Manufacture and Characterization of Composite Based on Sugar Palm Stem Powder Reinforced by Matrix Polyester Resin, Epoxy Resin and Polyurethane Resin
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ABSTRACT
Composite based on sugar palm stem powder has been made through conventional technique of mold and press from the sugar palm stem powder reinforced by matrix polyester resin, epoxy resin, and polyurethane resins. The composition of sugar palm stem powder were varied with 2;4;6;8 and 10% wt mass fraction also the 90;92;94;96 and 98 % wt mass fraction are enhanced by the polyester resin, epoxy resin and polyurethane resins in 300 MPa pressure treated with temperature of 120°C for polyurethane resin and temperature of 70°C for polyester resin and epoxy resin for 20 minutes. The test result of physical and mechanical properties generates 1.19 gr/cm³ of the density optimum number, 1.83% porosity, 2.83% water absorption, 80.47 kJ/m² impact strength, 80.42 MPa flexural strength, 5.95 MPa tensile strength and the result of SEM to see the surface structure of the sample which is homogenous. The study shows the mechanical properties and physical properties which meet the Standard JIS A 5905 : 2003, that is flexural strength >32 MPa and 0.3 – 1.3 gr/cm³ density.

Keywords: Sugar Palm Stem Powder, Composite, Physical Properties, Mechanical Properties

I. INTRODUCTION
Today, the technological advancement in the industrial world is growing rapidly. This encourages many inventions of several alternative technologies as a way to fulfill people’s needs, especially the building material. Researchers keep making new innovations by targetting a building material to be used and processed in order to improve its function. The material needed should be high in quality and has a high mechanical property. Composite is one of the alternatives to produce a material with higher mechanical properties.\textsuperscript{15}

Composite is a material formed by two or more constituent materials. The constituent material has unique properties and characteristics and more superior than its constituent material. Some of the excellence of the composite are, flexible, strong, light but sturdy without forming, has good electric isolation, stainless and easy to combine with other material. The eco-friendly composite-based material on the natural fiber could be obtained in the surrounding environment. Today, natural fibers are often used because there are a lot of it and very cheap so it is often used as an enhancing material such as kenaf, abaca, rosella, hay, and many other abundant and renewable natural fibers in Indonesia.\textsuperscript{10}

Sugar palm stem is one of the abundant and renewable natural resources in Indonesia, Sumatera Utara is one of the provinces with wide sugar palm (\textit{Arenga pinnata Merr}) forest. According to the data from Plantation Agency of North Sumatera Province in 2017, North Sumatera has 6.101 Ha of sugar palm trees in immature plant category, producing plant category, non-producing plant category with 3.746 tons of production result.\textsuperscript{5}. 

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This section contains information about matrix types and fiber types that are used in the fabrication of polymer composite components. It also gives detail about advanced composites and natural fiber composites. Polymer composites have been used extensively in aerospace, automotive, marine, building and construction, furniture, sports goods, telecommunication, and railway industries because of light weight, high strength, high stiffness, aesthetics, corrosion resistance and they ability to cope with extreme stresses over long periods. [14]

Resin is the polymer in the composite as a matrix, functioning as a binder, composite structure protection, strengthening the composite and act as tension transfer media received by the composite and protecting the fiber from abrasion and corrosion. Thermoset resin is a matrix system type commonly used as a composite material. Its popularity in its usage in composite arise from these reasons, has low melting strength, has good ability in interacting with fiber and require low work temperature. Besides, it is cheaper than thermoplastic resin. Polyester is defined as a polymer contains at least a group of ester connector per repeater unit. They could be obtained from several reactions, the most important thing is the polyesterification between dibasic acid and diol or its derivative. [12]

Epoxy resin is one of the polymer types from the thermoset group. Thermoset resin is a liquid resin transformed into a solid material by chemical polymerization formed a three-dimensional polymer chain. The mechanical properties depend on the molecular unit formed a dense membrane and crossed membrane length. Epoxy resin has isotropic properties and temperature-sensitive, cannot melt, cannot be reprocessed, the atoms bind strongly, no chain displacement. Epoxy resin is honey-like liquid before the hardening process and becomes a fragile solid material after the hardening process. Generally, epoxy has a good characteristic, it is able to bind metallic compound, well and tough. Epoxy resin is excellent for the matrix in composite with glass fiber enhancer. The use of epoxy resin could fasten the hardening process because epoxy resin produces heat so it fastens the process of hardening. [11]

Polyurethane is a polymer material contains various urethane compound (-NH-CO-O-) formed by the reaction between polyol (alcohol with more than two clusters of reactive hydroxyl per molecule) and diisocyanate or polymeric isocyanate with a proper catalyst availability and additive materials. Polyurethane has a unique characteristic and more superior than other material to produce and or support the production activity. Polyurethane is also considered as a low-energy-consumption material, make expenditure on improvement and machine or factory tools maintenance in order to be cheaper and efficient due to its excellence and characteristics. The use of polyurethane in buildings and factories, concrete deck layering, partition wall, room condenser layering, tank layering, power station and house generator set, ceiling layering, inside walls layering, cold storage and also karaoke room layering. Usually, polyurethane is used as an adhesive solution produced by the hydroxy compounds reaction to isocyanate. The elastic, strong, scratch-resistant, and oil-resistant polyurethane is totally useful. [6]

II. METHODS AND MATERIAL

A. Appliance and Materials Research

The appliance used are 100 mesh sieves, oven, mixer, digital balance, moulding, beaker glass hot plate hot press hydraulic, Universal Testing Machine, Impactor Wolpert and Scanning Electron Microscope (SEM). The material used is sugar palm stem powder, 2% and 17.5% NaOH, Aquadest, alcohol, polyester resin, epoxy resin and polyurethane resin
B. Research Variables

Research variables on the manufacture of composite materials include raw material composition and characterization.

| Sugar Palm Stem Powder (%wt) | Matrix (Polyester, Epoxy and Polyurethane Resins) (%wt) |
|------------------------------|---------------------------------------------------------|
| 2                            | 98                                                      |
| 4                            | 96                                                      |
| 6                            | 94                                                      |
| 8                            | 92                                                      |
| 10                           | 90                                                      |

As for the characterization of composite materials include: physical properties (density, porosity and water absorption), mechanical properties (impact strength, flexural strength and tensile strength) and Scanning Electron Microscope (SEM).

C. Research Procedures

Sugar palm stems are taken and chosen from the immature tree category. Then the stems are cut into 5 x 5 x 2 cm cubicles. The stems are cleaned by soaking it in alcohol then air-dried in the open space. After they dried, the stems are cooked with NaOH 17.5% solution in a 2500 mL beaker glass by using a hot plate for two hours in 100°C temperature to eliminate the lignin and then dried. The dry sugar palm stem is ground by blender then sifted with 100 mesh sieve to obtain the powder of sugar palm stem. Weighed with ingredient variation (2; 4; 6; 8 and 10)% by using a digital analytic balance. The mold is cleaned from dirt. The metal plate is layered by an aluminum foil as the base and cover. Then the mold and metal plate are lubricated by wax to avoid the sample to become sticky when removed from the mold. The matrix used is weighed with the variation (90; 92; 94; 96 and 98)%. Mix it with the mixer until smooth, and pour the mix into the (10x2x1) cm mold. Then, the mold is covered with a metal plate layered with aluminum foil and put it on the hot press in temperature of 120°C temperature in polyurethane matrix and temperature of 70°C polyester resin and epoxy resin matrix for 20 minutes. Then the sample is removed from the mold and ready to be physically tested for its density, porosity, water absorption, and mechanically tested for its flexural strength, impact strength, tensile strength and microstructural test by using the Scanning Electron Microscope (SEM).

III. RESULTS AND DISCUSSION

A. Physical Properties of Composite (Density)

Figure 1. The density versus variation of sugar palm stem powder composition

Density is one of the physical characteristics that shows the comparison between object mass against the volume or the amount of matter mass per unit volume. From Figure 1 the score of density obtained is (0.9 – 1.19) gr/cm³ and shows that there is a decline caused by the addition of palm sugar powder. Based on JIS A 5905:2003, the composite of test sample is qualified 0.3 – 1.3 gr/cm³.
B. Physical Properties of Composite (Porosity)

![Porosity vs Composition Graph](image)

Figure 2. The porosity versus variation of sugar palm stem powder composition

Porosity can be defined as a comparison between the volumes of pore against total volume of composite. From Figure 2 the highest score of porosity is 1.83% on epoxy resin matrix and the lowest is 0.22% on polyester resin matrix. So, by the addition of palm sugar powder the value of porosity is escalating and if there is no addition of palm sugar powder, the value of porosity is declining. Composite of styrofoam waste, asphalt, nut fiber and black sand was value 12.36%.[18]

C. Physical Properties of Composite (Water Absorption)

![Water Absorption vs Composition Graph](image)

Figure 3. Water Absorption versus variation of sugar palm stem powder composition

Water absorption test is conducted to determine the amount of water absorbed by the sample soaked for 24 hours in room temperature. On Figure 3, the value of water absorption obtained is around (0.19 - 1.83)%. Water absorption test is directly proportional with porosity test which can be stated that the more amount of palm sugar stem powder added to the sample composition, the score resulted is escalating and inversing with the density test. Result of composite with corn husk fibes was value (0.75 - 3.55)%.[9]

D. Mechanical Properties of Composite (Impact Strength)

![Impact Strength vs Composition Graph](image)

Figure 4. The impact strength versus variation of sugar palm stem powder composition

By acknowledging the amount of energy absorbed by the material, the impact strength of test material can be obtained. Figure 4 explains that the highest score of impact strength obtained is 80.47 kJ/m² on epoxy resin matrix and the lowest score obtained is 15.1 kJ/m² on polyester resin matrix. Thus, by the addition of palm sugar stem powder, the score of impact strength test is escalating. And result composite with jute/epoxy 0.214 kJ/m², banana/epoxy 0.543 kJ/m², Ramie/epoxy 0.211 kJ/m², coir/epoxy 0.174 kJ/m² and curaua/epoxy 0.1109 kJ/m².[1]. Result of silk hybrid fibre composite was value 31.83 kJ/m².[17]
E. Mechanical Properties of Composite (Flexural Strength)

![Image of Flexural Strength Graph]

Figure 5. The flexural strength versus variation of sugar palm stem powder composition

Flexural strength test is aimed to uncover the endurance of composite against encumbrances and to uncover the elasticity of a material. Figure 5 explains that the highest score of flexural strength test obtained is 80.42 MPa on epoxy resin matrix and the lowest score obtained is 3.47 MPa on polyurethane resin matrix. It is caused by the increasing amount of powder addition so the matrix is not capable to bind homogenously. The decrease of score of flexural strength test is caused by the imperfect binding between palm sugar stem powder and the matrix along with each addition, therefore it causes void. Based on JIS A 5905:2003, the composite of test sample is qualified with score of flexural strength is more than 35 MPa.

F. Mechanical Properties of Composite (Tensile Strength)

![Image of Tensile Strength Graph]

Figure 6. The tensile strength versus variation of sugar palm stem powder composition

Tensile strength test is aimed to uncover the ability of material in holding weight/mechanical power until the occurrence of failure. Figure 6 shows that the highest score of tensile strength test obtained is 5.95 MPa polyurethane resin matrix and the lowest score obtained is 1.071 MPa on polyester resin matrix. The decline occurred is caused by the increasing amount of palm sugar stem powder addition so the matrix is not capable to bind homogenously, therefore it causes void. Result tensile strength from reinforcing effects of dendritic short carbon fibers for rigid polyurethane composite was value 24.7 MPa.\[13\]

G. Analysis of SEM

![Image of SEM Graph]

Figure 7. Result SEM of Composite Matrix Polyester Resin

On Figure 7, there are pretty much dark color which are cavities on the composite with less evenly distributed polyester resin matrix. However, the bright part shows that polyester resin shows that polyester resin binds well with the powder, thus it covers pores even though the surface is less evenly distributed.

![Image of SEM Graph]

Figure 8. Result SEM of Composite Matrix Epoxy Resin
The result of SEM test of composite matrix epoxy resin can be seen on Figure 8 which shows that the bright color and the dark color are balanced, where the dark color is cavity and the bright color is good bond of epoxy resin and powder. Thus, it is able to fill the fiber’s cavities well, even though there are some cavities that are not perfectly covered. However, in this condition the epoxy resin matrix and the powder are well-bound, proven by the result of impact test on the composition of 10 gr of the lower part that resulting in the highest impact strength among other composite, which is (80.47 J/m²).

Figure 9. Result SEM of Composite Matrix Polyurethane Resin

The test result of SEM composite with polyurethane resin matrix can be seen on Figure 9. The dark color and the bright color are not balanced yet, where the dark color is cavity and the bright color is the bound of polyurethane and palm sugar stem powder that can be concluded as not good enough since it still has many cavities and uneven surface due to the amount of void generated.

IV. CONCLUSION

In this work, by the addition of palm sugar stem powder the value of density is declining. On the other hand, the value of porosity and water absorption are increasing on the impact strength test. However, the value of porosity and water absorption are declined on the flexural strength test and tensile strength test. The measurement of physical characteristics of palm sugar stem powder composite results in optimum value of density of 1.19 gr/cm³, porosity of 1.83%, water absorption of 1.83%, impact strength of 80.47 kJ/m², flexural strength of 80.42 MPa, and tensile strength of 5.95 MPa. The result of this research shows the mechanical and physical characteristics that qualify the Standard of JIS A 5905 : 2003 which is flexural strength of >32 MPa and density of 0.3 - 1.3 gr/cm³. It is due to lignin, hemicellulose, and alpha cellulose contained in palm sugar stem powder appropriate in making composite and combined with the binding matrix. Also, the composite with epoxy resin matrix has better test than polyester resin and polyurethane resin proved in the test of the physical and mechanical characteristics.

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