




Analysis of Volume Fraction and Fiber Orientation on Tensile Strength and Impact Strength of Cannabis Sativa-Polyester Fiber Composites

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Abstract

The development of composite materials in the engineering field is increasingly being used. This is due to its superior properties compared to conventional materials, such as the ratio between strength and density is quite high, rigid, the manufacturing process is very simple and resistant to corrosion and fatigue loads. The article determines the composition of the volume fraction and orientation of the fibers that have the most optimal tensile strength and impact on Sativa-Polyester Cannabis fibers. In this study, the fiber volume fraction was varied into 10%, 15%, 20% and the orientations were 0°, 30°, 45°, 60° and 90°. The method of making specimens in this study used a hand lay up with the ASTM tensile and impact test standards. The result indicates that the fiber volume fraction of 20% with the fiber orientation of 90° has the highest average tensile strength value of 30.56 MPa, compared to other variations. And the fiber volume fraction of 20% with a fiber orientation of 90° has the highest average value of impact strength, namely 493.6 Joules

ARTICLE INFO

Article history:

Received

May 14, 2022

Revised

June 15, 2022

Accepted

June 29, 2022

Keywords: Volume Fraction, Cannabis Sativa Fibers, Fiber Composites

Published by

Website

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INTRODUCTION

Today, the use of composite materials has begun to be widely developed in the manufacturing industry. The use of environmentally friendly and recyclable composite materials is a demand for today's technology. One of the composite materials that is expected in the industrial world is a composite material with filler material in the form of natural or artificial fibers. Basically a composite material is a combination of two or more different materials into a microscopic unit form, which is made of various combinations of properties or a combination of fiber and matrix. Currently fiber-reinforced composite materials are

engineering materials that are widely used because of their specific strength and stiffness which are far above engineering materials in general, so that their properties can be designed according to requirements[1], [2]. [3] conducted a study on the Effect of Volume Fraction of Composites Kenaf Fiber and Rayon Fiber with Polyester Matrix on Tensile and Impact Strength, this study aimed to determine the mechanical properties of composites on tensile strength and impact strength with variations in fiber volume fraction 10%, 15%, and 20%. The method is carried out by arranging straight kenaf fiber / straight rayon fiber with a polyester matrix of type 2504 with variations in fiber volume fraction of 10%, 15%, and 20%. The hardener used is MEKPO with a concentration of 1%. Composites are made by the press mold method. The composite consists of kenaf / rayon fiber with a polyester matrix of type 2504 with MEKPO hardener. The main variables of the study were the variation of fiber volume fraction 10%, 15%, and 20%. Specimens and testing procedures for tensile and impact izod refer to ASTM D 638 – 03 and ASTM D 256 - 03 standards. The results of this study showed that the addition of fiber volume fraction was 10%, 15%, and 20%. able to increase tensile strength and impact strength. The highest tensile strength of the rayon fiber composite was 51.23 MPa, which was higher than that of the kenaf fiber composite of 28.35 MPa at $V_f = 15\%$. Meanwhile, the highest impact strength in rayon fiber composites was 0.031 J/mm² which was higher than the kenaf fiber composites at 0.014 J/mm² at $V_f = 20\%$.

[4] Conducted his research on the Effect of Fiber Volume Fraction on Mechanical Properties of Polyester Polymer Matrix Composites Reinforced by Gebang Sheath Fiber. This research was conducted to determine the best volume fraction that can be used as a polyester matrix composite with gebang midrib fiber reinforcement. The intended mechanical properties are the impact strength and micro-photograph of the fracture surface resulting from the impact test on this composite. This composite fiber-reinforced midrib with a polyester polymer matrix uses volume fractions of 0% (without fiber), 20%, 40%, and 60% of the fiber in the composite according to ASTM D 6110-04. Ten samples per volume fraction were made to determine the average specimen strength. From the research, it is known that the highest impact value is in the 60% fiber volume fraction, which is 4,495.04383 J/m³, while the lowest impact strength is in the 0% volume fraction (without fiber) which is 604.50120 J/m³. In the fiber volume fraction of 0%-60%, the average fiber fracture is brittle and the fiber pull out mechanism is categorized as having a brush fracture pattern in the 60% fiber fraction.

[5] conducted a study on the Analysis of Tensile Strength and Bending Strength of Hybrid Composite Fibers of Tongue-in-law and Burlap Sack with 5% Rice Husk Ash Filler with Epoxy Matrix. rice husk ash filler with epoxy with random fiber direction matrix. The variation of the volume fraction of Sansevieria

and Hybicus cannabinus fibers was 0%: 35%, 10%: 25%, 15%: 10%, 20%: 15%, 25%: 10%, 35%: 0%. The method for making a composite specimen is in the form of a supine with a fiber length of 2cm. The test was carried out by bending test following the tensile test of AS7 standard D790 and ASTM D3039 standard. The results showed that the composite with rice husk ash filler had a higher flexural strength and tensile strength than the composite without rice husk ash filler, where the highest buckling strength was at 0% / 35% volume fraction of 32.00 MPa (using filler), and the lowest bending strength of 0%/35% volume fraction of 21.69 Mpa (without filler). While the tensile test has the highest strength at 15% / 20% volume fraction of 8.24 MPa (using filler), and the lowest tensile strength at volume fraction 0% / 35% is 3.43 MPa (without filler).

[6], [7] conducted a study on the Effect of Volume Fraction on Tensile and Flexural Strength of Wood Powder Reinforced Resin Composites. In this study, the composite was made of polyester with variable filler fraction volume of 15%, 30%, 45% and the type of filler was Mahogany (*Swietenia mahogany*). The measurement filler used is 50 mesh. The polymer matrix used is BQTN 157 unsaturated polyester resin. The tensile test of the experimental specimen is based on ASTM D638 M-93. And the bending specimen is based on D790-92 Standard. The highest tensile strength at 30% volume fraction is 2.081916 kg/mm². For composite materials with mahogany composite material particles with a volume fraction of 15% filler has an average flexural strength of 34.98 N / mm². The particles with a volume fraction of 30% have the highest average flexural strength of 45.6780 N/mm². The highest modulus of elasticity (E) and shear modulus (G) were obtained by composites with a filler volume of 635,464 kg/mm² and 958,85 MPa.

[8], [9] conducted a study on the Analysis of the Impact Strength of Polyester-Coconut Tapis Fiber Composites with Variations in Length and Volume Fraction of Fiber Treated with NaOH. The purpose of this study was to analyze the impact strength of coconut filter-reinforced polyester composites treated with NaOH at varying lengths and fiber volume fractions. 1% hardener type MEKPO with variations in length of coconut filter fiber 5 mm, 10 mm and 15 mm while the variation of fiber volume fraction 20%, 25%, 30%. The composites were made using a press hand lay-up technique with fiber treatment using a mixture of NaOH-Air. Treatment of coconut filter fiber is soaked in boiling water at 100 °C for 1 hour, then coconut filter fiber is dried using an oven at 65 °C for 12 hours after that coconut filter fiber is soaked in a solution of NaOH - Water (5 grams NaOH + 95 ml of water) for 2 hours. The composite was then post-cured for 12 hours at a temperature of 65 °C. Composite test specimens were cut according to ASTM D 256 standard for impact test specimens. Furthermore, the composite specimens were subjected to impact testing. Impact strength increases with increasing volume fraction and fiber length. The greatest impact strength

value was found in the impact test with a 15 mm fiber length composite with a 30% Volume Fraction of 0.0255 Nm/mm² . The results of the microstructure observation show that at 15 mm fiber length the bond between the matrix and fiber is stronger than the 5 mm and 10 mm fiber length variations so that the resulting composite is stronger and has a greater impact strength value. The longer the fiber used will reduce the crack deflection so that the impact strength is getting better. Likewise, the higher the volume fraction causes the matrix flow to decrease so that the impact strength will increase.

Composites are widely developed because they have the desired properties because they cannot be obtained from other materials when they stand alone. Thus, the discourse on the plan to ban the use of fiberglass is currently one of the considerations for switching to the use of environmentally friendly fiber. Fiberglass using glass fibers (matte) can cause itching if in contact with the skin. This material is made of chemicals and glass fibers that are difficult to degrade naturally. Mechanical recycling of fiberglass will produce CO gas and dust that are harmful to health, so alternative raw materials that are safer and environmentally friendly are needed. One type of natural fiber that can be used is hemp fiber. Hemp (*Cannabis Sativa*) is a versatile plant whose population is widely spread in Indonesia[10].

In this study, fiber from *Cannabis Sativa* will be taken which can be an alternative raw material for composites. Composites with natural fiber reinforcement are being developed more intensively. This is related to the widespread use of composites in various engineering and industrial fields as well as the demands for the use of materials that are cheap, lightweight, strong mechanical properties and not corrosive, so that they can be alternative materials other than metals. Starting from simple ones such as household appliances to industrial sectors, both small-scale industries and large-scale industries such as in the aircraft, automotive, and sports equipment industries. Therefore, one of the efforts to increase the usefulness of *Cannabis Sativa* is to utilize *Cannabis Sativa* fiber as a composite raw material that can be applied to various industries. This research is focused on knowing the tensile strength and impact of the material in accordance with the desired application.

The direction and application of this research is to obtain a new material which is a mixture of polyester with natural fiber (*Cannabis Sativa* fiber) so that it is expected to be useful as an alternative for making car bumpers which are currently made of fiberglass.

Literature Review

In the industrial world, composite materials mean consisting of two or more different materials that are combined or mixed into one. According to Kaw (2005) composite is a material structure consisting of 2 or more combinations of materials, which are formed on a macroscopic scale and are physically united. The word composite in the sense of a composite material means consisting of two or more different materials which are combined or mixed macroscopically. [11] suggested that the word composite (composite) is an adjective which means arrangement or combination. Composite comes from the verb "to compose" which means to compose or combine. So in simple terms, composite material means a combination of two or more different materials[12].

Composite materials generally consist of two elements, namely fiber as a filler material and a binding material for these fibers called the matrix. In the composite there is a main element, namely fiber, while the binding material uses polymer materials that are easy to form and have high binding power[13]. The use of the fiber itself is primarily to determine the characteristics of composite materials, such as stiffness, strength and other mechanical properties. As the fiber filler is used to withstand most of the forces acting on the composite material, the matrix itself has the function of protecting and binding the fibers so that they can work well against the forces that occur. Therefore, for fiber materials, materials that are strong, rigid and brittle are used, while for the matrix materials, materials that are tough, soft and resistant to chemical treatment are chosen. One of the advantages of composite materials is the ability of the material to be oriented so that its strength can be adjusted only in a certain direction that we want, this is called "Tailoring Properties" and this is one of the special properties of composites, namely light, strong, not affected by corrosion, and able to compete with metal, without losing its mechanical characteristics and strength[14].

Fiber

Fiber is a reinforcing material in composites that has a function as the main barrier. The number of fibers, the orientation of the fibers, the length of the fibers, or the shape of the fibers and the composition of the fibers are the most important factors in determining the strength of the composite. The more fibers contained in the composite, the greater the strength of the composite, namely mechanical strength [15].

Cannabis Sativa Fiber

Cannabis sativa plants have been known to humans since about 2000 years BC. Cannabis Sativa comes from central and western China [16], and until now hemp is growing very well in the bamboo curtain country. The Cannabis

Sativa plant was first discovered by a botanical researcher from the Netherlands named George E. Rumphius in 1660 in East India and was given the name *Ramium majus*.

Then in 1737 the plant was described in *Hortus Cliffortianus* by Carl von Linné (Linnaeus) as *Boehmeria nivea*. *Cannabis Sativa* was first introduced to the Netherlands in 1733, *Cannabis Sativa* began to be planted in Indonesia in 1937, covering plantation areas in West Java, Central Java, East Java, North Sumatra and Sulawesi ([17])

Cannabis Sativa is an annual plant with the form of many clumps of herbaceous plants that produces fiber from the bark of the stem, *Cannabis Sativa* fiber is classified as a long, strong and good fiber for textile raw materials because it has a structure similar to cotton fiber [18]. To take the fiber, the stems of the flax plant are harvested every two months and processed with a decorticator machine to produce crude fiber (china grass). Before being spun into yarn, the crude fiber which still contains a lot of sap needs to be cleaned through a degumming process, and a bleaching and softening process by applying oil so that it becomes a white and limp fiber (rami top).

In the manufacture of composites, the layout and direction of the fibers in the matrix will determine the mechanical strength of the composite, where the location and direction can affect the performance of the composite. The layout and direction of the fiber is classified into 3 parts, namely: One-dimensional reinforcement, which has maximum strength and modulus in the direction of the fiber axis, 2. Two-dimensional reinforcement (planar), has strength in both directions or each direction of fiber orientation. 3. Three-dimensional reinforcement, has a higher isotropic strength than the previous two types[19], [20].

Fiber Length

The length of the fiber in the manufacture of fiber composites in the matrix greatly affects the strength. There are 2 uses of fiber in a composite mixture, namely short fiber and long fiber. Long fibers are stronger than short fibers. Natural fibers when compared with synthetic fibers have lengths and diameters that are not uniform in each type. Therefore, the length and diameter greatly affect the strength and modulus of the composite. Fiber length to fiber diameter is often referred to as the aspect ratio. The greater the aspect ratio, the greater the tensile strength of the fiber in the composite. Long fiber (continuous fiber) is more efficient in laying than short fiber. However, short fibers are easier to lay than long fibers. Fiber length affects the processability of the fiber composite. In general, long fibers are easier to handle than short fibers. Long fibers are normally formed by a filament winding process, wherein the coating of fibers with a matrix will produce a good distribution and favorable orientation. Judging from the theory, long fibers can carry loads and stresses from a stress

point to another fiber. In an ideal continuous fiber structure, the fibers will be stress free or have the same stress. During fabrication, some fibers will receive high stresses and others may not be subjected to stress so that the above conditions cannot be achieved [21]. Meanwhile, short fiber composites, with the correct orientation, will produce greater strength than continuous fiber. This is the case for whiskers, which have uniform tensile strength as high as 1500 kips/in² (10.3 GPa). Short fiber composites can be produced with low surface defects so that their strength can reach their theoretical strength. The factor that affects the variation in fiber length for chopped fiber composites is the critical length. The critical length is the minimum length of fiber in a fiber diameter required at stress to achieve high fracture stresses [22].

METHOD

The research material used a composite of Boehmeria Nivea fiber with YUKALAC 157 BQTN-EX brand Polyester resin. Tensile testing uses a Universal Testing Machine with the Tarno Grocki brand with a capacity of 10 tons, with the ASTM D638 testing standard. As for the impact test using the Charpy method, using the ASTM D256 testing standard. Variations in volume fraction of cannabis sativa fiber 10%, 15%, and 20%; and fiber orientation 0°, 30°, 45°, 60°, and 90°.

RESULT AND DISCUSSION

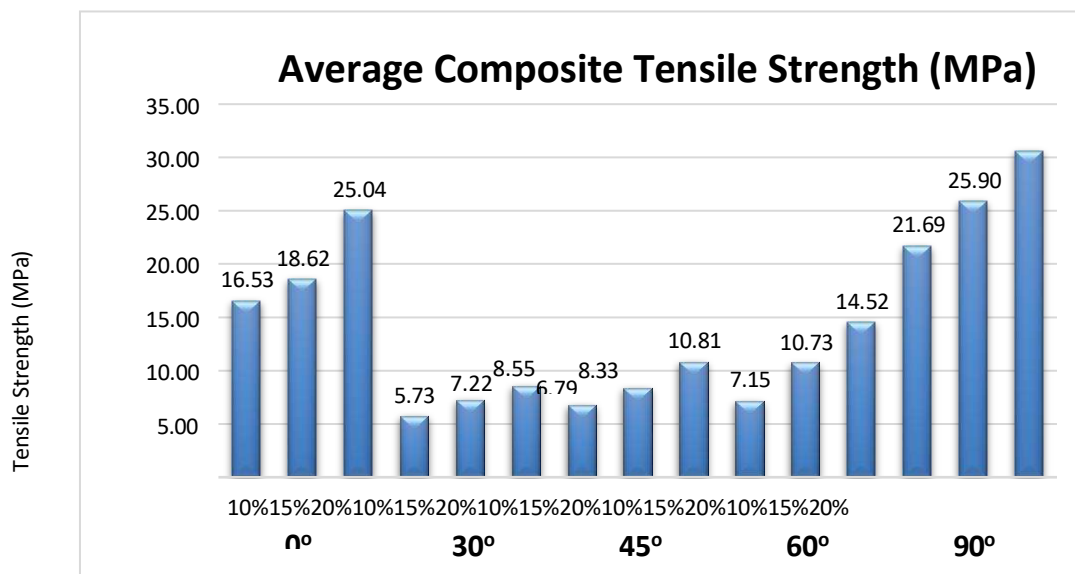


Figure 1 Average Composite Tensile Strength

In Figure 1 it can be seen that the average tensile strength at 20% volume fraction at 90° fiber orientation has the highest average tensile strength, while at 10% volume fraction at 30° fiber orientation has the lowest average tensile

strength. This shows that the two independent variables volume fraction and fiber direction orientation have a significant effect on the tensile strength of the composite. This shows that the fiber orientation of 90° affects the increase in tensile strength by providing reinforcement to the composite because the direction of the loading force is in the same direction as the fiber direction so that the fiber also supports the composite when loading occurs. The large volume fraction also has an effect because the fiber composition greatly increases the strength of the composite against the given load.

Impact test results

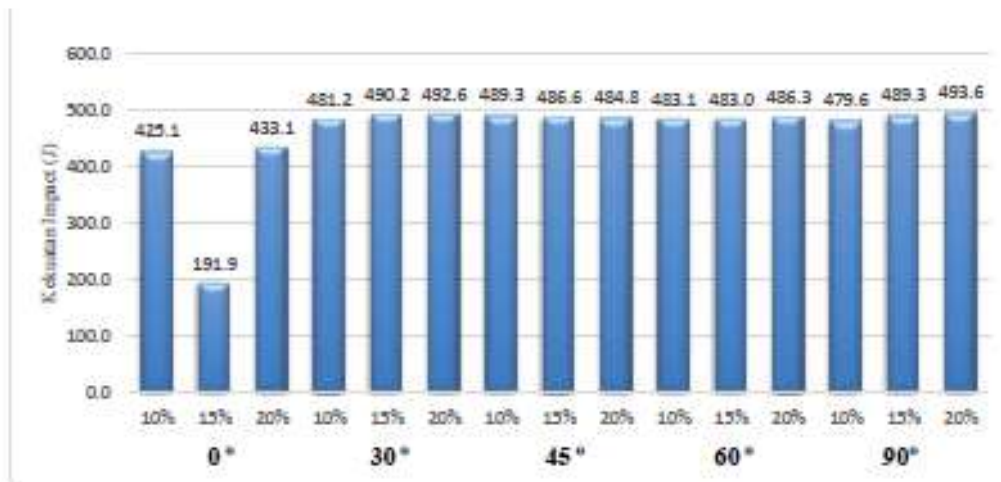


Figure 2 The Impact Strength of Composite

In Figure 2, it can be seen that the average impact strength at 20% volume fraction at 90° fiber orientation has the highest impact strength value, while 15% volume fraction at 0° fiber orientation has the lowest impact strength value. This shows that the two independent variables volume fraction and fiber orientation have a significant effect on the impact strength that occurs in the composite. This shows that the 90° fiber orientation has an effect on increasing the impact strength by providing reinforcement to the composite because the direction of the loading force is in the same direction as the fiber direction so that the fiber also supports the composite when loading occurs. The large volume fraction also has an effect because the fiber composition greatly increases the strength of the composite against the given load.

CONCLUSION

From the results of the research that has been carried out, the following conclusions can be drawn that the most optimal composition between volume fraction and orientation of Cannabis Sativa fiber is 20% volume fraction with fiber orientation 90° with an average tensile strength value of 30, 56 MPa and 20% volume fraction with 90° fiber orientation with an average impact strength value of 493.6 Joules.

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