Flexural Strength of Hybrid Mendong – C-glass/Epoxy Thermoseting Composites

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Abstract. Hybrid composite materials are those composites which have a combination of two or more reinforcement fibre in order to better mechanical properties. This paper concerns with development of hybrid composite materials using mendong and C-glass as the reinforcement and epoxy bakellite EPR 174 resin as the matrix, using hand lamination process. The mendong fibre was treated with alkali (NaOH). Hybrid mendong – C-glass/epoxy composite specimens were arranged to make a unidirectional (0°), bidirectional (0°/90°) and bidirectional (± 45°) fibre orientations with a 50% v/v fibre fraction content. The specimens were then tested using flexural tests, and the results were analyzed using two parameters Weibull distribution. The result shows that the flexural strength of hybrid mendong – C-glass/epoxy composites with a unidirectional (0°) is higher than other fiber orientations.

Keywords: hybrid, mendong – C-glass, Weibull, flexural

1. Introduction
Indonesia is a country with the potential for abundant natural fibers, the types of natural fibers such as pineapple, banana, ramie, coconut, bamboo, water hyacinth, and mendong. The advantages of natural fiber composites is a material that can be recycled, more environmentally friendly, potentially abundant, less costly than synthetic fibers and green composites [1].

The usage of natural fibres can be found widely in a variety of industries, such as in automotive, aerospace, building, plastic and textile. One of the noticeable applications of natural fibres is to replace synthetic fibres or man-made fibres as reinforcement in the composites production. There has also been an increasing interest in the use of polymer fibre composites reinforced natural fibres. Polymer composites have widely been less environmental impact compare to synthetic fibres [2].

Mendong fiber is a cultivated plant that have good economic potential, but during the use of the fibre itself only as a floor mat, strap, as well as handicraft products. Due to the potential of the mendong fibre is so large in Indonesia, the researchers attempt to improve the role of mendong not only as a traditional product, but can be used as raw material of natural fibre composites.

The main disadvantages is the poor compatibility between hydrophobic polymer matrix and the hydrophilic fibres. This leads to the formation of weak interfaces, which result in poor mechanical properties of the composites [3]. Alkali treatment of natural fibres is one of most common treatments
of the natural fibres [4] that increased the interfacial bonding between the fibre and the matrix.

In recent years, the natural fibre composites have received a full attention in many applications, natural fibers are satisfying both economic and ecological interest [5]. The use of natural fibre mendong as reinforcement in composites is to increase the use of natural fibres which is abundant in Indonesia become a hybrid composite that is by incorporate glass fibres. Hybridization with glass fibre provides a method to improve the mechanical properties of natural fibre composites and its effect in different modes of stress depends on the design and construction of the composites [6].

The development of composite materials improving their performance limits based on the reinforcement of two or more fibres (synthetic fibre with another synthetic fibre or synthetic fibre with natural fibre or synthetic fibre with metallic fibres) in a single polymeric matrix, which leads to the advanced material system called hybrid composites with a great diversity of material properties, is still in its infancy [7].

The purpose of the present research is to develop a flexural strength of hybrid mendong – C-glass/epoxy thermosetting composites which consist of mendong and C-glass fibres as a reinforcement and epoxy bakellite EPR 174 as a matrix. Some previous studies have been conducted to determine the flexural strength of glass fibre and graphite fibre composites for (0°/90°) and (0°/45°) fibre orientation [8] and glass/epoxy composites for (0°/90°) and (± 45°) fibre orientation [9]. In this research, the fibre orientations, such as unidirectional (0°), bidirectional (0°/90°), and bidirectional (± 45°), were selected to make the hybrid composite laminates.

The fibre volume fraction used was 50%. Such considerations are based on [10] [11], where the failure mode occurring in ramie/epoxy composites is brittle failure for 10-30% fiber volume fraction, debonding and delamination at 40-50% fiber volume fraction. In the present study, two parameters Weibull distribution was used to analyze the test results [12] [13] [14] which is in the form of Eq.1:

\[ F(x; b, c) = 1 - \exp\left(-\left(\frac{x}{b}\right)^c\right), b > 0, c > 0 \] (1)

\( F(x; b, c) \) represents the probability that the fracture strength is equal to or less than \( x \). Using the equality \( F(x; b, c) + R(x; b, c) = 1 \), the reliability \( R(x; b, c) \) is given by Eq.2:

\[ R(x; b, c) = \exp\left(-\left(\frac{x}{b}\right)^c\right), b > 0, c > 0 \] (2)

Several methods have been used to estimate the two parameters \( b \) and \( c \). In this study, a linear regression method was chosen for practical purposes. Hence, a linear regression model in the form of \( Y = mX + r \) is obtained as in Eq.3:

\[ \ln\left[\ln\left(\frac{1}{1-F(x; b, c)}\right)\right] = c\ln(x) - c\ln(b) \] (3)

Since \( F(x; b, c) \) is unknown in Eq.3, therefore, it is estimated from observed values: order \( n \) observations from smallest to largest, and let \( x_{(i)} \) denote the smallest observation (\( i = 1 \) correspond to the smallest and \( i = n \) corresponds to the largest). Then a good estimator of \( F(x; b, c) \) is the median rank of \( x_{(i)} \) as in Eq.4:

\[ F(x_{(i)}; b, c) = \frac{i-0.3}{(n+0.4)} \] (4)

By using Eq.3 and Eq.4 and based on least square minimization of linear regression, both parameters \( b \) and \( c \) can be estimated. Then, by using Eq.2, the reliability curve can be drawn.

2. Materials and Methods
The fibers are used in this research is C-glass and mendong and the type of matrix is epoxy bakellite EPR 174. Mendong fiber was soaked in alkali solution containing NaOH concentrations of 5% for 2 hours at ambient temperature [15], then dried under the sun for 6 hours. The composite specimen consists of number of layers in which mendong fibre layers and C-glass fibre layers are placed alternatively by adding the required amount of epoxy bakellite EPR 174 resin until we obtain required thickness.
The processing method was using a hand lay up with the optimum fiber volume fraction is 50%. The fibers was arranged as such that in the end it will produce a unidirectional $0^\circ$, bidirectional $(0^\circ/90^\circ)$, and $\pm45^\circ$. The flexural tests were carried out according to ASTM D-7264 using universal testing machine Tensilon with a maximum capacity of 10,000 N.

Figure. 1 and 2 shows a mendong fibre that has been arranged and the hybrid mendong–C-glass/epoxy thermosetting composites lamination results respectively then the composite was formed into a flexural test specimen.

3. Results and Discussion
The final specimen test results and typical stress-strain curves for unidirectional $(0^\circ)$, bidirectional $(0^\circ/90^\circ)$, and $\pm45^\circ$ fibre orientation specimens for flexural tests respectively are given in Figure 3, 4, 5 and Figure 6, 7, 8.
Figure 7. Stress-strain bidirectional (0°/90°).

Figure 8. Stress-strain bidirectional (±45°).

The example of final reliability distribution shows in Figure 9 for linear regression of unidirectional 0° hybrid mendong–C-glass/epoxy thermosetting composite specimens. Whereas Figure 10, 11 and 12 shows the reliability curve for unidirectional (0°), bidirectional (0°/90°), and bidirectional (±45°) composite specimens.

Figure 9. Linear regression of unidirectional (0°).

Figure 10. Reliability curve unidirectional (0°).
Figure 11. Reliability curve bidirectional (0°/90°).

Figure 12. Reliability curve bidirectional (±45°).

Figure 10, 11 and 12 shows the reliability of fracture of the specimens, it means that the probability of the specimens to fail is 50% in a particular stress level. In this research, the reliability chosen is 50%. Table 1. shows the comparison the flexural strength of hybrid mendong–C-glass/epoxy and mendong/epoxy thermosetting composites [16] for 50% reliability level.

Table 1. Comparison the flexural strength of hybrid mendong – C-glass/epoxy and mendong/epoxy thermosetting composites.

| Fibre orientation | Flexural strength hybrid mendong- C-glass/epoxy (MPa) | Flexural strength mendong/ epoxy (MPa) |
|-------------------|--------------------------------------------------------|---------------------------------------|
| Unidirectional (0°) | 263                                                    | 123 [16]                              |
| Bidirectional (0°/90°) | 91                                                     | -                                     |
| Bidirectional (±45°) | 62                                                     | -                                     |

Based on the table shows of both fibre orientations and flexural strength and its improvement of bidirectional (±45°), bidirectional (0°/90°), unidirectional (0°) and 62, 91, 263 MPa. The increase of flexural strength was caused by fibre orientations. It shows that the hybrid mendong – C-glass/epoxy thermosetting composites with unidirectional (0°) having higher flexural strengths when compared to bidirectional (0°/90°) and bidirectional ±45° fibre orientations. These result related to the ability of fiber to withstand againsts affective loads where reinforcement fibre is working to rise of most those loads, this ability decreases with increasing of fibre orientation angle at (0°/90°) and (±45°).

Whereas based on the results of the literature study shows that mendong/epoxy thermosetting composites having low flexural strengths when compared to hybrid mendong – C-glass/epoxy thermosetting composites with unidirectional 0° fibre orientations. Therefore, it can be concluded that with the addition a C-glass fiber and thus the flexural strength of the composite was increased.

It is important also to compare the results of the current study with similar flexural strengths of natural hybrid natural-glass fiber composites available in the literature. Table 2. shows such a comparison.
Table 2. Comparison the flexural strength with other hybrid natural-glass fiber composite systems.

| Composites                       | Flexural strength (MPa) |
|----------------------------------|-------------------------|
| Glass EC 2400 P207-Ramie/polyester | 105 [17]                |
| UCEFLEX UC 5530 -M               |                         |
| E-Glass - Jute/epoxy LY556       | 11 [18]                 |
| Glass-Palmyra/epoxy              | 59 [19]                 |

It shows that the mechanical properties found in the present study are able to compete with other hybrid natural and glass fiber composites. Therefore, it can be concluded that hybrid mendong – C-glass/epoxy has a good potential to be developed further for wide application, whether in the furniture industries as well as in the building structure equipment.

4. Conclusion
The present study concludes that hybrid mendong – C-glass/epoxy have a better mechanical properties compared with mendong/epoxy and hybrid natural-glass fiber composite systems. So by adding a C-glass fiber and thus the flexural strength of the composite was increased. Furthermore, the flexural test of composites gives best results at unidirectional 0° fibre orientations. Despite the simple manufacturing processes, the specimens produce good qualities with moderate flexural strengths. Therefore, mendong – C-glass/epoxy has a good potential to be developed further, for wider application in the furniture industries and building structure equipment.

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