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By SRIYANTI SRIYANTI

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High Compressive Strength of Palm Oil Empty Fruit Bunches (*Elaeis guineensis*) Composites

Ida Sriyanti[a], Lina Agustina[b], Iftita Selviana[c], Leni Marlina[d]

Physics Education Study Program, Sriwijaya University, Indonesia

[a]ida_sriyanti@yahoo.com, [b]linaphysics09@gmail.com, [c]iftitaselviana@yahoo.com, [d]leni_fisika@yahoo.co.id

Keywords POEFB, PVAc, silica nanoparticles, composites, compressive strength

Abstract. Simple mixing and hot pressing methods were used to fabricate high-strength and light-weight composite from POEFB by using PVAc as adhesive and silica nanoparticles as fillers. The mechanical strength of the composite was examined in term of compressive strength. The optimum composition of POEFB/PVAc was 13:2. A compressive strength of 82.88 MPa was obtained for samples prepared at pressing pressure of 80 MPa, a pressing temperature of 150^{o}C and a pressing time of 15 min. The addition of silica nanoparticles increased the compressive strength by about 20%. A compressive strength 100.30 MPa was measured. At pressing pressure of 100 MPa, pressing temperature of 225 ^{o}C, and pressing time of 15 minutes, we found compressive strength of 115.35 MPa. XRD data showed that silica nanoparticles, PVAc, and PVAc + silica nanoparticles were in amorphous phase. The compressive strength data showed that our composite is stronger than the composite made by Masturi. Thus, it is feasible to be used in many applications, especially in furnishings.

Introduction

South Sumatera is one of the greatest provinces in which palm oil farm area is about 696,503.29 Ha [1]. Palm oil empty fruit bunches (POEFB) is one of palm oil industries wastes. Generally, palm oil industries produce 1.1 – 1.5 tons of POEFB for each ton of crude palm oil (CPO) [2]. However, there are some insignificant solutions for this waste problem. POEFB is burned or discarded as it is not used or processed. It directly contributes to the environmental pollution.

On the other hand, the use of woods as the basic material for home furnishings has generated serious problem in terms of global warming. Deforestation, especially in Indonesia, has reduced forested area. It is the impact of the human needs of woods for many purposes. It is important to find alternatives to replace wood based materials in human needs.

In the present work we report on the use of POEFB to make composites that might be reused to make some home furnishings. This approach could have two simultaneous advantages: reduction of the deforestation rate and a solution to environmental problem caused by POEFB. Characterization of some of the composites' important properties, such as compressive strength, was performed. A previous report by Kumagai and Sasaki [3] on the use of rice husks to make composites found that the compressive strength of the composites reached 55.7 MPa and Masturi [4] found that the compressive strength of the home waste composite reached 84.37 MPa.

The use of silica nanoparticles as fillers was also performed. The addition of silica nanoparticles reinforces the mechanical strength of the composites. Sriyanti, et al. utilize silica nanoparticles in fabricating nanocomposite from sawdust [5] and Hadiyawarman, et al. utilize silica nanoparticles in fabricating nanocomposite from dry waste [4,6]. Besides, silica nanoparticles can also be used in fabricating nanocomposite from clay [7-9].

Experimental

In this experiment, POEFB brought from Tanjung Siapi-api, South Sumatera, Indonesia. The composites were made from POEFB. Commercial polyvinyl acetate (PVAc; FOX^{TM}) was used as an adhesive. The filler material was silica nanoparticles purchased from Bratachem (Indonesia).

As the first step, POEFB were cut into small pieces with size of about 1 mm and crushed by using mechanical blender. Polyvinyl acetate (PVAc; FOX^{TM}) was used as an adhesive. In specific mass, it was dissolved in 10 mL of water and stirred for 20 minutes by using magnetic stirrer. Water could be used as solvent because PVAc is a hydrophilic polymer. POEFB was then put into the PVAc solution, mixed and dried in oven for 15 minutes. The mixture was then put into a cylindrical mold and hot-pressed at varied presing pressures and temperatures. The fabricated samples had diameter of 26 mm and height of 15 – 18 mm. The samples containing PVAc and POEFB with optimum compressive strength are used for further experiment. In this experiment, silica nanoparticles were added to the samples.

The main characterization performed was the measurement of compressive strength. The measurement was performed by using a Torsee (Tokyo Testing Machine MFG, Ltd.). The size of silica nanoparticles was measured by using a scanning electron microscope (SEM JEOL JSM-6360LA) and its crystallization was determined by X-ray diffraction (XRD).

Results and Discussion

We first determined the optimum mass fraction of POEFB and PVAc. From the experiment, as shown in Figure 1, the optimum mass fraction of POEFB/PVAc is 13:2. From this optimum mass fraction, we found that the optimum compressive strength is 82.88 MPa.

The compressive strength of composite is related to the spaces of polymer chains and particles mobility. Before the addition of POEFB, PVAc consists of flexible polymer chains which have many spaces. Besides that, without any addition, particles in polymer chains are mobile. When POEFB is put into PVAc solution, it impregnates into most of polymer chains spaces. Thus, the spaces are reduced and the compressive strength is increased until the composite reaches its optimum compressive strength. Since the polymer chains spaces are limited, the addition of more POEFB to the optimum mass fraction will not increase the compressive strength.

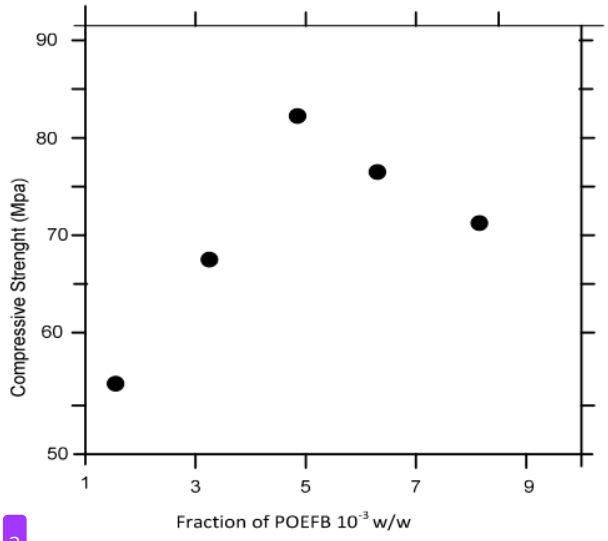

Figure 1. POEFB mass fraction effect on the composite compressive strength. The pressing pressure was maintained at 80 MPa, the pressing temperature at 150^{o}C, and the pressing time at 15 min.

The optimum mass fraction of POEFB and PVAc was then used to make composite with higher compressive strength by using silica nanoparticles as fillers. As shown in Figure 2, an optimum compressive strength of 100.39 MPa was obtained when the mass fraction of POEFB/PVAc/Silica nanoparticles was 13:2:0.75.

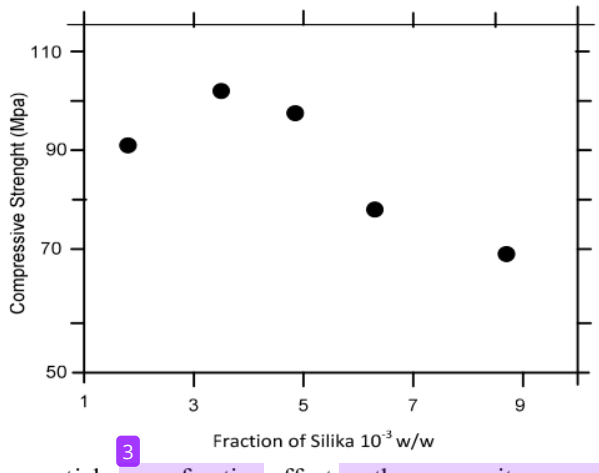

Figure 2. Silica nanoparticle mass fraction effect on the composite compressive strength. The pressing pressure was maintained at 80 MPa, the pressing temperature at 150°C, and the pressing time at 15 min.

The addition of silica nanoparticles increases the compressive strength of the composite. Silica nanoparticle has extremely high surface area as it can easily impregnate into the polymer chains spaces [6]. Polymers have lower compressive strength than the compressive strength of woods, metals, and ceramics. One of the ways to modify its mechanical properties is by reinforcing polymers with particulate fillers [10].The impregnation process is better than the impregnation of POEFB which has size in milimeters.

After having the optimum fraction of POEFB, PVAc, and silica nanoparticles, we varied the pressing pressure to obtain higher compressive strength. As shown in Figure 3. We found that initially the compressive strength is increased as we increased the pressing pressure, then it reached a saturation value at pressing pressure of 100 MPa. At this pressing pressure, we obtained optimum compressive strength of 115.35 MPa. However, this optimum compressive strength is higher than the compressive strength of composite made by Masturi (84.37 MPa) [4] and Kumagai (55.7 MPa) [3].

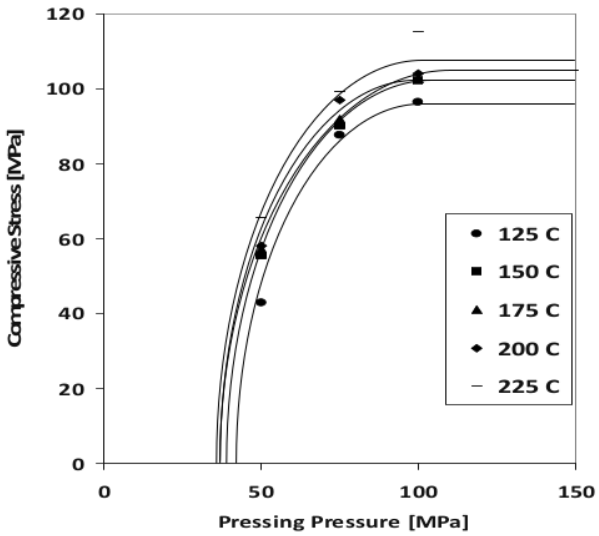

Figure 3. Pressing pressure variation effect on the composite compressive strength. The pressing time was fixed at 15 min.

This saturation value relates to the Young's modulus of the composites [10]. The addition of nanoparticles improves the modulus since they have less stiffness than the composite. Addition of pressing pressure eases the nanoparticles to impregnate into the polymer chains. The impregnation affects the increasing of composite density, shortening distance between particles, and decreasing porousity. These effects give contribution to the increasing of compressive strength since composite has more efficient compression transfer mechanism.

The characterizations we used in this experiment were SEM to determine the size of silica nanoparticles and XRD to determine the crystallization of PVAc, silica nanoparticles, and PVAc + silica nanoparticles. The size of silica nanoparticles is shown in Figure 4. SEM image shows that particles are in size of about 100 nm.

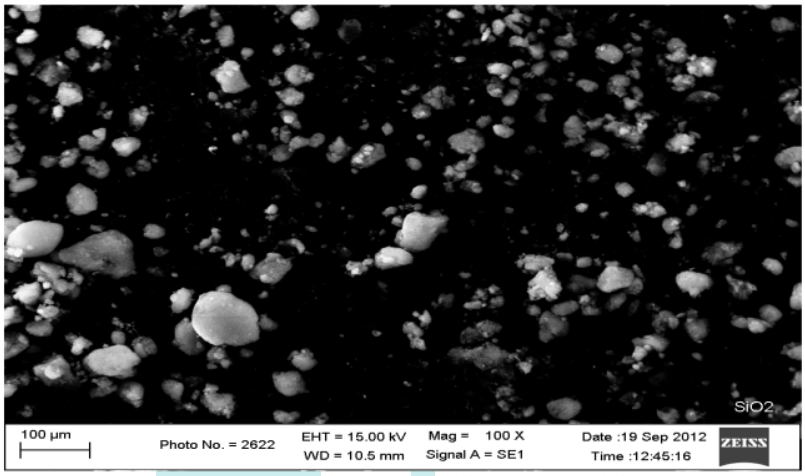

Figure 4. SEM images of silica nanoparticles

Figure 5 shows the XRD of PVAc, silica nanoparticles, and PVAc + silica nanoparticles. All samples show no sharp peak in 2θ. The behaviour of these curves indicates that both silica nanoparticles and PVAc are in amorphous phase. The addition of silica nanoparticles into PVAc increases the amorphous characteristic as shown in Figure 5c.

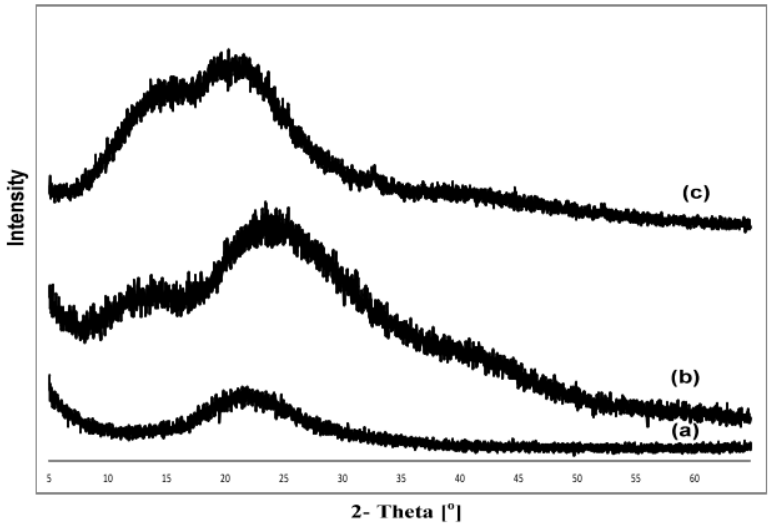

Figure 5. XRD images of (a) Silica Nanoparticles, (b) PVAc, and (c) PVAc – Silica Nanoparticles.

Conclusion

We succeeded in making composites with simple mixing and hot pressing methods by using POEFB, PVAc, and silica nanoparticles. Mass fraction of PVAc/POEFB of 13 : 2 has compressive strength of 82.88 MPa. Composite with high compressive strength of 100.39 MPa was obtained using silica nanoparticles at a pressing pressure of 80 MPa, pressing temperature of 150 ^{o}C, and pressing time of 15 minutes. When the pressing pressure of 100 MPa was applied, the compressing strength increased until reached a saturation value at 115.35 Mpa. These results are better than those of Masturi of home waste composite [4] in which its compressive strength is 84.37 MPa and also better than Kumagai and Sasaki of rice husk composite reached 55.7 MPa [3]. Thus, the composite is feasible to replace wood-based composite, especially in furnishing.

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