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Arenga Pinnata Fiber Reinforced Composite: A Review On Characteristics And Mechanical Properties

Nanang Endriatno [1]

[1] *Halu Oleo University*

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CORRESPONDENCE

E-mail: nanang.endriatno@uho.ac.id

A B S T R A C T

Natural fibers as composite reinforcement have been widely used because they are eco-friendly and sustainable. Arenga pinnata (AP), or Sugar palm tree, is cultivated in tropical regions and is thought to hold promise as a source of natural fibers. The potential use of fibers derived from the Arenga pinnata in a number of applications has been studied, especially as composite materials. This review focuses on the emerging use of Arenga Pinnata Fiber (APF) in several applications. A detailed discussion of its properties was highlighted. Aside from that, this paper also discusses the several treatments that have usually been applied to the Arenga Pinnata Fiber Reinforced Composites (APFRC) and their mechanical properties. APFRC is a material that possesses notable mechanical properties, is cost-effective, biodegradable, renewable, has a low density, has a high cellulose content, has long durability, and is also resistant to seawater. The performance of composite materials is primarily determined by their constituent elements and manufacturing techniques. Modifying the orientation of fibers also has a direct influence on the tensile strength, compression resistance, and elastic modulus of composites. Furthermore, it is expected that it will have the capability to produce APFRC, serving as a promising substitute for traditional polymers in diverse applications, particularly in engineering fields like automotive, marine, medical industries, and sports, serving as substitutes for materials derived from petroleum. Thus, it is anticipated to have the ability to make a significant contribution towards achieving sustainable development goals.

INTRODUCTION

Composites have been identified as the most promising and discerning material of the current century. Currently, there is a growing need in the market for lightweight materials with high strength for specific purposes, which is why composites reinforced with fibers of synthetic or natural materials are becoming increasingly important. The fiber-reinforced polymer composite provides a high strength-to-weight ratio or low weight, high strength, high stiffness, and enhanced durability, damping, flexural strength, and resistance to corrosion, wear, impact, and fire. The extensive array of unique characteristics has resulted in the utilization of composite materials in various sectors such as mechanical, construction, aerospace, car, biomedical, marine, and numerous other industrial industries. The performance of composite materials is primarily determined by their constituent elements and manufacturing techniques [1], [2].

The growing global apprehension about the environment and recognition of renewable green resources is consistently driving the need for eco-friendly, sustainable, and biodegradable natural fiber reinforced composites (NFRC). Due to their exceptional physicochemical and mechanical qualities, natural fibers currently hold a significant position in the composite sector. Natural fibers possess the qualities of being capable of decomposing naturally, compatible with living organisms, environmentally beneficial, and derived from replenishable sources. Consequently, they are widely

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employed as substitutes for costly and finite synthetic fibers, such as glass fiber, carbon fiber, and aramid fiber, in numerous applications. Moreover, the NFRC find use in several sectors such as automotive, aerospace, personal protective equipment, sports, and medical industries, serving as substitutes for materials derived from petroleum. In recent decades, several studies have been conducted on natural fiber reinforced composites to tackle the issues related to reinforcement fibers, polymer matrix materials, and composite production procedures. Despite its advantages, natural fiber reinforced composites (NFRC) nevertheless have significant limitations. These include inadequate bonding between the fiber and the polymer matrix, as well as suboptimal mechanical qualities resulting from the hydrophilic characteristics of the natural fibers. A current comprehensive evaluation enhances comprehension of the behavior of the composites as well as the constituent materials [3].

In the past ten years, significant endeavors have been undertaken to advance the production of composites manufactured from natural fibers. This advancement facilitated the innovation of Natural Fiber Reinforced Composites (NFRC) with enhanced mechanical qualities by engineers and researchers. Agnivesh [4] researched the mechanical properties of jute, abaca, coconut, kenaf, sisal, and bamboo fiber-reinforced composites. Prior to choosing an NFRC for a certain application, it is essential to assess its suitability by examining its mechanical qualities, including tensile, flexural, and impact strengths.

In recent times, there has been a significant surge in research and invention in the field of NFRC. The advantages of these materials, such as low environmental impact and low cost, justify the interest in them compared to other materials such synthetic fiber composites. These materials have the potential to be used in a wide range of applications. A significant amount of work has been dedicated to enhancing the mechanical performance of these materials in order to broaden their capabilities and potential uses [5].

NFRC is a material that possesses notable mechanical, biodegradability, renewability, and low density characteristics. NFRC exhibits favorable characteristics that render it suitable for a wide range of advanced applications in diverse fields including automotive manufacturing, paper production, flexible optoelectronics, scaffold construction, optical devices, pharmaceutical products, medical biomaterial substitutes, spacecraft and aircraft engineering, as well as tissue repair specifically in wound dressing [6].

Advanced transport structures often utilize reinforced composite materials, such as kevlar, carbon, spectra, glass fiber, aramid, carbon nanotube, and zylon, which are known for their great strength. Nevertheless, the world is undergoing a transformation, with a growing emphasis on environmentally friendly materials. This shift is driven by the diminishing availability of inorganic resources like petroleum and other minerals. Natural fibers can be categorized as green materials, which refers to materials that are renewable. R.A. Ilyas[7] discussed the latest advancements in biocomposites, focusing on Natural Fiber Reinforced Composites (NFRC). NFRC is a material that possesses notable mechanical and barrier qualities, is cost-effective, biodegradable, renewable, and has a low density. The aforementioned features render NFRC highly advantageous for a wide range of innovative applications in industries such as automobile manufacturing, paper production, flexible optoelectronics, scaffolding, optical devices, pharmaceuticals, medical biomaterial substitutes, spaceship and airplane construction, and tissue restoration (specifically wound dressing). This concise article provides a summary of the utilization of natural fibers reinforced polymer composites.

The sugar palm (Arenga pinnata) is a non-timber forest species renowned for its several advantageous properties. The majority of the physical and production components of this plant possess economic worth and can be utilized. The extraction of juice sap, palm fruit, leaves, palm fiber, and stems is carried out for the purpose of commercial and home utilization, resulting in the production of various goods [8], [9], [10], [11]. Arenga pinnata fibers, ropes, and nets were derived from AP ropes by the utilization of conventional implements. Ropes and nets were utilized as agricultural implements [12]. NA Muda [13] provided an overview of the plant tissue culture research conducted on sugar palm (Arenga pinnata), a tree belonging to the Arecaceae family and Arenga genus. Sugar palm is primarily cultivated for its sugary sap, sweetened endosperm, and highly valuable industrial black fibers.

This study Carrying out a literature study on palm fiber, namely, the properties of palm fiber, modification of palm fiber, making it into composites, and mechanical testing. Therefore, this review is advantageous for future researchers as a fundamental literature to explore composite applications utilizing Arenga Pinnata Fiber (APF) materials. Furthermore, this review gives valuable information to assist researchers in addressing these challenges in their future research endeavors.

CHARACTERISTICS OF ARENGA PINNATA FIBER (APF)

M. Imran [14] Carried out a literature study on palm fiber, namely, the properties of palm fiber, modification of palm

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fiber, and making it into composites. The research results show that palm fiber has the potential to be developed as a reinforcement because of its attractive qualities. Palm fiber has a high cellulose content, resulting in good fiber quality. Fiber has long durability, and is also resistant to seawater; besides that, it is easy to process because it is widely available in the form of woven fiber.

The physical and chemical characteristics of the Arenga Pinnata (sugar palm) were investigated by Rudi Hartono [15]. Physical characteristics encompass the measurements of moisture content, density, and shrinkage. In addition, the chemical features of the extractive are present in both hot and cold water. The sugar palm plant utilized for the study was sourced from Sidikalang, Dairi district, North Sumatra, and had a 15-year growth period. The selection of the test sample is based on the axial orientation of the trunk, specifically the base, middle, and end sections, as well as the horizontal orientation of the trunk, specifically the sections at the core, middle, and near the bark. The findings indicated that the mean moisture content ranged from 120.31 to 603.48%, the specific gravity ranged from 0.12 to 0.51, and the shrinkage ranged from 28.06 to 77.69%. The concentration of extractable substances in cold water ranged from 11.66% to 87.22%, but in hot water it ranged from 10% to 90%.

The sugar palm is commonly utilized for sap extraction, which is subsequently processed into brown sugar. Nevertheless, this particular species has the potential to serve as a palm tree that accumulates starch. Yoshinori [16] examined the development characteristics and starch yield of Arenga Pinnata (sugar palm) on Muna Island, Southeast Sulawesi, Indonesia, where they are widely cultivated and utilized. The elongation growth of the trunk was finished at the emergence stage of the first female inflorescence, which occurred when the tree was estimated to be 10-12 years old. At this point, the trunk had achieved a length of 10-16 meters and a weight of 1000-1400 kilograms. However, the diameter of the trunk barely changed as it aged, remaining between 25-35 centimeters.

Rush and Ahmad Ilyas [17] utilized palm fiber, which is considered agricultural waste, into useful material by carrying out chemical pre-treatment, namely delignification and mercerization processes. Chemical treatment on palm fiber was initially carried out by extracting palm fiber cellulose. The mechanical treatment is carried out by passing the cellulose through a smoothing tool to avoid blockages in the subsequent process of high-pressure homogenization. The cellulose was then characterized for its chemical properties, physical properties, and morphology (i.e., scanning electron microscopy, transmission electron microscopy, X-ray diffraction analysis), and thermogravimetric analysis. The nanofibers were obtained under a pressure of 500 bar for 15 cycles, resulting in a yield of 92%. The findings indicated that the nanofibrillated cellulose exhibited an average diameter of 5.5 ± 1.0 nm and a length in the range of several micrometres. In addition, the raw fibers exhibited enhanced crystallinity (81.2%) and improved thermal stability, making them suitable for use as a reinforcing material in bio-nanocomposites. The created nanocellulose exhibits remarkable versatility and holds immense potential across a wide range of applications, including but not limited to bio-packaging and tissue regeneration scaffolds.

MRM Huzaifah [18] investigated the fabrication of composites using vinyl ester (VE) reinforced with Arenga Pinnata Fiber (APF). The sun protection factors (SPFs) were acquired from three distinct geographical regions: Kuala Jempol (located in Peninsular Malaysia), Tawau (located in West Malaysia), and Tasik Malaya (located in Indonesia). The SPFs were employed as a reinforcing material with a constant loading of 10 wt.%. The enhanced VE composites were fabricated utilizing a wet lay-up compression molding technique. The evaluated physical parameters were water absorption, thickness swelling, and moisture content. Tests were conducted on the tensile, flexural, and impact strength of the APF composites to assess their mechanical properties. A thermogravimetric analysis (TGA) was conducted to investigate the thermal characteristics. This investigation validated that the characteristics of the composites were influenced by the potency of the fiber. The APF/VE composites derived from Kuala Jempol exhibited superior tensile, flexural, and impact strength in comparison to the APF/VE composites sourced from Indonesia and Tawua. Furthermore, SPF Jempol/VE exhibited the highest levels of water absorption, thickness swelling, and moisture content. Thermal property analysis revealed that APF Tawau/VE had the greatest degree of mass reduction among the fibers from the three different geographic regions. According Huzaifa Physical properties of sugar palm fiber from indonesia have Diameter: 0,457 ± 0,095 mm, density: 1,4426 ± 0,0035 g/cm^3), water Absorption: 80,32 ± 13,3 %, and moisture content: 5,63 ± 0,4. Whereas the chemical composition of APF from Indonesia, for cellulose: 44,47 %, hemicellulose: 8,93 %, lignin: 41,425 %, ash: 0,91 %.

MECHANICAL TESTING OF ARENGA PINNATA FIBER REINFORCED COMPOSITES (APFRC)

As economic expansion continues, there will be a corresponding rise in the material needs of the industrial sector. Industries must adhere to the usage of materials that are both safe for human health and environmentally sustainable, while also making use of locally sourced raw resources. Presently, enterprises across several sectors continue to rely on synthetic materials derived from petroleum byproducts, which often contain numerous harmful compounds. Therefore, natural fiber has the potential to be used as an alternative for synthetic materials, especially in Indonesia which is rich in natural fibers resources. This will significantly influence the socio-economic conditions of the local community, fostering the expansion of the rural economic sector. Natural fibers possess significant economic worth and can be utilized as raw materials for diverse requirements in vital sectors. An efficient natural fiber processing method will yield globally marketable products with assured product quality. Irwan Suriaman [19] examined the impact of alkali treatment on the enhancement of mechanical properties in ramie, arenga pinnata, and coir fiber. The mechanical qualities were assessed by conducting tensile strength testing on individual fibers, following the ASTM D3822 standard, using a textechno favigraph machine. Furthermore, this study is corroborated by data obtained from thermogravimetric analysis (TGA), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). The findings demonstrated that the fibers subjected to alkali treatment exhibited superior mechanical properties in comparison to the untreated fibers. After undergoing alkali treatment, the fibers of ramie exhibited an 81% increase in tensile strength, whereas arenga pinnata fibers showed a 52% increase and coir fibers showed a 56% increase. An advantage of this alkaline treatment approach is its absence of heating and its practical treatment procedures, which distinguish it from other treatments.

Aidah Jumahat [20] investigated the impact of varying the volume percent of Arenga Pinnata fibers on the tensile and compressive characteristics of a composite material made from Arenga Pinnata fibers and epoxy (referred to as APREC). The composites were fabricated with varying volume fractions of Arenga Pinnata fibers, specifically 10%, 15%, 20%, and 25%, utilizing unidirectional (UD) fiber alignment. The specimens of all APREC materials underwent tensile and compression testing to examine how the volume fraction of fibers affects the modulus of elasticity, strength, and strain at failure. Scanning electron microscopy (SEM) was utilized to examine the morphological structure of fractured specimens. This analysis aimed to assess the fracture mechanisms that occurred when the specimens were subjected to either tensile or compressive loading. The findings demonstrated a positive correlation between the quantity of Arenga Pinnata fibers and the stiffness of the composites. This is demonstrated by the increase in tensile and compressive modulus of the specimens as the fiber volume content was raised. The tensile modulus of the APREC specimen increased by up to 180% when 25 vol % of Arenga Pinnata fiber was included, compared to the Pure Epoxy specimen. The tensile strength of the specimens rose by 28%, from 53.820 MPa (for Pure Epoxy) to 68.692 MPa (for Epoxy with 25 vol % APREC addition). Simultaneously, the compressive modulus had a growth of 3.24%, while the compressive strength grew by 9.17%. The results indicate that including Arenga Pinnata fibers has a substantial positive impact on the tensile and compressive characteristics of APREC.

Saaed Abdullah Mousa [21] created a biopolymer composite using sugar palm fiber and cassava starch that has the ability to break down naturally AND seeks to examine the physical and structural properties of the biocomposite films. The casting technique was used to combine Arenga Pinnata Fiber (APF) with cassava starch (CS) as the matrix and fructose as the plasticizer, resulting in a biocomposite. The thermoplastic CS composite sheet was subjected to varying levels of SPF loading, ranging from 0% to 20% dry starch in increments of 5%. The inclusion of SPF significantly enhanced the physical and thermal characteristics. It increased the material's thickness while reducing its density, water content, and biodegradability. Nevertheless, the composite films did not exhibit any noteworthy enhancement in their tensile properties. SEM micrographs indicate that the filler has been assimilated into the matrix. The APF/CS films exhibited a more varied surface due to their increased APF content. The inclusion of APF may have altered the film properties of cassava starch, thereby affecting the films' performance. The primary focus of this study is to provide insights into the biopolymer composite film and emphasize its significant potential in the food packaging industry.

The tensile and flexural strength of composite material made from Arenga pinnata fibers and epoxy also was investigated by widodo [22]. The fibers of Arenga pinnata were immersed in a 5% sodium hydroxide (NaOH) solution for a duration of 2 hours. The composite specimens were constructed using several orientations of Arenga pinnata fibers, specifically 0°+0°, 0°+45°, 0°+90°, and 45°+90°. The fibers of Arenga pinnata were combined with epoxy and hardener, with the fibers accounting for 40% of the total volume. The purpose of this experiment was to create a specimen test using the hand lay-up (HLU) procedure. The dimensions of the specimen used for the tensile and flexural tests were derived from the ASTM D-3039 and ASTM D-7090 03 standards, respectively. The results of the tensile and flexural tests conducted on the Arenga pinnata fiber-reinforced epoxy composite indicate that the 0° + 0° orientation exhibits the highest tensile and flexural strength. Specifically, the tensile strength is measured at 77.385 MPa, while the flexural strength is

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recorded at 76.38 MPa. The tensile test demonstrates that aligning the fibers parallel to the applied tensile force yields the greatest enhancement in strength. The bending test demonstrates that aligning the fibers perpendicular to the compression force results in the highest level of flexural strength.

A.H. Abdullah [23] examined the impact of the weight fraction of fibers on the flexural and dynamic mechanical characteristics of Arenga pinnata fibers and their hybrid epoxy composites. Four composite configurations were created in this study utilizing hand lay-up technique. The configurations were constructed by altering the weight ratios of Arenga pinnata (AP) and glass fiber (GF). The configurations included AP100% - 0% GF, AP70%-30%GF, AP30%-70%GF, and AP0% -100%GF, respectively. The flexural modulus demonstrates that the pure Arenga pinnata composites (AP100%-0%GF) exhibit greater strength compared to both hybrid and pure glass fiber composites (AP0%-100%GF). The progressive increase in the weight fraction of glass fiber has led to a decrease in the flexural characteristics. Through the use of dynamic mechanical analysis (DMA), it has been observed that the storage modulus of pure Arenga pinnata composites consistently surpasses that of pure glass fiber composites, indicating superior thermal resistance. The findings suggest that Arenga pinatta fiber, when combined with epoxy composites, exhibits a significant potential comparable to glass fiber composites for use in engineering applications.

Siti Humairah [24] fabricated a novel silicone biocomposite (Arenga pinnata-silicone biocomposite) and evaluate its mechanical capabilities, physical properties, and morphological qualities. The study examines the impact of incorporating Arenga pinnata filler into silicone rubber by analyzing the mechanical characteristics of pure silicone rubber and a biocomposite consisting of 12 wt.% Arenga pinnata and silicone. A uniaxial tensile test was performed on these soft materials to acquire stress-strain data, which was subsequently transformed into engineering stress-stretch (σ_E–λ) data. The experimental data were used to determine the material constants by fitting them to the Neo-Hookean and Mooney-Rivlin models. The physical properties of the material were analyzed by a density test, while the surface morphology was evaluated using a Scanning Electron Microscope (SEM). The specimen, when mixed with 12 wt.% of Arenga pinnata filler, has an average maximum tensile strength of 0.65 MPa. This indicates a reduction in its potency when compared to pure silicone rubber (with an average maximum tensile strength of 0,85 MPa). On the contrary, it has been discovered that the inclusion of Arenga pinnata fiber has resulted in an augmentation of both the rigidity and density of the silicone rubber. Upon comparing with experimental data, it is evident that both the Neo-Hookean and Mooney-Rivlin models more accurately replicate the elastic properties of the 12 wt.% Arenga pinnata-silicone biocomposite in comparison to pure silicone rubber. Upon examination of the scanning electron microscope (SEM) images, it is evident that there are no clusters or clumps of the Arenga pinnata filler, indicating a successful dispersion of the filler. The photos also demonstrate strong interfacial bonding between the filler and the matrix. Thus, it can be inferred that the inclusion of Arenga pinnata filler has improved the characteristics of the pure silicone rubber. Furthermore, this study advocates for the advantages of including natural fibers as fillers in composite materials.

S.F.K. Sherwani [25] analyzed the mechanical characteristics of hybrid composites made from Arenga Pinnata Fiber (APF) and glass fiber (GF) reinforced poly(lactic acid) (PLA). The purpose is to evaluate their suitability for application in motorcycle components. An investigation was conducted to evaluate the mechanical qualities (hardness, compressive strength, impact resistance, and creep behavior) and flammability characteristics of APF/GF/PLA hybrid composites with those of commercially available motorcycle Acrylonitrile Butadiene Styrene (ABS) plastic components. The composites were first synthesized using a Brabender Plastograph, and then subjected to compression molding. This study also demonstrated the stress-strain curves for both tensile and flexural behavior. The findings indicated that the APF/GF/PLA material treated with alkaline exhibited the highest levels of hardness and impact strength, measuring at 88.6 HRS and 3.10 kJ/m2, respectively. Based on the findings, it was observed that both alkaline and benzoyl chloride treatments had the potential to enhance the mechanical characteristics of APF/GF/PLA hybrid composites. Additionally, a short-term creep test indicated that the alkaline treated APF/GF/PLA composite exhibited the least amount of deformation due to creep. The results of the horizontal UL 94 testing demonstrated that the alkaline-treated APF/GF/PLA hybrid composites exhibited commendable flame resistance. Nevertheless, alkaline-treated APF/GF/PLA composites are highly appropriate materials for motorcycle components.

Arenga Pinnata fiber has recently emerged as a promising candidate for enhancing the strength of material matrix composites through fiber reinforcement. Suriani [26] analyzed the impact of fiber content on the occurrence of manufacturing faults and the adhesion between Arenga Pinnata fibers and Fiberglass/Kevlar hybrid composite material in boat construction. The testing coupons were prepared by varying the volume fraction of Arenga Pinnata fiber, specifically at 30%, 45%, 60%, and 75%. The lengthy Arenga Pinnata fiber was manually positioned and organized within the mold using the hand lay-up process. The testing coupon has been configured with a thickness of 5mm. The determination of manufacturing flaws and interfacial adhesion was conducted using Scanning Electron Microscopy (SEM) techniques. The scanning electron microscopy (SEM) results indicated that specimen D (60%) of Arenga Pinnata demonstrated the lowest occurrence of manufacturing flaws, along with a strong interfacial connection and effective bonding between the fiber and matrix, in comparison to the other tested specimens. Specimen E, with a failure rate of 75 %, has the most significant manufacturing flaws. In conclusion, 60 % of the Arenga Pinnata fiber contents demonstrated reduced manufacturing flaws and shown strong interfacial adhesion. The manufacturing flaws and interfacial adhesion of the Fiberglass/Kevlar hybrid composite material were significantly determined by SEM analysis.

Suriani [27] investigated the impact of magnesium hydroxide on the burning rate, mechanical characteristics, and surface morphology of an epoxy composite reinforced with Arenga pinnata fiber hybrid and polyester yarn (APF/PET). The inclusion of magnesium hydroxide serves as a flame retardant. The composites were fabricated using varying weight percentages of fibers (0%, 20%, 35%, and 50%) together with two constant materials, namely magnesium hydroxide and polyester yarn, with epoxy resin serving as the matrix. The addition of the flame retardant resulted in a reduction of the horizontal burning rate of APF/PET reinforced epoxy, with a decrease observed as the amount of 35% APF increased. The fiber loading reached 50% as a result of the deterioration in the mechanical characteristics of the hybrid composite, which can be attributed to the absence of an interfacial connection between the fibers and matrix. Scanning electron microscopy revealed that the distribution of Arenga pinnata fibers and matrix in the hybrid composites was similar, but there was less adhesion between them. This lack of adhesion negatively impacted the mechanical properties of the composites.

the impact of the mix of sugar palm fiber (Arenga Pinnata) and polyester resin as composite materials has been investigated by Achmad Kusairi Samlawi [28]. The metrics under consideration are impact strength, tensile strength, and modulus of elasticity. These parameters are being compared to the Badan Klasifikasi Indonesia (BKI) standard, which is the set of regulations governing the classification and construction of ships in Indonesia. The mass fraction of fiber and resins is 30:70%, 40:60%, and 50:50% respectively. The fiber is oriented at angles of 0, 90, 0, and 90 degrees, and the production process employs the hand lay up method. The ASTM D5942-96 standard is used for conducting impact testing, while the ASTM D638-03 standard is used for conducting tensile testing. The results indicate that the composition consisting of 50% of each component exhibits the highest test value compared to other compositions. This composition has an average impact strength of 1.703 x 1016 kg/mm^2, a tensile strength of 27.13 N/mm2, and a modulus of elasticity of 790.01 N/mm^2. Despite the fact that the impact test, tensile test, and modulus of elasticity results for the sugar palm fiber (Arenga Pinnata) material are currently below the BKI standard, it still shows promise as a potential raw material for the production of Jukung (a traditional boat in Banjarmasin) and can be further developed.

CONCLUSIONS

Arenga Pinnata Fiber (APF) has the potential to be developed as a reinforcement because of its attractive qualities. APF has a high cellulose content, resulting in good fiber quality. Fiber has long durability, and is also resistant to seawater. Positive correlation between the quantity of Arenga Pinnata fibers and the stiffness of the composites. This is demonstrated by the increase in tensile and compressive modulus of the Arenga Pinnata Fiber Reinforced Composites (APFRC) as the fiber volume content was raised. The performance of composite materials is primarily determined by their constituent elements and manufacturing techniques, Modifying the orientation of APF also has an impact on the tensile strength, compression, and elastic modulus of composites. The strength of composite materials in engineering applications can be regulated by manipulating the orientation of the fibers to ensure strength is concentrated in specific directions. Furthermore, it is expected that the technology will have the capability to produce APFRC that are strengthened by arenga pinnata fiber. These composites have the potential to serve as a viable substitute for traditional polymers in a wide range of applications, particularly in engineering fields such as automotive, marine, medical industries, and sports. Thus, it is anticipated to have the ability to make a significant contribution towards achieving sustainable development goals.

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NOMENCLATURE

σ_E meaning of Engineering Stress (Mpa)

λ meaning of Stretch

wt.% meaning of Weigth Percent (%)

AUTHOR(S) BIOGRAPHY

Author(s) Name

Nanang Endriatno obtained a Doctor of Engineering in Mechanical Engineering in 2018 from Kanazawa University Japan. He is a Lecturer, in Mechanical Engineering Department, Halu Oleo University, Indonesia. His area of research covers construction and material.

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