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Mechanical Properties Of Biocomposites With Unsaturated Vinyl Ester Matrix Reinforced With Durian Skin Fiber As A Green Composite Application

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***Abstract*— In this study, a biocomposite based on vinylester fortchem 411 VE filled with durian skin fiber (DSF) was successfully synthesized using the casting method with the aid of a catalyst to accelerate the biocomposite fabrication process. DSF was treated with 7% NaOH. The biocomposite was loaded separately with treated DSF at 3 to 6% by weight, and its tensile properties were investigated. The tensile strength and elastic modulus of the biocomposite decreased with the addition of DSF particles, and lower values were found compared to the matrix. Additionally, alkali treatment on DSF reduced the strain and modulus of the biocomposite compared to the composite without DSF filler. The opposite trend was found in the case of elongation at break. However, biocomposites with treated DSF showed greater elongation compared to biocomposites without DSF filler. This was indicated by the presence of air voids and roughness on the fractured surface of the biocomposite treated with DSF.**

Keywords*— Durian skin fiber (DSF), vinylester fortchem 411 VE, alkali treatment, casting, biocomposite, tensile properties.

I. INTRODUCTION

In the present era, the use of materials made from plastic is highly demanded for various human needs, such as vehicle parts/components including doors, roofs, trunk covers, front dashboards, etc. [2]. Plastic materials indeed offer many benefits to humans, but they also pose negative impacts on the environment due to their non-biodegradable nature, resisting decomposition by soil or microorganisms in the soil. This can result in several environmental and health problems for humans themselves [13]. Therefore, one solution to reduce these impacts or problems is to transition to environmentally friendly plastic biocomposite materials that can degrade over time [3].

However, these materials have a drawback, namely lower mechanical properties compared to synthetic plastics, such as low tensile strength, and their application is still limited in the industry. To address this issue, additional components are needed to enhance the mechanical properties of plastic biocomposites, such as additional natural fiber filler materials [15]. The mixture of plastic/polymer material with the addition of natural fiber fillers is called green composite or biocomposite, which has the advantage of being biodegradable and having adjustable mechanical properties [1].

Meanwhile, biocomposite material can be defined as a combination of two or more different phase materials. For example, biopolymer material is combined with two or more additional materials such as natural fibers or particles used as reinforcements, resulting in improved mechanical properties in the biocomposite material. There are several examples of bioplastics used as matrices in biocomposite materials, including Polyester, vinylester, epoxy, polyethylene, PLA (Polylactic Acid), PVA (Polyvinyl Alcohol), PHA (Polyhydroxyalkanoates), Chitosan, etc. Among these examples of bioplastics, PLA (Polylactic Acid) stands out [5].

Research on biocomposites with natural powder/particle fillers has attracted many researchers due to their environmentally friendly nature, lower associated costs, low density, resistance to abrasion, high filling capability resulting in high stiffness, easy recyclability, easy availability in nature, and affordability [9]. The hydrophilic nature of natural fibers causes low adhesive forces between natural fibers and composite matrices. Therefore, to enhance the adhesive forces

between natural fibers and composite matrices and optimize the cellulose content in natural fibers, chemical treatment of natural fibers is necessary [12]. A commonly used chemical treatment method by researchers is alkalization, which can regenerate cellulose on the surface of particles or natural fibers [6].

II. Material and Methods

A. Materials

Vinylester Fortchem 411 VE in liquid form with a density of 1.20 g/cm³, purchased from UD. Aneka Kimia Jember, was used in this study. The durian skin fiber (DSF) used in this research is of the local durian variety native to Jember, obtained from street vendors in the Jember Regency area. The durian skin fibers (DSF) were air-dried for 14 days under sunlight before the alkali treatment process. Meanwhile, NaOH and deionized water were procured from UD. Aneka Kimia Jember, East Java, Indonesia.

B. Production of Durian Skin Fiber

Durian skin fiber (DSF) is extracted from the skin of durian fruit in various sizes. Subsequently, the durian skin is cleaned thoroughly using flowing water. Dry the cleaned durian skin fiber under sunlight for 14 days until completely dry. The alkali treatment process involves soaking 10 grams of dried durian skin fiber (DSF) in a 7% NaOH solution for 3 hours at room temperature. Afterward, neutralize it using demineralized water until neutral (pH 7). The dried fiber is then subjected to a milling process using an ice blender machine until it becomes finely textured. Once finely textured, sieve the material using a mesh with a size of 100 to obtain durian skin fiber (DSF) powder with particle sizes ranging from 149-177 μm.

C. Fabrication of Green Composite with Vinylester Fortchem 411 VE/Durian Skin Fiber (DSF)

The fabrication of green composite with durian skin fiber (DSF) is performed using the casting method. The durian skin fiber (DSF), which has undergone alkali treatment, is then weighed to determine volume fractions of 3%, 6%, and 9%. Additionally, prepare a biocomposite with a 0% fraction for use as a reference in the tensile strength and morphology analysis of the biocomposite. Weigh the Vinylester Fortchem 411 VE resin and mix it with the durian skin fiber (DSF). Catalyst is also used to accelerate the reaction and hasten the curing process of the biocomposite. Once evenly mixed, pour the green composite composition into a glass mold and let it stand for 24 hours at room temperature. Place the biocomposite composition in a vacuum machine to reduce voids. The green composite is successfully produced with a thickness of 3 mm and is ready for testing according to biocomposite standards ASTM D638 type 1 [8].

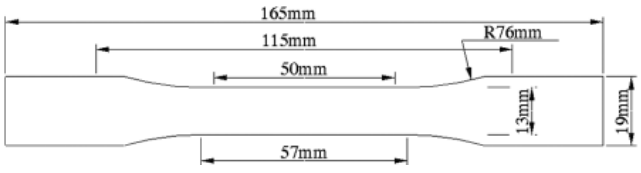

Fig. 1. Standard ASTM D638 for Composite

D. Tensile Strength

Tensile testing is employed to analyze the tensile strength properties of the Vinylester Fortchem 411 VE/DSF biocomposite. The tensile testing machine used is the Computer Universal Testing Machine HT-2420 manufactured by Hung Ta, model HT-2420, with a loading capacity of 20 kN. Tensile testing results include tensile strength, elastic modulus, and elongation at break values. All specimens subjected to tensile testing are in accordance with the American Society for Testing and Materials (ASTM) D638 Type IV standard.

III. Result and Discussions

A. Tensile Strength

Fig. 2. Tensile test graph

Generally, during tensile testing, there are two categories of fractures: brittle fractures and ductile fractures. The key distinction between these types lies in the material's capacity for plastic deformation. Brittle fractures involve minimal or no plastic deformation and lead to material failure relatively quickly. In contrast, ductile fractures entail substantial plastic deformation, and the material takes a comparatively longer time to withstand a specific load [7].

The impact of NaOH treatment and DFS filler on the tensile characteristics of the biocomposite is illustrated in Figure 3. It is evident that as the proportion of durian skin fiber (DSF) filler rises, the tensile strength and elastic modulus of the Vinylester Fortchem 411 VE/DSF biocomposite decline. This trend aligns with findings from earlier research [4] have mentioned that improvements in the mechanical characteristics of biocomposites result from chemical interactions occurring within the polymer chain. The introduction of cellulose to the matrix limits the mobility of polymer chains, as demonstrated by the integration of well-connected cellulose polymer chains into the matrix polymer chains [10].

Other researchers [11] have indicated that treating plant cellulose with alkali can lead to changes in its morphology, structural crystallinity, and fibrillation, involving the degradation of lignin, pectin, and hemicellulose throughout the alkali treatment. In contrast to the findings of the

Vinylester Fortchem 411 VE/DSF biocomposite study, which shows a decline in tensile strength, this decrease is linked to the existence of trapped air (voids) during the mixing process, causing disruption in the interfacial bonding between fibers and the matrix. This is also caused by poor adhesive forces, resulting in suboptimal stress transfer within the composite. As seen in the graph below, there is a significant decrease from the 0% fiber composition to the 3% and 6% fiber compositions. Subsequently, there is an increase in the tensile strength value at the 9% fiber composition. This is due to the even distribution of fibers and the absence of fiber agglomeration in the biocomposite.

In this tensile test, the addition of fibers is expected to enhance the tensile strength of the biocomposite, providing a reference for replacing commonly used synthetic plastic products. The tensile test results are shown in Figure 2. The tensile strength decreases with the addition of 3% durian skin fiber (DSF), with a value of 51.98 MPa, and 6% with a value of 51.98 MPa, then experiences an increase in tensile strength again with the addition of 9% durian skin fiber, reaching a value of 41.423 MPa. The lowest tensile strength value for the biocomposite with 6% durian skin fiber is at 38.437 MPa. This phenomenon occurs due to poor interfacial bonding inducing microvoids between the filler and the matrix, leading to microcracks. In another study on biocomposites with pineapple leaf and kenaf fiber fillers, there is also a decrease in tensile strength values. This may be attributed to the insufficient percentage of matrix to cover the entire surface area of the fibers due to inadequate fiber moisture, leading to poor interfacial bonding between the fibers and the matrix [13].

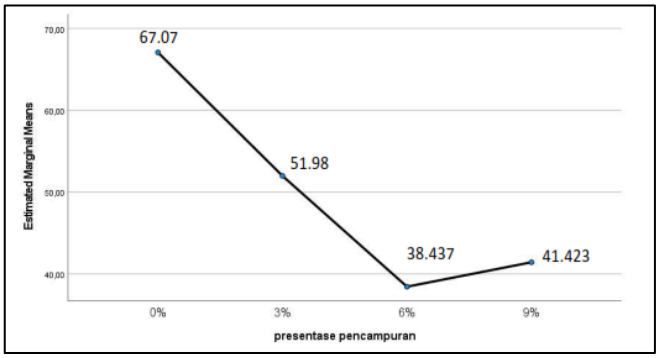

Fig. 3. Tensile test graph

In Figure 3, illustrating the yield strength graph, it can be seen that the addition of durian skin fiber (DSF) influences the yield strength of the biocomposite. Significant changes are observed in the 6% and 9% blends with values of 24.11 MPa and 24.46 MPa, respectively. The 3% fiber blend also experiences a decrease from the pure VE resin yield strength, with a value of 40.41 MPa.

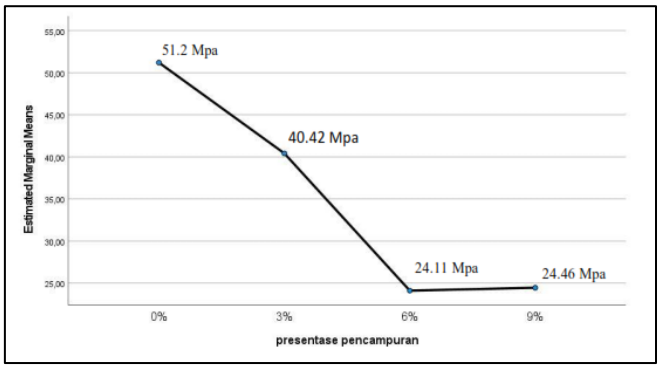

Fig. 4. Yield strength graph

Maximum force refers to the highest force applied to the test specimen before failure or rupture occurs. During tensile testing, the test specimen is subjected to a gradually increasing tensile load until reaching the point of failure. The force applied at the moment of failure is the maximum force that the material can withstand. To determine the ductility of a material, the maximum force is a crucial parameter. In Figure 4, which illustrates the maximum force graph, the addition of durian skin fiber (DSF) mass reduces the ductility of the biocomposite. A decrease is observed with the addition of durian skin fiber (DSF) powder mass at 3% and 6%. Meanwhile, the addition of durian skin fiber powder mass at 9% shows an increase compared to the 6% mixing. Figure 4 demonstrates that the maximum force of pure polyester/vinyl ester is higher than that of the biocomposite with the addition of durian skin fiber (DSF) powder.

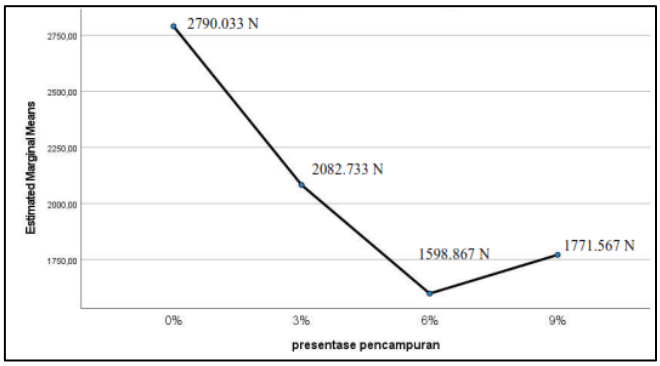

Fig. 5. Maximum force graph

IV. Conclussions

Based on the results of the biocomposite study with a Polyester/Vinyl Ester alloy matrix reinforced by the addition of mass fractions of durian skin fiber powder for tensile property characterization, it can be concluded that the addition of mass fractions of durian skin fiber powder to the Polyester/Vinylester matrix affects the tensile strength properties of the biocomposite. The tensile strength value of pure Polyester/Vinyl Ester is 67.07 MPa. With the addition of the powder, the tensile strength decreases, reaching its lowest point with a 6% powder addition, with a tensile strength value is 38.437 MPa.

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