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The Effect of Fiber Pretreatment On Physical and Mechanical Properties in Water Hyacinth Fiber Composite

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ABSTRACT

This study aims to determine the effect of fiber pre-treatment through immersion in an alkaline solution with time and concentration variables on the physical and mechanical properties of the water hyacinth fiber composite. Knowing the optimal combination of variables will result in an increase in the mechanical properties of the rational composite so that it can be considered as an alternative to synthetic fiber. The engineering technique in this research is by immersing the continuous water hyacinth fibers that have been woven in unidirectional direction (00). Immersion is done using NaOH solution with a concentration of 2%, 6% and 12% on the variation of immersion time for 4, 8 and 24 hours. The immersed lamina fiber is then tested for humidity (ASTM D 2654) and tensile test (ASTM D3039). The process of making composites by flowing methyl methacrylate (MMA) polyester resin matrix in the water hyacinth fiber lamina arrangement uses the vacuum bagging method. Composite compositions of composite are chosen at 20% by weight fraction, while the ratio of resin to hardener is 50:1. In the preparation stage for the characterization of mechanical properties, the composites were cut using laser cutting to obtain dimensions corresponding to ASTM D3039. The SEM test was performed to observe the fracture results from the composite tensile test and morphology of the fiber. Alkali treatment can reduce fiber moisture, improve fiber morphology, and increase compatibility between fiber and composite matrix. The alkalization method with water hyacinth fiber immersion in NaOH solution can be used to increase the tensile strength of bio composites. The results of mechanical tests on water hyacinth fiber composites show a rational increase in tensile strength and has the potential to be used as an alternative to synthetic fibers. The application of water hyacinth composite fiber using methyl methacrylate resin can be applied for medical, building, transportation, sports and other applications that require safety in terms of contact with the body.

Key words : Alkali, NaOH, Synthetic fiber Water hyacinth fiber composite,

1. INTRODUCTION

The use of materials that have specific properties that are not possessed by common materials such as metals, ceramics and polymers is very necessary in modern technology. The process of combining two or more materials to form a new material which is then called a composite is done in order to achieve the desired properties.

Unlike metal alloys, each composite material still has its own chemical, physical and mechanical properties. Composite consists of filler and matrix. The advantages of composite materials are its high strength and stiffness with low density, so as to reduce the weight of the final product.

Composite materials have been used in many applications, including medical, aerospace, automotive, marine, infrastructure, military, aircraft and sports equipment. The use of synthetic fibers as raw materials in the production of composites is starting to be replaced by natural fibers. This was triggered by the depletion of petroleum resources and the problem of global warming. Synthetic fibers are made from nonrenewable source that is petroleum, causing uncertainty in its use in a sustainable manner in the future.

Environmental issues raise awareness of the use of renewable materials. The use of raw materials sourced from nature makes research continue to develop to produce products that are inexpensive, biodegradable, and also little energy consumption. Natural fiber composites or commonly called bio composites are preferred over synthetic fiber composites because they have various advantages such as being environmentally friendly, biodegradable, recyclable, inexpensive, and rational physical and mechanical properties. [1].

The fact is that synthetic fibers are preferred over natural fibers because synthetic fibers have several advantages, which are relatively uniform in nature and size, also the fibers' strength can be made to be the same along the fibers. Research has been carried out to determine the mechanical properties of both natural and synthetic fibers. Synthetic fiber has a tensile strength of Fiberglass S of 4.6 GPa, while natural fibers namely ramie fiber has a tensile strength of 0.98 GPa. Higher than Flax 0.81 GPa and jute 0.47 GPa. [2]. Polymer fibers have good strength and rigidity and are widely applied in the automotive and shipping industries, while carbon fiber has the highest specific modulus and specific strength compared to other fibers (Steadman, 1970 and has high temperature resistance, friction resistance, and corrosion resistance and can be processed for a variety of fiber variations [3].

Natural fibers are generally suitable for use as composite reinforcement because of their relatively high strength and low density to overcome the limitations of natural fibers, treatment is needed both physically and chemically to produce a composite with consistent quality. In general, the fiber treatment method is divided into two: physically and chemically. Physical methods will change the structure and surface properties of the fiber without any chemical composition changes, whereas chemical method is done by adding a third material between the fiber and the matrix (coupling agents).

One type of natural fiber is obtained from water hyacinth plants. The use of water hyacinth fiber as a composite reinforcement is very interesting to be studied continually because water hyacinth has a potential characteristics namely high content of cellulose despite its small cellulose diameter. Water hyacinth contains about 60% cellulose, 8% hemicellulose and 17% lignin. Abdel [4] Said composition of cellulose is higher than kenaf (31-57%), jute (41-48%), and Abaca (56-63%) [5]. Water hyacinth is a type of aquatic plant that floats and its existence is considered as environmentally disturbing. This plant has a very fast growth rate which in turn covers the surface of the water and causes problems such as damage to environmental ecosystems, irrigation problems, being a site for mosquito breeding, and triggering an increase in health problems. Growth of water hyacinth growth is controlled in order to maintain water balance by using herbicides, removing water hyacinth from water, and utilizing water hyacinth plants. Currently, the most common use of water hyacinth is in the form of handicraft products. Various products can be produced and provide added value by utilizing water hyacinth into paper, biogas, bioethanol, biohydrogen, biopolymer, biobutanol, briquettes, high calorific value fuel, and composites [6].

The existence of abundant water hyacinth with high cellulose content has the potential to be used as a composite reinforcing material, as an alternative to synthetic fibers. The potential for development is wide open because water hyacinth fibers have advantages such as being a raw material that is abundant, inexpensive, easily obtainable, and also non-toxic. So far, the composite industry using natural fiber reinforcement is not widely reported in Indonesia, because most are still dominated by carbon fiber or glass fiber. Therefore, in recent years research on natural fiber-reinforced composites began to be developed with the aim as an environmentally friendly alternative material, utilizing abundant natural wealth.

But like other natural fibers, water hyacinth has limitations in terms of moisture conditions, physical properties, chemical content, and mechanical properties that are not evenly distributed. [7]. The moisture of natural fibers that reach 20% can have an impact on the mechanical properties of composites. [8]. The presence of hydroxyl groups on the surface of cellulose, hemicellulose, and pectin makes natural fibers hydrophilic. The incompatibility between the nature of the hydrophobic polymer matrix and the hydrophilic fiber properties results in a low bonding interface between the fiber and the polymer, which leads to inefficient transfer of stress. [9].

Several fiber treatment methods to improve adhesion between fiber and matrix include mercerization / alkali treatment, acetylation, and silane treatment. Alkaline treatment using sodium hydroxide (NaOH) is the method most often used to modify the structure of natural fiber cellulose [10]. Immersing the fiber in sodium hydroxide solution will change the orientation of the cellulose crystal structure and form an amorphous region by enlarging the fiber cell wall. This increases the accessibility of the resin to enter the system [11].

Alkali treatment is a process in which natural fibers interact with a small concentration of base in order to expand and to obtain good structure, dimensions, morphology, and mechanical properties [12]. The alkali treatment method will reduce fiber diameter, increase aspect ratio, and increase the effective surface of the fiber for the matrix to flow. Alkali treatment or commonly known as mercerization is known as the most economical fiber surface modification method that increases fiber wettability and bonding with the matrix. In addition, alkali treatment also increases the density of fibers to obtain stronger composites [13].

The engineering technique in this research is by immersing the continuous water hyacinth fiber that has been woven in unidirectional direction (00). Continuous fiber has better effects on the mechanical properties of composites than short fibers [14]. Immersion using NaOH solution with a concentration of 2%, 6% and 12% on the variation of immersion time for 4, 8 and 24 hours. The process of making composites by flowing methyl methacrylate matrix in the composition of the water hyacinth fiber lamina uses the vacuum bagging method. The immersed fibers are then subjected to tensile and humidity tests, as while the characterization for mechanical properties of the composite is carried out by conducting tensile test. SEM test was conducted to determine the morphology of the fracture of the

tensile test.
By utilizing vacuum bagging technology and fiber alkalization method for making composites, the optimal combination for concentration and time variables will be acquired in order to obtain a rational increase in mechanical properties of water hyacinth composite to be considered as an alternative for synthetic fiber.

2. PRELIMINARY RESEARCH

The effect of alkali treatment on the mechanical properties of natural fiber composites has been extensively studied. In tensile testing, it was found that alkali treatment on composites with natural fiber reinforcement would increase fracture strains two to three times compared with composites without any treatment [15]. Research by Li, Flax-epoxy composite and hemp-euphorbia resin composite with alkali treatment will eliminate pectin and increase the tensile strength and modulus by 30% [5]. Meanwhile, the alkaline immersion effect for coir-polyester composites in 5% NaOH solution for 72 hours is known to increase flexural strength and impact strength by up to 40% [16]. In another study by Kabir, immersing jute fiber for 4 hours with a concentration of 5% increased flexural strength by 20%. [10].

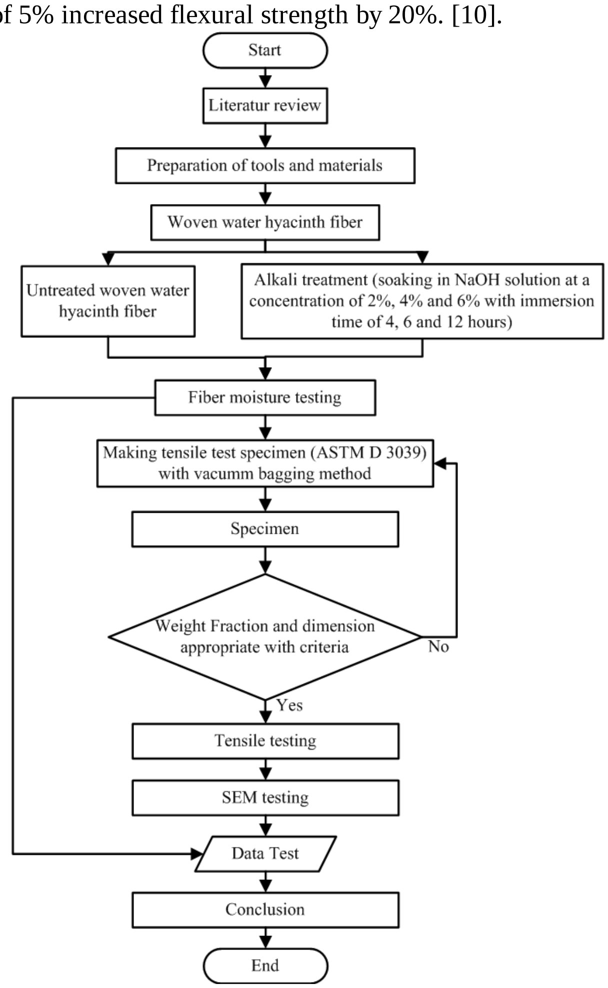

Figure 1 : methodology of water hyacinth fibers treatment as composite reinforcement

The surface treatment of water hyacinth fibers has been studied in order to improve the mechanical properties of composites reinforced with water hyacinth fibers. Water hyacinth fiber immersed in a solution of 15% sodium hydroxide in composites with a 20% fiber content with polylactide acid matrix in composites printed with compression-molded shows the tensile strength of 43.11 MPa. Other studies on water hyacinth fiber composites with epoxy resin matrix through the method of hand lay-up and the use of silane coupling have a tensile strength of 28.36 N/mm2 [17].

3. METHODOLOGY

The fabrication flow can be seen on Figure 1

4. MATERIALS AND METHOD

4.1 Water Hyacinth fiber

The research conducted this time is in the form of experimental design by making composite test specimens with raw material from woven water hyacinth fibers. From the physical characteristics, water hyacinth has a moisture content of 4.9 (wt%), fixed carbon 13.8 (wt%) and the largest content in the form of volatile matter is 61.2 (wt%) [18].

In the experimental test, the hyacinth stems were selected with a length that had reached 30 cm. Plants are separated from the roots and leaves and then washed clean to remove impurities. Water hyacinth plants are then ground until the surface is flat and then dried for 15 days with sunlight radiation to reduce water content. The collection of fiber in water hyacinth is aided by using metal brush. The water hyacinth stems are brushed/combed longitudinally using the wire brush so that the fibers will be separated from the plant. The brushing process is repeated until a fiber of approximately 1 mm is obtained. The fiber is then woven manually using a conventional loom to obtain the water hyacinth fiber lamina as shown in Figure 2.

Figure 2 : Woven water hyacinth fiber

A. Matrix

The use of the matrix in the manufacture of composites aims to obtain composites with better mechanical properties. A matrix is a phase in a composite that has the largest (dominant) part or volume fraction. The matrix has important functions in terms of transferring and distributing loads to the fiber, maintaining fiber orientation, protecting the fiber from environmental abrasion, and contributing to composite properties such as strength, and toughness.

Composites are formed by surface bonding between the matrix and the fiber. The matrix will bind the fiber so that the load imposed on the composite will spread evenly. This inter-surface bonding occurs because of the adhesion and cohesion forces. In composite materials, adhesion cohesion forces can occur through interlocking between surfaces, electrostatic forces, and Van der Waals.

To determine the matrix, it is necessary to look at the properties of the matrix such as resistance to heat, setting speed and desired physical properties. Besides, the matrix must have a match with the fiber so that no unwanted reactions do not occur on the surface of contact between the matrix and fiber.

The making of water hyacinth composite this time uses Methyl Methacrylate (MMA) as a matrix. MMA has a curing time of 40 minutes to 1 hour and is faster than epoxy. This resin has good biocompatibility properties so it is usually applied to make dentures and orthopedics. MMA has physical properties that are colorless, non-toxic, strong-smelling, and have a density of 0.94 g/cm3, as for the mechanical properties of MMA is strong, tough and lightweight, and has a high impact strength that is above polystyrene. The matrix is made by mixing methyl methacrylate and hardener in the form of powder with a weight percentage ratio of 50: 1. The mixture is stirred for 3 minutes until a homogeneous mixture is characterized by a change in color from clear to slightly turbid white.

4.2 Water Hyacinth Fiber Treatment

The treatment of water hyacinth fibers is by the method of mercerization/alkali treatment that is by immersing in a solution of NaOH. NaOH or Sodium Hydroxide or better known as caustic soda is a chemical compound with high alkali. The form of pure NaOH is white solid in the form of pellets, powders, and butanes and is hygroscopic so that the storage must be in an airtight container.

Preparation of an alkaline solution is obtained by dissolving NaOH with 97% concentration into water. The concentration of NaOH solution was prepared using a fraction weight of 2%, 6%, and 12%. High alkaline concentrations will damage the morphology of the fiber and will reduce the tensile strength of the composite [19]. That is in the previous study for NaOH concentrations above 15% the fraction weight would damage the fibers caused by high alkali concentrations [20].

A 2% concentration by weight fraction was obtained by mixing 1000 grams of water with 20 grams of NaOH. With the same weight of water, for concentrations of 6% and 12%, 60 grams and 120 grams of NaOH are needed. Water hyacinth fibers are dipped in each concentration for 4, 12, and 24 hours and then rinsed with distilled water repeatedly to remove the remaining NaOH solution. The rinsed fiber is squeezed with a little pressure to remove any remaining water. The water hyacinth fiber is then dried in the sun for 3 days under the sun's heat.

4.3 Composite Manufacturing Process

The technique of making natural fiber composites is basically the same as the technique used in synthetic fiber composites. Several factors such as fiber type, fiber content, fiber orientation, and fiber moisture content influence the manufacturing of composites.

The composite manufacturing process is carried out to unite the fiber with the matrix. The process of making composites in this study is by vacuum bagging or depression molding method. The lamina is laid on mold and the resin flows in the diaphragm with the help of a vacuum pump. Vacuum bagging, in essence, is the development of the wet lay-up process by using pressure with the aim of increasing consolidation. During solidification, a copolymerization process occurs so that the resin becomes solid and by increasing consolidation a high density and void reduction are obtained.

The vacuum bagging method uses atmospheric pressure to compress the laminate layer. Lamination is sealed in an airtight bag and then the vacuum pump sucks air inside the bag, the air pressure in the bag decreases while the air pressure outside the bag is fixed at 1 atmosphere. Atmospheric pressure pressures the inside of the bag because of the difference in pressure between the outside and the inside of the bag. The vacuum bagging method has advantages including the easy working process, the ability to follow the shape of the mold, the evenly distributed density of matrix and fiber, and also the ability to make complex shapes [21]. The tools used for the vacuum bagging process are vacuum pumps, hoses, vacuum bags, glass, sealants, waxes, taps, trap containers and flow medium. Below is the scheme for vacuum bagging method, as shown on Figure 3.

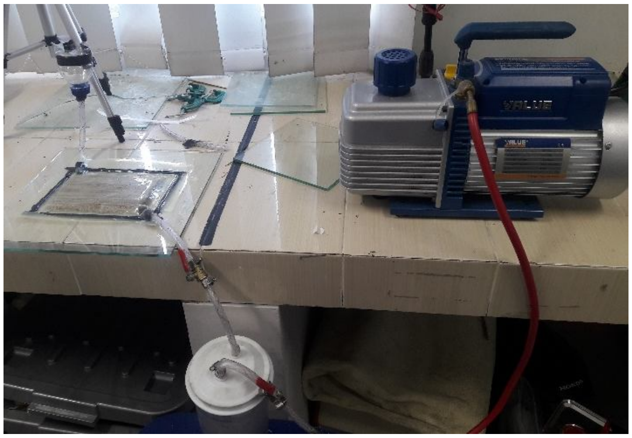

Figure 3 : Scheme for vacuum bagging method

4.4 Specimen Preparation

Preparation of the specimen begins with cutting the water hyacinth fibers that have been woven into 200 mm x 100 mm. 6 pieces of water hyacinth lamina are then weighed with a digital scale to find out their mass. Wax is applied over the glass surface which functions as a releasing agent, making it easier to take the composite after curing. Fibers are arranged in a uniform fiber direction (0^0) and placed between two glasses. For the vacuum process, the lamina is closed using a vacuum bag and isolated using a sealant until it is tight so air does not enter the system. Methyl methacrylate resin is flowed into a mold that has been filled with water hyacinth lamina fiber with the help of a 1 Hp vacuum pump suction. The resin will fill the mold that has been filled with water hyacinth lamina until full and then sited for 1 hour for the setting/curing process.

Fabricated composites are removed from the glass mold and the remaining resin that is attached is cleaned/cut. The composite is then weighed to find out its mass. The weight of the resin used is the difference from the weight of the composite with the weight of the water hyacinth fiber before fabrication. The composition of the fiber and matrix content is an important parameter that influences the mechanical properties of the composite. Comparison of compositions can be expressed in terms of volume and weight fractions. However, weight fractions are more widely used because of the ease in which measurements are actually taken.

The composite is then cut using laser cutting to obtain tensile test specimens. Dimensions of tensile test specimens refer to ASTM D3039 which is a rectangle with a size of 200 mm x 12.5 mm x 4 mm. Each combination of parameters (concentration and time) made 3 specimens.

Natural fibers with long shapes have the possibility of a lack of uniformity in dimensions. This makes the strength of the fiber has a random variable. Each test will be likely to produce a different value. This non-uniform test data can be used to shape the distribution of true power. Average strength and variation of strength distribution become important qualities in determining the properties of composites.

(a) (b)

Figure 3 : Scheme for vacuum bagging method

This research uses full factorial design methodology, thus a total of 30 tensile test specimens are required. 27 specimens are subjected to alkali treatment, while the other 3 not. The marking uses codification, as an example is 2A4-1, where 2A shows a concentration of 2% NaOH and the number 4 behind indicates the immersing time for 4 hours. Number 1 shows test sample number 1. The test were performed at room temperature to determine the strength of the composite. Image the results of composite fabrication and tensile test specimens shows in Figure 4 a and b respectively.

For composite characterization, some reports [22] [23] can be found for reference.

5. EXPERIMENTAL CHARACTERIZATION

5.1 Tensile Strength Composite

Tensile test is carried out to determine the effect of the alkali treatment on the bond strength between the fiber and the matrix. The effectiveness of fiber surface modification can be obtained by comparing the results of untreated composite tests with tensile test results at various concentrations and immersion times.

Tensile testing is a fairly simple material test. Specimens were subjected to tensile tests using a Universal Testing Machine with a cross head speed of 5 mm / min and a load cell of 500 kg. Tensile testing is done by uniaxial loading, i.e. pulling the specimen in the direction of the fiber until it breaks. Expenses imposed and elongation will be recorded in a computerized system. Tensile strength and modulus of elasticity are analyzed based on a stress-strain graph. By tensile testing we will obtain a stress curve so that the mechanical properties of composites such as tensile strength and elastic modulus can be known. Three specimens were tested and the mean values were the results used for analysis.

5.2 Scanning Electron Microscopy

Scanning Electron Microscope (SEM) is a type of electron microscope which images the surface of the sample by scanning using a high beam of electrons. The electrons that interact with the atoms that make up the sample produce a signal that contains information about the sample from the surface topography, composition and other properties such as electrical conductivity. SEM is designed to observe the surface of solid objects directly. SEM has a magnification capability of 10-3,000,000 times, depth of field of 4 – 0.4 mm and resolution of about 1 – 10 nm. The combination of high magnification, large depth of field, good resolution, the ability to know the composition and crystallographic information makes SEM widely used for research and industrial purposes. SEM focuses the electron beam (electron beam) on the surface of the object and takes pictures by detecting electrons that appear from the surface of the object.

6. RESULT AND INTERPRETATION

In this experimental study design, this study has only reached the stage of tensile test specimens. From the research so far, there has been a decrease in weight before and after soaking the water hyacinth fiber in NaOH solution. This can be seen visually by reduction the diameter of the fiber. Percentage weight reduction of 4.95% at a concentration of 2% and 16.07 at a concentration of 12% NaOH solution.

There is an increase in the tensile strength of the composite with the fiber treated. Maximum strength was achieved at 60.2 MPa with a variable concentration of 12% solution and 12 hours soaking time. Whereas the composite test without fiber treatment was 54.5 MPa so there was an increase of 11%.

With the vaccum bagging method, it can be accuracy controlled both fiber and matrix weight fractions. The amount of deviation is 8.6% from the specified composition. The next step is SEM testing to observe the morphology of the fiber and the fracture structure of the specimen due to alkali.

7. CONCLUSION

The effect of water hyacinth immersion in alkali solution for manufacture of composites was investigated by tensile testing. Based on the data study obtained, it can be concluded that the alkali treatment can effectively increase the tensile strength of water hyacinth with the MMA matrix. With the availability of abundant raw materials and rational strength, water hyacinth fibers have the potential to be used as an alternative material to replace synthetic fibers in composite applications.

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