Study on Mechanical Properties of Pandan Duri (Pandanus Tectorius) Fiber-Reinforced Biocomposites Materials for Aerospace Application

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Abstract. Composite materials are essential in the automotive and aerospace industries due to their abiity to reduce weight and offer cost competitiveness. Fiber-reinforced polymer (FRP) nanocomposites are particularly well-suited for these applications. In this study, we explore the potential of pandanus tectorius, a promising natural fiber, as a discontinuous fiber reinforcement material in polyester composites. Four different content of fiber levels - 0, 5, 10 and 15% - are examined to assess their impact on mechanical properties. The composites are fabricated using the hand-lay technique, which is recognized as a cost-effective method for production. Our findings reveal that the mechanical properties of the compsites, particularly those with 0% and 5% fiber content, demonstrate significant strength, with measured values of 68.4 MPa and 62.1 MPa, respectively. This study highlights the potential of Pandanus tectorius fiber as a viable alternative to synthetic fibers, emphasizing its role in enhancing the mechanical characteristics of biocomposites for aerospace applications.

Keywords: Pandanus tectorius fiber, Biocomposites, Mechanical property, Natural fiber.

1 Introduction

Natural fiber reinforced polymer composites have gained significant popularity in recent years[1][2], particularly within the automotive and aerospace industries[3][4], due to their inherent versatility and sustainable qualities. These composites offer a combination of desirable properties, including low density, biodegradability, non-toxicity, environmental friendliness, cost-effectiveness, and acceptable mechanical characteristics[5]. A variety of plant-based fibers are available worldwide, many of which have been explored for their potential in creating eco-friendly composites[6]. Among these, the distinctive advantages of lignocellulosic natural fibers position them as viable alternatives to conventional synthetic fibers, including glass, Kevlar, and carbon fiber[7]. Consequently, there is a growing trend in the utilization of lignocellulosic natural fibers across various industries[8].

While glass fiber remains the predominant choice for reinforcement in polymer-based composites, it presents significant disposal challenges due to its non-biodegradable nature. In contrast, natural fibers, despite their many benefits, have limitations, including brittleness[9], sensitivity to low processing temperatures[10], and moisture absorption[11]. Various natural fibers, such as jute, bamboo, coir, and coir, have been examined for their mechanical properties and potential applications[12]. One notable fiber source is Pandanus tectorius, a species of pandanus (commonly reffered to as screw pine) native to Indonesia[13], Malaysia[14], eastern Australia and Pacific Islands[15]. This plant thrives in coastal lowlands, typically near the ocean's edge and has emerged as a valuable fiber source for composites and various industrial applications. This plant species is abundantly found in tropical regions, especially in Yogyakarta, Indonesia[16][17]. The plant is characterized by its long green leaves adorned with thorns along the edges and large brown stems. Its prop roots, extending into the ground, contribute to the overall fiber content and thickness of the plant.

This study aims to address the growing interest in natural fiber reinforced polymer nanocomposites by focusing on the extraction of fibers from pandanus tectorius. While existing research has examined the mechanical properties of pandanus tectorius-based reinforced composites[18][19], it is acknowledged that relying on a single composited materials may not suffice for the diverse requirements of

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composite applications. Therefore, this research employs polyester resin as the matrix material, incorporating screw pine fiber as the reinforcement with varying fiber content of 0, 5, 10, and 15 wt.%. the objective is to explore the feasibility and mechanical performance of these novel composites in various applications.

2 Materials and Characteristic

2.1 Materials Process

Polymer matrix nanocomposites consist of a polymer matrix (resin) combined with a dispersed fibrous reinforcement phase. In this study, polyester resin is selected as the matrix material, while pandanus tectorius fiber is employed as the reinforcement material. The fiber is used at varying weight percentages of 0, 5, 10, and 15 wt.%, each with a length of 200 mm. for fiber extraction, fully grown prop roots are chosen due to their superior fiber quality. The extraction process involves cutting the prop roots from the shrub and slicing them into thin sheets with a thickness of approximately 4-5 mm. to ensure the appropriate formulation of the composite, the quantities of fiber and polyester resin are calculated based on the weight of the mold used for composite production. The weight fraction and density of the components are determined using the specified equation, which takes into account the total weight of the constituents to maintain the desired fiber content in the final composite materials.

$$\rho_{c}=\frac{1}{\left(\frac{m_f}{\rho_f}\right)+\left(\frac{m_m}{\rho_m}\right)} \tag{1}$$

2.2 Characterization

Polyester resin is YUKALAC 157 BQTN-EX, and catalyst MEKPO (Methyl Ethyl Ketone Peroxide). Bending strength was determined according to ISO 178-1993 standard on an UN-7001-LC50 Standard by ASTM D790-03 at ITD Adisutjipto lab, the specimen for bending test as seen in Fig 1. Scanning Electron Microscope (SEM) of the composite of Pandanus tectorius treated with 10% NaOH was analyzed by a scanning electron microscope JCM-7000 (JEOL-Japan) at University Gadjah Mada lab, with an acceleration voltage of 5 kV and 15 kV.

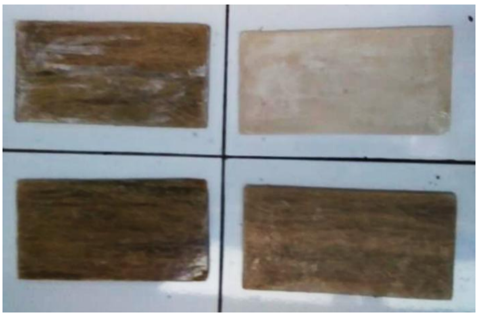

Fig. 1. Bending strength specimen 120 x 15 x 5 mm (ASTM D790-03)

3 Result and Discussion

3.1 Pandan Tectorius Based-fiber

The fabricated Pandanus tectorius plant and based-fiber images are presented in Fig 2. Natural fiber composite materials have lower physical and mechanical properties than glass fiber and carbon fiber composites, namely, tensile strength, flexural strength, impact strength, and stiffness. The main reason is that natural fibers have many other impurities and especially hygroscopic properties. this statement related with another author[20]. Therefore, it affects the adhesion between the fiber and the plastic. the quality of the fiber-resin interaction surface plays an important role in the use of natural fibers as reinforcing fibers for composites. Therefore, physical and chemical methods have been used to solve this problem, thereby improving the properties of the composite or overcoming the phenomenon of sub-standard reduction in strength. The stress transfer at the interface between the two fiber–resin phases is determined by the degree of adhesion, which is essential for effective stress transfer and load distribution on the system across the interface phase split. In order to have good mechanical properties of this composite material, the improvement of the interaction on the phase division surface becomes the main concern of content fiber application studies. One of the simple, effective and, economical methods is to use common chemicals such as NaOH to extract with hand layout method at the same time pretreat[21].

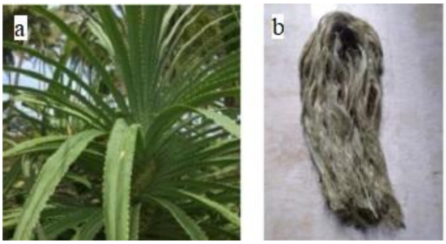

Fig. 2. Photograph (a) pandanus tectorius plant, and (b) prop roots and extracted fiber

3.2 Physical

Based on the research findings, it has been determined that the density of pandan tectorius fiber is 0.96[22][23], whereas the density of glass fiber (fiberglass) is 1.4 g/cm^3[24]. Therefore, we can deduce that the density of pandanus tectorius fiber is less than that of fiber as seen in Fig 3.

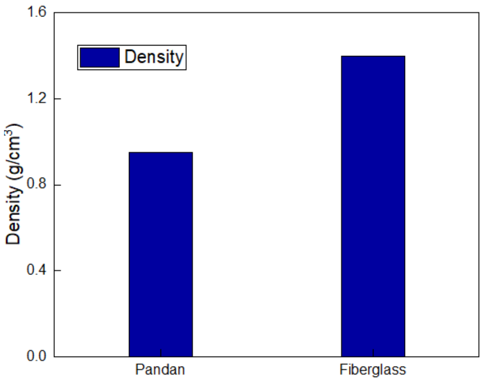

Fig. 3. Comparison of density between Pandan tectorius based-fiber and fiberglass

3.3 Mechanical Properties

The study investigates and discusses the mechanical properties of a polyester composite reinforced with pandanus tectorius at four different weight percentage: 0, 5, 10, and 15 wt.%. To conduct the bending tests, samples were machined according to the ASTM D790-03 dimensional standards, specifically using an I-section specimen measuring 120 x 15 x 5 mm. The mechanical properties were determined through a 3-point bending test. Table 1 presents the bending strength values for different pandanus tectorius based-fiber content.

Table 1. Bending strength value composite with varian content of wt.% pandan tectorius based-fiber

No.	Content of fiber	Max. weight	Pressure	σL
Sample 1	0 wt.%	18.873 kgf	180.05 N	68.39 MPa
Sample 2	5 wt.%	20.432 kgf	200.23 N	62.06 MPa
Sample 3	10 wt.%	17.825 kgf	174.68 N	51.05 MPa
Sample 4	15 wt.%	16.345 kgf	160.18 N	48.19 MPa

Fig. 4 exhibits the variation of bending strength for the pandanus tectorius reinforced polyester nanocomposite materials. The bending strength values gradually decreases with increasing fiber content by 5 wt.%. Specifically, for 0 wt.% and 5 wt.% specimens, respectively. The bending strength value is nearly the same, with a decrease 68.39 MPa to 62.06 MPa, respectively, there is gap about 6.33 MPa (9.2%). Meanwhile, the bending strength consistently decreases by 25.3% and 29.5% for other fiber contents, respectively. Among the various fiber contents, the 5 wt.% pandanus tectorius fiber demonstrates better performance. The mechanical properties can achieve by an optimal fiber length, NaOH treatment during fiber preparation, and formalin process.

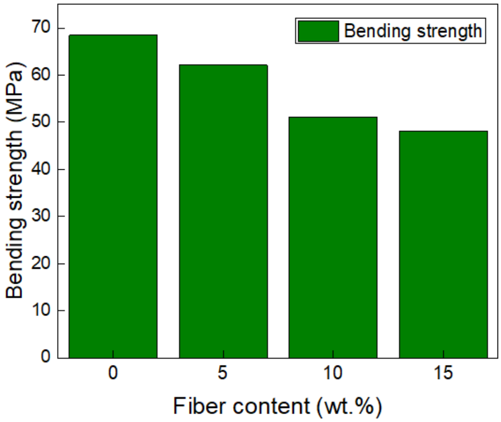

Fig. 4. Bending strength of fiber with different content of 0, 5, 10, and 15 wt.%.

Fig. 5 and 6 display the scanning electron microscope (SEM) images of composites with fiber contents of 5 wt.% and 10 wt.%, respectively. The SEM images reveal a dense and pore-free matrix surface that appears smooth. However, voids can be observed surrounding the fibers, along with a small pore and a large hole. Notably, the composite with a 10 wt.% fiber content exhibits a higher number of voids. The presence of these voids within the fibers contributes to surface roughness, which, in turn, reduces the bending strength and fails to improve the interfacial adhesion between the fiber and matrix in the polymer composite. N. Sgriccia et. al.[25] demonstrated that Natural fiber composites absorb more water than glass fiber composites. When natural fibers undergo alkali treatment, the lignin and hemicellulose present on their surface are removed. However, among the natural fiber composites, those treated with silane, particularly kenaf, exhibited a higher flexural modulus than the rest.

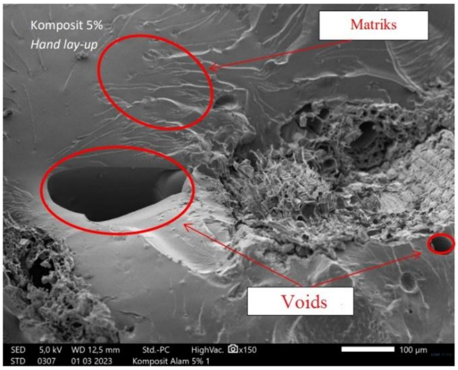

Fig. 5. SEM image of composite with content of fiber 5 wt.%.

The relationship between changes in mechanical properties and different fracture surface modes can provide valuable insights. Illustrates the composition of fractured surfaces in composites. The results reveal that crack bridging, matrix toughening, and fiber breakage contribute to decreasing the mechanical strength and to specific wear rate in hybrid composites. However, insufficient fiber bonding and a weak interface bond may hinder the hybrid effect from reaching its full potential.

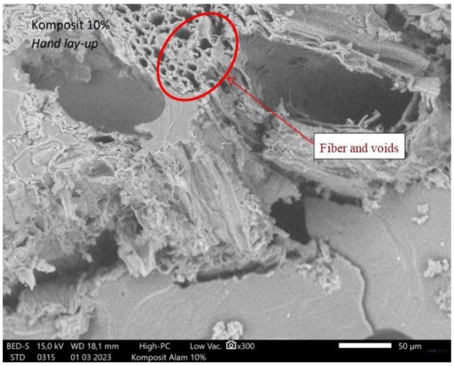

Fig. 6. SEM image of composite with content of fiber 10 wt.%.

Edi syafri et. al[26] demonstrated that Cellulose, the primary constituent of natural fibers, exhibits varying quantities depending on the plant type and its treatment. Nevertheless, through chemical treatment, it undergoes decomposition into cellulose fibrils with a diameter ranging from approximately 2 µm to 20 µm. After undergoing acid hydrolysis treatment, the chemical composition revealed a notable 90.5% increase in cellulose content, accompanied by an 89.6% reduction in hemicellulose. Furthermore, X-ray analysis (XRD) indicated a rise in crystallinity from 39.5% in the raw fibers to 67.7% following hydrolysis. Utilizing cellulose derived from Pandanus tectorius fiber as a reinforcement in biocomposites presents an environmentally sustainable alternative to synthetic fibers. Hussein Alrobei[27] explained that Screw pine fiber, an increasingly advanced and highly promising natural fiber, is utilized in the form of discontinuous fibers to reinforce materials. The study examined three different volumetric proportions (3 mm, 6 mm, and 9 mm) of screw pine-reinforced polyester composite. The mechanical properties were analyzed for fiber loadings of 10%, 20%, 30%, and 40% using various fiber lengths (3 mm, 6 mm, and 9 mm). Among these, the composite with a nanofiber content of 30% and a fiber length of 9 mm exhibited the highest impact strength, flexural strength, tensile strength, and robust elasticity module.

In this study, it was observed through experimentation that the bending strength of pandanus tectorius fiber reinforced polyester composites decreases as the fiber content increases. However, it was also found that modifying the experimental method can enhance the overall mechanical properties.

4 Conclusion

The study conducted a mechanical assessment of polyester composites that were strengthened with Pandanus tectorius fiber, considering various weight percentages of the fiber. It was observed that natural fiber reinforced polymer composites possess a lower density compared to fiberglass. The mechanical properties of nanocomposite materials demonstrated a bending strength of 9.2 MPa, which is lower than fiberglass. This suggests that by incorporating NaOH, formalin treatment (chemical), adjusting length of fiber and weight of percentage in the polyester matrix, the mechanical properties can be improved.

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