The Characterization of the Sandwich Composite Consisted of Coconut Fibre-Polyester Resin and its Variations of Wood Core

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ABSTRACT

The traditional fishing vessels in Indonesia are usually made of wood material. The weakness of this vessel material is that it is easily weathered when exposed to seawater. For this reason, it is necessary to have vessel material engineering from composite sandwiches. This study aimed to prepare and investigate the flexural test, impact test, optical microscopy (OM), and scanning electron microscopy (SEM) observations of sandwich composites based on coconut fibre-polyester resin and wood core. The fabrication uses a hand lay-up method with a constant volume fraction (20% coconut coir fibre) and wood core variations type. The primary wood variations used are albizia chinensis, mahogany, shorea, and camphor. The Surface modification of fibre and wood core was conditioned without treatment and with treatment with about 5% NaOH solution for 2 hours. The study showed that the highest bending and impact strength was sandwich composite with camphor wood cores with alkali treatment for 39.75 MPa and 37.22 J/cm^2, respectively. The OM observations showed that the core and skin interface area failed to delaminate after flexural and impact tests. SEM observations also showed that

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the bond alkalization treatment between the matrix and the fibres was quite good. In the composite skin fracture area, there is a lot of fibre brake, and a little thread pulls out. The skin matrix also shows the presence of voids. Generally, this sandwich composite is feasible for application as a material for traditional fishing vessels.

Keywords: *Sandwich Composites; Flexural Tests; Impact Tests; Coconut Fibre; Wood Core*

Introduction

Traditional fishing vessels in Indonesia are usually made of wood. This wooden vessel material is easily weathered when exposed to seawater. For this reason, it is necessary to engineer the material for waterproof fishing vessels and ensure the performance is engaging. Sandwich composites are one of the most potential ship material engineering to be developed. Sandwich composites consist of two thin skins, strong and stiff shells with a thick and light core material stacked sequentially as skin-core-shell [1]. Two layers of face sheet skin to withstand tension and compression stress, and the core material mainly bears shear emphasis [2]. Sandwich materials are often used in engineering applications because of the advantages of high bending rigidity, low structural weight and good environmental resistance [3]-[4].

Most industries try to use natural fibres as reinforcement for the manufacture of composites. The choice of natural fibres as a composite reinforcement material is because natural fibres are strong, competitive and environmentally friendly compared to synthetic fibres [5]. Types of natural fibres can be classified into several plant categories: kenaf, jute, bamboo, banana and bagasse. Fibre materials from seeds such as kapok, cotton, and coconut fibre. Fibre materials from leaves such as abaca, pineapple, and sisal. The fibre also can be obtained from grass/reeds such as wheat, rice, and corn. These natural fibre materials have been widely studied as composite reinforcement materials [6]-[7]. Natural fibre has three essential parts such as cellulose, hemicellulose and lignin. Of the three parts, cellulose is a component that affects the properties of the composite [8].

The main problem in developing natural fibre-reinforced composites is the hydrophilicity of the fibres. Hydrophilicity causes the adhesion ability to decrease and ultimately affects the mechanical properties of the composite [9]-[10]. The alkalization treatment is the most effective because it can remove wax content and impurities from the fibre surface, resulting in a rough and hydrophobic surface [11]-[12]. Alkali treatment will increase the cellulose content and remove fibre constituent components that are less effective in determining interfacial strength, namely hemicellulose, lignin or pectin [13]. Reduction of the constituents will increase the surface roughness resulting in better mechanical interlocking. The influence of alkalis can increase tensile and flexural strength due to better interfacial bonds between the fibre and the matrix [14]-[15]. Chemical treatment increases the adhesion ability of natural fibres with the polymer matrix and improves the mechanical properties of the composites [16].

Several synthetic polymer matrices have been studied in composites such as polyester resins [17]-[20], melamine-urea-formaldehyde [21], polypropylene [22], polyethylene [23] and other synthetic polymers. Synthetic polymers are excellent composite-forming materials because they bind the reinforcement well. Synthetic polymers are potential matrix material candidates as fishing vessel composite materials because they have excellent water resistance [24]. However, combining composite sandwiches with a polyester resin matrix reinforced with natural fibres has not been explored more deeply, especially in the determination of wood species. This research is a breakthrough because of its advantages, such as good mechanical properties, lower production costs and environmental friendliness.

In this study, researchers studied the characteristics of flexural strength, impact strength, and fracture morphology of sandwich composites composed of wood core and coco fibre -polyester resin as the face skins. The mechanical properties data obtained will later be used as initial information on fishing vessel materials. This research is instrumental in designing traditional fishing vessels in Indonesia.

Materials and Methods

Materials

The polyester resin used in this study was unsaturated polyester resin with the trademark Yukalac 157 BQTN-EX produced by PT. Justus Sakti Raya, Indonesia (specific gravity 1.21 g/cm^2; flexural strength 9.4 kg/mm^2; flexural modulus 300 kg/mm^2; young modulus 1.18 GPa; water absorption at 25 ^{o}C 0.188-0.466%). The coconut fibre (density 1.1-1.5 g/cm^3), shorea wood, albizia chinensis wood, mahogany wood and camphor wood were obtained from CV Tiga Sehati, Jember, Indonesia (Google Maps Coordinate: -8.167767164206186, 113.70906795282784). The specifications for each type of fibre are shown in Table 1. Sodium hydroxide (NaOH 99%) and MEKPO catalyst (purity 45%; molar mass 210.23; density 1.17 g/cm^3) (technical grade) were purchased from UD Aneka Kimia, Jember, Indonesia.

Preparation of wood core and coir fibre

The wood as the core of the sandwich composite was shaved and smoothed with a thickness of 1 cm respectively. The wood and coconut coir fibre were washed and cleaned with water, then dried under the sun for 5-7 days. The alkalization process was done by soaking coconut coir fibre and wood in 5%

NaOH solution for 2 hours at room temperature. After that, the coconut coir fibre and wood were washed with distilled water until neutral pH. Then, it was dried under the sun for 3-5 days and continued in a drying oven for 24 hours at 60 °C.

Table 1: Chemical composition of several kinds of wood

No	Type of Woods	Chemical Compositions (%)			
		Cellulose	Hemicellulose	Lignin	Others
1	Shorea wood	44	28	23	4.5
2	Albizia chinensis	42	23	18	16
3	Mahogany wood	38	27	29	5
4	Camphor wood	52	19	26	3

Manufacturing of sandwich composite

The manufacturing of composite sandwiches was the hand lay-up method. The sandwich composite manufacturing process places a 10 mm thick core wood board into the mould, then coats it with a top composite skin with a thickness of 4 mm. Coconut fibre was arranged in a longitudinal direction with a volume fraction of 20%. The resin matrix was mixed with the hardener (1%), stirred until evenly distributed, and poured into coconut fibre with a volume fraction of 80%. After that, rolling was done on the skin's surface, followed by pressing. This process was carried out at room temperature. After drying, the specimens were disassembled from the mould and made the bottom skin. The making of bottom skin by reversing the bottom position, and it was placed on top and then put into the mould. The following process was the same as making the upper skin.

Flexural test

The flexural test used the Universal Testing Machine Hung Ta 2328 TM 113 (30 kN). The test was carried out according to ASTM C 393 standards. The test was carried out at room temperature for all specimens. In each variation, the test was carried out five repetitions. Then, the five data were averaged.

Impact test

The impact test was carried out using a Charpy 300 J impact testing machine. The test was carried out according to ASTM D5942 standards. The test was carried out at room temperature for all specimens and repeated five times for each variation.

Optical microscope observations

The microstructure observation of sandwich composites using an optical microscope model Olympus BX 41M. The observation was made with a magnification of 100x and 500x. The fracture surface was cut to 20 x 18 mm and then observed.

Scanning Electron Microscope (SEM) observations

The fracture surface observation of sandwich composite using a Scanning Electron Microscopy (SEM) model of the Phillips XL 30 with a voltage of 10 kV. The observations were made under vacuum with a secondary electron signal for the imaging process with a magnification of 100x. The fracture surface was cut into 5 x 10 mm and observed.

Results and Discussions

Mechanical properties

Regarding mechanical properties, composite sandwich materials are influenced by core and skin materials (matrix and reinforcement). In addition, it is also influenced by the bond between the core and the skin composite and the matrix bond with the reinforcement in the skin. Figure 1 shows the flexural properties of sandwich composites with variations of core wood, without alkalization treatment and alkalization treatment 5% NaOH on core wood and coco fibre.

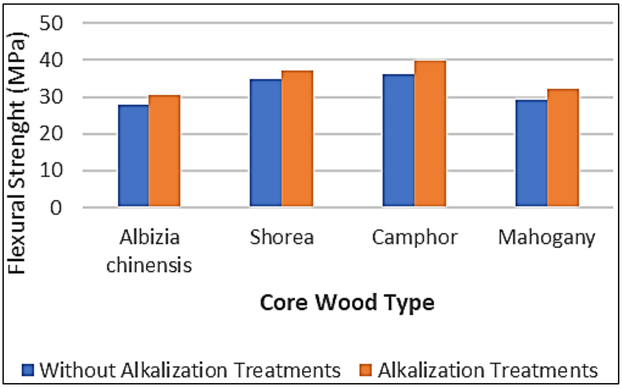


Figure 1: Flexural strength properties of all samples tested

From the flexural test data shown in Figure 1. the highest flexural strength value was obtained for the sandwich composite on camphor core wood with alkalization treatment with a value of 39.75 MPa. The lowest flexural strength was obtained from sandwich composites on albizia chinensis core wood, without alkalization treatment for 27.75 MPa. The properties of camphor wood are strong and ductile, while albizia chinensis wood is less strong and brittle. This phenomenon shows that the core wood significantly impacts the flexural strength of sandwich composites. In the presence of 5% NaOH alkalization treatment for 2 hours on core wood and coco fibre reinforcement, the sandwich composite experienced a significant increase in flexural strength. The average increase in flexural strength was between 6.9% to 10.5%. This result proves that the alkalization treatment makes the interfacial bond between coco fibre and core wood with resin stronger [14]-[16], [24].

Impact strength properties

Figure 2 shows the impact strength properties of sandwich composites with variations of core wood, without alkali treatment and 5% NaOH alkalization treatment on core wood and coconut fibre. From the impact test data shown in Figure 2, the highest impact strength value was obtained for the sandwich composite on camphor core wood with alkalization treatment for 37.22 J/cm^2. The lowest impact strength was obtained from sandwich composites on albizia chinensis core wood without alkalization treatment for 27.47 J/cm^2.

The results of this study show that camphor wood is strong and ductile compared to albizia chinensis wood, which is more brittle. The mechanical properties of the core wood have a very significant impact on the impact strength of the sandwich composite. In the presence of 5% NaOH alkalization treatment for 2 hours on core wood and coco fibre reinforcement, the sandwich composite experienced increased impact strength.

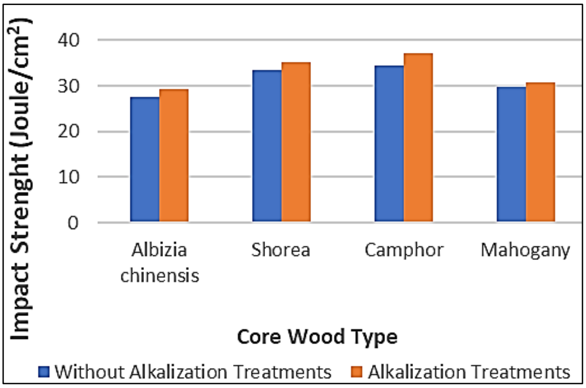
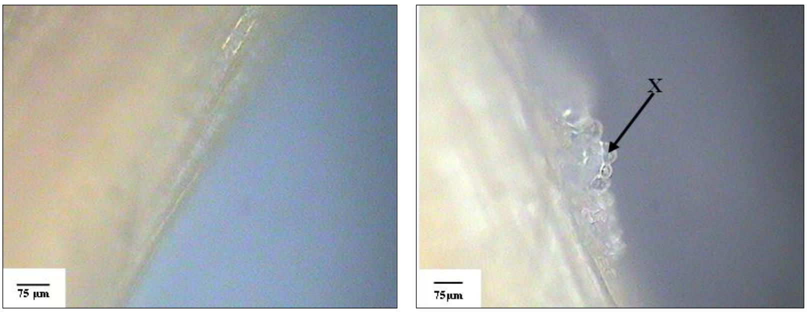


Figure 2: Impact strength properties of all samples tested

On average, there was an increase in impact strength between 3.7% to 8.4%. Fibre can distribute the stress generated evenly. The orientation of the fibre direction in this study is the longitudinal direction perpendicular to the direction of the pendulum beating so that it can withstand the shear stress when the impact test pendulum is impacted [25].

Microstructure of sandwich composite

Figure 3 shows microscopy observations on the surface of coco fibre with and without alkalization treatment. Figure 3(a) shows the surface of the coco fibre clean from the dirt after alkalization (5% NaOH).



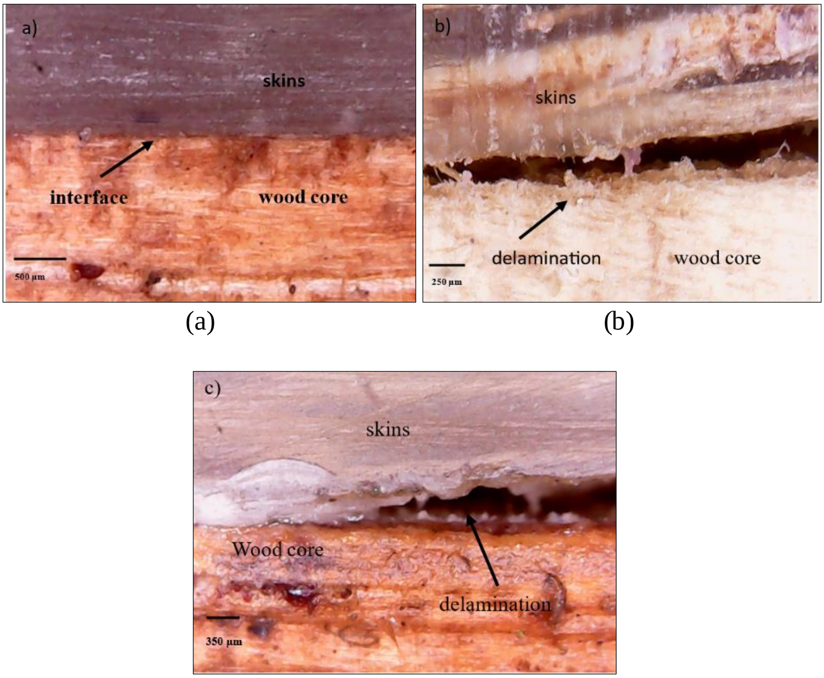
(a) (b)

Figure 3: Micro photo of coco fibre; (a) with alkalization treatment (5% NaOH), and (b) without alkalization treatment

A clean surface and good drying will make the fibre ductile and not brittle, facilitating bonding between the fibre and the matrix [14]-[16]. Figure 3(b) shows the surface of coco fibre without alkalization treatment. The figure shows that the coco fibre's surface has a lot of dirt, which inhibits the bond between the fibre and the matrix. The increase in flexural and impact strength of sandwich composites with alkalization treatment is due to the loss of impurities attached to the fibres, which become coarse [11]-[12].

Figure 4 shows the results of microscopy observations of the sandwich composite at the core wood interface with the skin. Figure 4(a) shows the interface between the core wood and the skin, which are well bonded before the mechanical test is carried out. Figure 4(b) shows the interface between the core and skin after flexural testing, and Figure 4(c) after impact testing. From the figure, it can be seen that delamination has occurred in the skin and core interface. Bending or impact loads cause buckling in sandwich composites [1], [26].

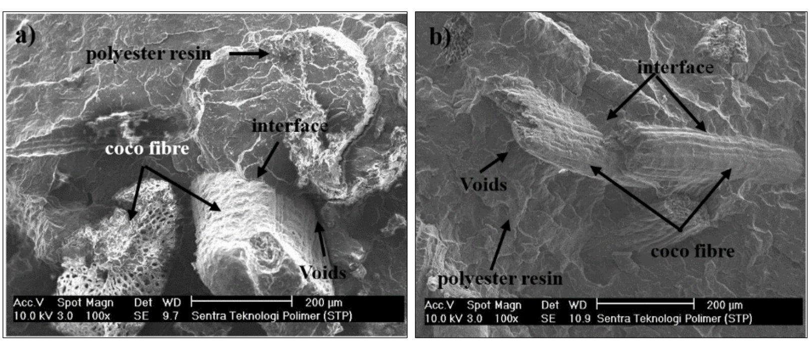
The lower skin experiences a compressive force, while the lower skin experiences a tensile strength. The skin interface with the core cannot withstand the load perfectly due to the shifting movement of the core, resulting in delamination [27]. This case indicates that the skin and core bonds that occur are not strong enough to withstand bending or impact loads.



(a) (b)

(c)

Figure 4: Micro photo of the interface of the core wood and skin of sandwich composite; (a) before the mechanical test, (b) after the flexural test, and (c) after the impact test



(a) (b)

Figure 5: Fracture morphology of composite sandwich skin; (a) after flexural test, and (b) after impact test

Figure 5 shows the results of SEM observations on the fracture surface of the sandwich composite skin after mechanical testing. Figures (5a) and (5b) show the fracture morphology of the sandwich composite skin after flexural and impact tests. It can be seen that the morphology of coco fibre is rather rough and most of the matrix can bind the fibre perfectly. This phenomenon proves that the matrix effectively transfers stress to the fibre due to the excellent bond between the polyester resin matrix and the fibre. Previous researchers also reported that the alkalization treatment of the fibre produced a rough surface and good bonding interactions at the interface [12], [14]-[15].

In the sandwich composite skin fracture, there are many occurrences of brake fibres. This fibre brake can increase the flexural and impact strength of the sandwich composite due to the slight shifts between the matrix and the fibres [16]. Due to bending or impact loads, cracks will move from the polyester resin matrix through the interface to the coco fibre. If the bond at the interface is strong, then the stress that occurs is directly transmitted to the coconut fibre. This phenomenon causes fibre break [28].

In the area of the sandwich composite, skin fracture also shows a slight occurrence of pull-out fibres. The process of the fibres pulling out can reduce the flexural and impact strength of the sandwich composite due to the emergence of shear stress between the matrix and the fibres. Fibres pull-out occurs because the debonding stress of the fibre-matrix is less than the breaking stress of the fibre, so the debonding process occurs first, followed by a break in the fibre resulting in fibres pull-out [28]-[29].

Several points on the surface of the matrix indicate the presence of voids. This phenomenon is due to the poor mixing of polyester resin with coco fibre in the fabrication process. These voids occur because of air trapped in the matrix and interface. The effect of nasty gaps is the poor bonding interaction between the matrix and the fibres and also reduces the strength of the matrix [13].

Conclusion

The sandwich composite with wood core and skin from polyester resin – coconut fibre is successfully produced by hand lay-up method at room temperature. The 5% NaOH alkalization treatment increased the flexural strength and impact strength. The type of core wood in the sandwich composite significantly affects the flexural strength and impact strength. The highest flexural and impact strength was found in the sandwich composite with a camphor wood core of 39.75 MPa and 37.22 J/cm^2. Fracture morphology at the interface between the core and the skins indicates delamination. The morphology of the fracture on the skin shows a rough surface on the fibre, lots of fibre breaks and little fibre pull out. This result shows a good bond between matrix and fibre. This sandwich composite may be suitable for application as a material for traditional fishing vessels.

Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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Conflict of Interests

All authors declare that they have no conflicts of interest

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