1. The specimens are machined to dimensions of 125 x 13 x (3.2 ± 0.4) mm$^3$ and being tested at a crosshead speed of 2.5 mm/min. Five specimens are utilized for each of the sample, thus result for flexural strength and modulus were recorded for analysis.

**Result**

1.4. Flexural Strength

Ability of the composites to withstand a bending load and deformation before it reached the breaking point can be described from the flexural strength. The flexural strength of hybrid carbon/Napier epoxy composites and hybrid glass/Napier epoxy composites are presented in Figure 1. The flexural strength of the Napier fibres reinforced epoxy composites (S0) increased from 47.31 to 186.68 MPa with an addition of carbon fibre at 6% of volume fraction (S1). The flexural strength of the hybrid carbon/Napier epoxy composites increased as the volume content of the synthetic fibre increased. Thus resulting the flexural strength by 229, 301 and 456 MPa for S2, S3, and S4 samples, respectively. This strength degradation was measured and represented equivalent strength reduction when comparing the results of both hybrid composites for each sample, whereas yielding increment by 212, 211, 200, and 265% for S1, S2, S3 and S4 samples, respectively. Therefore, the level of degradation reduces as the content of synthetic fibres increased, thus yielding a greater strength of hybrid composites.
Figure 3. Tensile strength of hybrid synthetic/Napier reinforced epoxy composites

1.5. Flexural Modulus

Figure 3 shows the flexural modulus of Napier fibres reinforced epoxy composites (So) increased from 2.5 to 6.8 GPa with a content of 6% volume fraction of glass (S1), thus yielding an increment about 28% from 6.8 to 8.7 GPa with 6% content of carbon fibre for S1 sample. As the carbon fibre content increased, the flexural modulus of the hybrid carbon/Napier epoxy composites steadily increased to 14.75, 18.65 and 25.76 GPa for S2, S3, and S4 samples, respectively. The increment of the flexural modulus clearly shows that the hybridization of hybrid carbon/Napier epoxy composites was stronger and more rigid, in comparison with hybrid glass/Napier epoxy composites, thus yielding a better flexural performance. The flexural properties of the composites were greatly influenced by the stiffness of both synthetic and natural fibres. Thus, the flexural modulus of hybrid glass/Napier epoxy composites for S1 sample was 6.77 GPa, representing a reduction of over 22%. Furthermore, the strength reduction for S2, S3 and S4 samples were measured by 41, 34, and 49%, respectively.
Conclusion
The flexural properties of hybrid carbon/Napier epoxy composites achieved an excellent hybridization compared to hybrid glass/Napier epoxy composites. The higher content of carbon and glass fibres in the reinforcement of the hybrid composites increased the strength and modulus of the hybrid composites. A good interfacial bonding between the adhesions of the fibre with the matrix, resulted a higher strength and modulus of the hybrid composites.

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