Mechanical Behavior of OPEFB Fiber Reinforced Polymer Composites - Polymeric Foam Sandwich Panels under Static Loading Conditions

Muftil Badri a*, Dodi Sofyan Arief a, Erik Sitio Johanes a, Ridho Zarli Rahmata a

a) Department of Mechanical Engineering, Universitas Riau, Indonesia

*Corresponding author: muftilbadri@eng.unri.ac.id

1.0 INTRODUCTION
The utilization of palm oil waste for useful technology products is still very limited in number. Some of them have been utilized among others for the manufacture of particle board. Utilization of palm oil waste to become a new commodity is certainly very necessary. In this research, oil palm empty fruit bunch (OPEFB) fiber will be processed as polymeric foam mixture. This material is subsequently used for the sandwich structure of the impact absorption sandwich panels on the motor vehicle supporting components. The impact energy absorbing structures made in this study are not only typical in the selection of materials (OPEFB fiber) but also the design of the construction.

The sandwich composition of foam materials can improve the absorption of the impact energy of the structure. The structure and design of hollow materials have the potential to protect the windshield. Research on the layered board structure has been doing with hollow material [1]. The design of layered board provides a significant influence on the absorption of impact energy [1]. The impact energy of absorbent material has reviewed [2]. The review results show that the design of hollow material structures is very influential to absorb impact energy [2]. A study of polymeric foam responses to impact loading has conducted [3]. The results obtained show that polymeric foam is effectively able to absorb impact energy [3]. Polymeric foam material product design has structural stability when subjected to impact load [4]. The difference in the density of foam material types in layered structures has compared, the results show that foam materials of lower density are able to absorb better energy.

Foam is defined as the spread of gas bubbles that occur in liquid and solid materials. Foam develops into micro cavities that have a diameter of 10 µm. Foams scattered on the polymer can reach $10^{9}/\text{cm}^3$ [5]. At present, the development of research has...
resulted in the physical and mechanical characteristics of foam materials[6]. Physical characteristics include geometry factors, such as cavity size and cavity wall thickness. In addition to physical characteristics there are also mechanical characteristics. Mechanical characteristics consist of density and elastic modulus.

Foams in polymers are formed by mixing solid and gas phases. These two phases occur quickly and form the surface of the foam material. Foams produced from polymers are air bubbles or air cavities that are joined in the polymer [7].

The gas used to form foam is called blowing agent. Giving blowing agent is done chemically and physics. Blowing agents chemically cause decomposition of material elements in a chemical reaction. Blowing agent physically occurs due to the gas given to the material. Polymeric foams that are flexible are generated by polyurethane reactions. Polyurethane in the formation of polymeric foam also serves as a blowing agent. The cavity formation process of flexible polyurethane reaction results is relatively fast. At the time of reaction polyurethane formation occurs expenditure of heat (exothermal) with temperature rise reach 75 to 160°C. Increased volume generated by polyurethane about 20 to 50 times the initial volume [8].

Research on the layered board structure with hollow material has been doing [1]. The design of layerd board provides a significant influence on the absorption of impact energy. According to [1], plated plates with hollow material fillers of square have type cavities and folders. Both models have a comparable behavior to the performance of structural resistance to static and impact loading deformations. Hollow material loading in the structural layer affects structural reliability subject to impact load.

The mechanics of impact and energy absorption on materials and structures has reviewed [2]. The review results [2] show that the design of hollow material structures is very influential to absorb impact energy. Heterogeneous and anisotropic materials have beneficial characteristics to reduce impact damage. This is due to the many mechanisms of kinetic energy transformation from emphasis on: rapid opening of surface cracks, delocalization of damage areas, plastic deformation, buckling, and the type of damage that alters the material response.

A study of polymeric foam responses to impact loading has conducted [4]. The results obtained by [1] show that polymeric foam is effectively able to absorb impact energy. The presence of cavities affects the elastic stress limit, the maximum stress, and the strain achieved for fracture. The elastic stress limit and maximum voltage of polymeric foam achieved by OPEFB fibers are lower than the resin because the cavity causes the voltage to be reduced. OPEFB fiber-reinforced polymeric foam breaks faster in small strains, indicating that OPEFB fiber-reinforced polymeric foam is more fragile than resin and polyurethane. Different failure modes on each material can provide information about the characteristic of the material. Polyurethane fails on a non-uniform locate deformation state, resin and polymeric foam reinforced OPEFB fibers show a failure dominated by shear failure.

The polymeric foam material product design has structural stability when subjected to impact load [3]. Based on the response data and characteristics it can be said that the elasticity and strength properties can be recommended that the OPEFB fiber-reinforced polymeric foam can be used as an alternative material for dynamic structures.

The layered structure with hollow material is performed on the research of [9] due to the low impact load. The impact test applied to the instrumentation falls at a certain height (drop tower). The composite sandwich used is a glass fiber reinforced polymer composite. The results of [9] showed that foam materials of lower density were able to absorb better energy in sandwich structures.

The size of OPEFB fiber diameter varies considerably. A single fiber form of OPEFB fiber was observed using an optical microscope. Several studies have been conducted to observe the size of OPEFB fiber diameter. A single OPEFB fiber diameter is ranging from 250 to 610 μm [10]. Based on [10] it can be seen that the size of OPEFB single fiber diameter varies considerably. The single fiber diameter of OPEFB fiber is 150 to. 442 μm [11] OPEFB single fiber diameter ranges from 150 to 500 μm [12,13].

2.0 EXPERIMENTAL METHOD

OPEFB that has been obtained and then grab the fiber by cut and separated from the OPEFB rod. The separated fibers were treated by 3 methods. Method 1, OPEFB fibers are boiled with water with a temperature of 50°C to 80°C for 30 minutes. Method 2, the OPEFB fiber was soaked with 5% NaOH solution for 2 hours. Method 3 OPEFB fiber boiled with 5% NaOH solution for 30 minutes with temperature 50°C to 80°C.

The first fiber using method 1 is partially taken and then cutting using a blender with a 2-speed variation. The fibers are cut with water to facilitate the enumeration of OPEFB fibers. Cutting using this blender is done for 5 minutes. The fiber that has become the sheet is carried out by using sunlight. Drying of fiber is done until the water content of the fiber has reached 0%. The fiber that has become the sheet is cut with dimensions of 25 mm x 15 mm. Fiber that has not been done by direct enumeration is done by drying until the water content reaches 0%. If the water content test results have not reached 0%, the OPEFB fiber is dried again until the moisture content reaches 0%. The fibers treated with method 2 and method 3 are carried out similarly to the fibers treated by method 1.

The working procedure of the composite technique of making VARI method shown in Figure 1 is by operating the pump, after the vacuum pump is operated then adjusting the pressure by closing the inlet channel then arranging the control valve opening to adjust the pressure. The pointer on the manometer is noted until it shows the number of pressure scales to be used.
The tensile test is carried out by giving the tensile load slowly until the specimen is broken. The tensile strength of the brake pad composites were determined by a universal testing machine (UTM) at room temperature. Each sample was placed between the lower cross member and lower cross head of the UTM, and the load was applied at a cross-head speed of 2.5 mm/min. The load at which failure occurred was used to calculate the tensile strength of the sample.

The flexural test is performed by loading the loads slowly down until the specimen reaches the yield point. In the flexural test, the top of the specimen is subjected to pressing and the lower part is subjected to tensile loading so that the specimen has a broken bottom because it is unable to withstand tensile stress.

The composites that have been made in this research are the multi-stage polymeric foam sandwich panels - OPEFB fiber composites with the resulting size 400 mm x 400 mm with a thickness of 8 mm. Then the composite plate is cut into test specimen according to ASTM D 638-02 standard for tensile testing, ASTM D 790-02 standard for flexural test, and ASTM E 23-00 standard for impact testing. Figure 4.1a shows the process of making multi-stage polymeric foam sandwich panels - OPEFB fiber composites by the VARI method.

3.0 EXPERIMENTAL RESULTS and DISCUSSIONS

Specimens of OPEFB fiber reinforced polymer composites-polymeric foam sandwich panels are shown in Figure 2.

![Figure 1: Vacuum assisted resin infusion (VARI)](image1)

![Figure 2: Specimens of OPEFB fiber reinforced polymer composites-polymeric foam sandwich panels](image2)

![Figure 3: Tensile strength of OPEFB fiber reinforced polymer composites-polymeric foam sandwich panels (method 1)](image3)
The average tensile strength of the composite by method 2 was 18.12 N/mm². The standard deviation of the tensile strength of the test results is known to be 4.11 N/mm². Tensile strength of multi-stage polymeric foam sandwich panels - OPEFB fiber composite with method 3 is shown in Figure 5.

The average flexural strength of composite with method 2 was obtained 116.37 N/mm², standard deviation was known 38.45 N/mm². Standard deviation of flexural test result (method 2) is known 38.45 N/mm². The average flexural strength of the multi-stage polymeric foam sandwich panels of OPEFB fiber boiled with 5% NaOH solution for 30 min with a temperature of 50º C to 80º C (method 3) was obtained 108.86 N/mm², the standard deviation of flexural strength test results known 31.57 N/mm².
From the tensile test results of multi-stage polymeric foam sandwich panels of OPEFB fiber obtained high tensile strength on composites with OPEFB fibers soaked with 5% NaOH solution for 2 hours. From the results of batch testing of polymeric foam sandwich panels of fiber OPEFB fiber obtained high flexural strength on composites with OPEFB fibers boiled with water with a temperature of 50º C to 80º C for 30 minutes.

Figure 9 is a micrograph of a multi-stage polymeric foam sandwich panels - OPEFB fiber composite fracture surface under static uniaxial tensile loading. From SEM observations, OPEFB fibers break up due to tensile loading. OPEFB fiber surface is broken relatively evenly perpendicular to the direction of the load. The photo of SEM shown in Figure 9 is OPEFB fiber which is soaked NaOH for 2 hours. The interface bonds of OPEFB and polymer fibers show that OPEFB fibers are able to increase composite tensile strength.

Figure 9: SEM on fracture surface of OPEFB fiber composite subjected to static uniaxial tensile loading

Figure 10 is a micrograph of a multi-stage polymeric foam sandwich panels - OPEFB fiber composite fracture surface under flexural loading. SEM observations were shown in Figure 10 is OPEFB fiber boiled with water at temperatures of 50º C to 80º C for 30 minutes. From interfacial bond images of OPEFB and polymer fibers, it is known that OPEFB fibers are not strongly bonded with polymers, this causes a decrease in flexural strength.

Figure 10: SEM on fracture surface of OPEFB fiber composite subjected to static flexural loading

4.0 CONCLUSIONS

The multi-stage polymeric fiber foam sandwich panels of OPEFB fibers with variation of OPEFB fiber treatment have been obtained. The average tensile strength of multi-stage polymeric foam sandwich panels with OPEFB fibers was soaked with 5% NaOH solution for 2 hours higher than those boiled using water and NaOH. While the flexural strength of the multi-stage composite polymeric foam sandwich panels with OPEFB fibers are boiled with water at temperatures of 50º C to 80º C for 30 minutes higher than those with soaked in NaOH and boiling NaOH.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the Research and Community Service Institute of Universitas Riau which supported this research by Penelitian Dosen Muda program in 2017, contract no. 789/UN.19.5.1.3/PP/2017.

REFERENCE


