TiMER

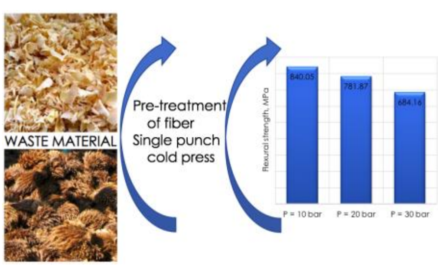
Trends in Mechanical Engineering Research

STUDY OF PARTICLE BOARDS CHARACTERISTIC BASED ON SENGON WOOD PARTICLE AND OIL PALM EMPTY FRUIT BUNCHES

Rizky Kurnia Putra[a], Sunardi Sunardi[a]*, Moh. Fawaid[b], Rina Lusiani[a], Iman Saefuloh[a], Agung Sudrajad[a]

[a] Department of Mechanical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia
[b] Department of Mechanical Engineering Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Banten, Indonesia
*Corresponding author: sunardi@untirta.ac.id

Graphical abstract



Abstract

Oil palm empty fruit bunches (OPEFB) as a by-product of the palm oil processing industry. This waste can cause problems for the environment and human health. Utilization of OPEFB waste as particle board material to reduce this waste. The composition of the particle board is based on volume fraction, namely 15% empty palm fruit fiber, 15% *epoxy resin, 20% PVAc adessive*, and 50% sawdust. The manufacturing process of samples was carried out using the *single punch cold press* method with compaction pressure of 10, 30, and 50 bar. The experimental results show that a compacting pressure of 10 bar can produce particle board performance according to SNI 03-2105-2006 with a characteristic density of 0.93 gram/cm^3, thickness swelling of 2.52%, hardness of 24 N/mm^2, flexural strength of 840.05 N/mm^2, and impact strength 6.00 kJ/m^2.

Keywords: particle board, biodegradable, oil palm empty fruit bunches, physical properties, mechanical properties

Abstrak

Tandan kosong kelapa sawit (TKKS) merupakan produk sampingan dari industri pengolahan kelapa sawit. Limbah ini dapat menimbulkan masalah bagi lingkungan dan kesehatan manusia. Pemanfaatan limbah TKKS sebagai bahan papan partikel untuk mengurangi limbah tersebut. Komposisi papan partikel berdasarkan fraksi volume yaitu 15% serat buah sawit kosong, 15% resin epoksi, 20% perekat PVAc, dan 50% serbuk gergaji. Proses pembuatan sampel dilakukan dengan metode *single punch cold press* dengan tekanan kompaksi 10, 30, dan 50 bar. Hasil percobaan menunjukkan bahwa tekanan kompaksi 10 bar dapat menghasilkan kinerja papan partikel sesuai SNI 03-2105-2006 dengan karakteristik kerapatan 0,93 gram/cm^3, pengembangan tebal 2,52%, kekerasan 24 N/mm^2, kekuatan lentur 840,05 N/mm^2, dan kekuatan impak 6,00 kJ/m^2.

Kata kunci: papan partikel, *biodegradable*, tandan kosong kelapa sawit, sifat fisik, sifat mekanik

Doi: xxx

Article history
Received
13 June 2023
Received in revised form
15 June 2023
Accepted
26 June 2023
Published
30 June 2023

1.0 INTRODUCTION

Oil palm empty fruit bunches (OPEFB) are solid waste produced by palm oil processing industries. The amount of palm oil production in Indonesia has increased from year to year. OPEFB becomes waste that can disturb the environment. Burning OPEFB waste can trigger air pollution which can interfere with human health.

Engineering processing of OPEFB waste must be carried out to minimize the impact it causes. One effort that can be done is to study the potential of OPEFB waste as a composite. Lusiani et al. [1] have utilized OPEFB fiber as a particle board. From this research, it is known that the fiber length of 15 mm produces the best particle board characteristics. OPEFB waste is made into particles by Raharjo [2] as particle board filler. The matrix used in this study was PVAc with variations of 20, 30, and 50%. The results of the research show that the thickness is very large and exceeds SNI 03-2105-2006.

Oil palm tree trunks can also be used as particle boards. Sunardi et al. [3] [4] showed that the finer the OPEFB stem filler, the better the mechanical properties. Several parameters tested, such as density, thickness development, flexural strength, and screw pullout strength, met the standard type 8 particle board based on SNI 03-2105-2006.

Manufacturing process parameters significantly influence the quality of the resulting particle board. Process parameters often observed are pressing pressure, pressing time, and pressing temperature. A different statement was reported by Fithriani et al. [5], which stated that the pressing time did not significantly affect the particle board's properties.

Mbakop et al. [6] compared the compaction temperature at 23 and 100 °C on hemp fiber composites' permeability and mechanical properties. This research shows that hot compaction increases the composite's tensile strength, flexural strength, and modulus. This finding was reinforced by Gharaibeh et al. [7] who stated that the heat treatment temperature of the composite did not significantly affect the volume of the microcrystalline cellulose compact.

Xiao et al. [8] showed that a compaction pressure of 800 MPa is the optimum value for manufacturing magnetic composites. A similar phenomenon was also conveyed by Gharaibeh et al. [7] that compaction pressure has a very significant effect on increasing the tensile strength of compacts of microcrystalline cellulose.

This research will explain the correlation between compaction pressure and particle board quality based on SNI 03-2105-2006. This research contributes to determining one of the process parameters for manufacturing particle boards based on organic materials in Indonesia.

2.0 METHODOLOGY

2.1 Materials

Oil palm empty fruit bunches. OPEFB waste is obtained from the palm oil processing industry in Pandeglang, Banten. OPEFB comprises 22.23% lignin, cellulose 37.76%, hemicellulose 68.88%, and ash 6.59%. OPEFB fiber was pretreated by soaking in 5% alkali for 2 hours [9]. The fiber length used in this research is 15 mm [10].

Sengon wood powder. Sengon wood particles were obtained from the waste of the woodcraft industry in Cilegon. The particle size of the wood in this research is 40 mesh.

Epoxy resin. Epoxy resin is a thermosetting material used extensively in structural composite applications. Epoxy resin was obtained from PT. Westers Industries Cikarang with the Multi-Purpose Ups brand.

Figure 1. The constituent materials of particle board composites

PVAc adessive. Polyvinyl acetate (PVAc) is a polymer that has powerful adhesive properties. The use of PVAc glue in this study was based on the consideration that when it comes into contact with water, it can be damaged, so the combination of PVAc and epoxy resin can improve mechanical properties but is degradable.

2.2 Sample preparation

OPEFB fiber is pretreated with alkaline immersion to modify the surface contour and release the lignin accompanying the fiber. Alkaline soaking was done using 5% NaOH solution for 2 hours, then washed with distilled water and dried for 48 hours at room temperature.

Epoxy resin and hardener are prepared in a 1:1 ratio and mixed with PVAc glue until smooth. After that, the fibers and particles are added gradually and stirred using *an electric mixer* at 700 rpm for 20 minutes

[11]. The homogeneous mixture was left for 15 minutes before being manufactured.

The composition of the particle board material was arranged based on volume fraction, namely 15% empty palm fruit fiber, 50% sengon wood particles, 15% *epoxy* resin, and 20% *PVAc* adessive [12]. The compaction process was carried out at the Laboratory of Metallurgical, Universitas Sultan Ageng Tirtayasa with a holding time of 120 minutes and varying pressures of 10, 30, and 50 bar.

Figure 2. Particleboard composite compaction process

2.3 Materials characterization

a. **Particle board density**. The sample used for the density test was 70x30x10 mm. The equation expresses the density of the particle board composite:

$$\rho = \frac{W}{V}$$

where, ρ is the density (gram/cm^3), w is the sample weight (grams), and V is the sample volume (cm^3).

b. **Thickness swelling**. Thickness swelling indicates the dimensional stability of particle board when in contact with a moist or wet environment. The sample used for thickness swelling testing is 70x30x10 mm. Based on the SNI 03-2105-2006 standard, samples were placed horizontally and lengthwise, then immersed at room temperature approximately 30 mm below the water's surface for 24 hours. The equation expresses the amount of thickness swelling:

$$TS = \frac{t_2 - t_1}{t_1} \text{ x } 100\%$$

Where t_2 and t_1 are the thickness of the sample after and before immersion, respectively.

c. **Hardness testing**. Composite hardness testing was carried out at the Center of Polymer Technology Laboratory, LIPI concerning the ISO 2039-1 standard. The indenter used is a steel ball with a diameter of 5 mm. The initial load of 9.8 N increases to 49 N, then is held for 30 seconds.

d. **Flexural strength**. Particle board flexural strength testing was carried out at the Center of Polymer Technology Laboratory, LIPI concerning the ASTM D790 standard. The method used is three-point bending with a beam-shaped specimen measuring 12.7x3.2x125 mm.

e. **Impact strength**. Particle board impact testing was carried out at the Center of Polymer Technology Laboratory, LIPI concerning the ISO 179-1 standard. The size of the impact test sample is 10x80x5 mm.

3.0 RESULTS AND DISCUSSION

3.1 Density of particleboard

Figure 3 shows that the density of particleboard composites increases with higher compaction in the manufacturing process. The density of this composite is relatively high, up to 1.02 gram/cm^3. This value has exceeded the density required by SNI 03-2105-2006, which is between 0.40–0.90 g/cm^3. These results indicate that providing a compaction pressure of 10 bar during the particle board manufacturing process can meet the criteria of SNI 03-2105-2006. The results of this study are consistent with those reported by Viel et al. [13] that the higher the compaction pressure, the higher the density of the composite.

The powder metallurgy process also shows the same phenomenon, that the higher compaction pressure, the density of copper metal also increases significantly [14].

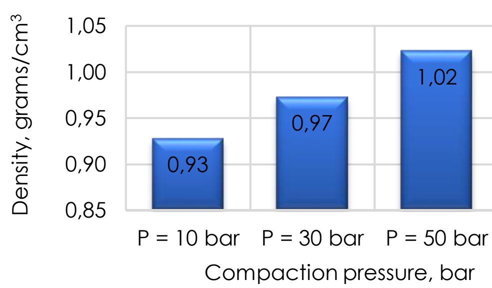


Figure 3. Correlation between compaction pressure and composite density

This increase in compaction pressure can trigger an increase in the contact area between the composite materials. This condition can cause the formation of interlocking between particles to become stronger. Research conducted by Asfarizal et al. [15] showed the same phenomenon, namely that the density of the composite was higher as the compaction pressure increased. Xiao et al. [8] also reported that the higher the compaction pressure, the higher the composite density obtained.

3.2 Thickness Swelling of particleboard

The thickness swelling describes the dimensional stability of the resulting particle board. This dimensional stability is needed to maintain the specified size tolerances. Particle board found on the market is very susceptible to damage if it comes into contact with water. Diffusing water into the particle board can weaken the bond between the matrix and the fiber and filler. For this reason, it is necessary to engineer the material making up the particle board so that it has resistance to water diffusion.

Figure 4 shows that the higher the compaction during the manufacturing process, the smaller the thickness expansion. This phenomenon is caused by the particle board's more negligible porosity, so the water diffusion rate into the material flows slower. The percentage of expansion of particle board thickness is in the range of 23.33%. Meanwhile, according to SNI 03-2105-2006, the allowable thickness expansion is limited to 25% for particleboard thickness ≤12.7mm, 20% for >12.7mm thickness, and 12% for particleboard on the market. Figure 4 showed that the particle board produced has exceeded SNI 03-2105-2006.

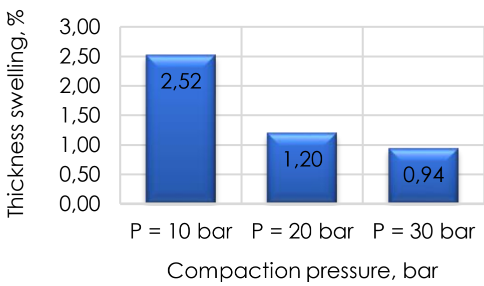


Figure 4. Correlation between compaction pressure and composite density

3.3 Hardness

Compaction pressure has a linear correlation with the surface hardness of the particle board composite. At compaction pressures of 10, 30, and 50 bar, the hardness was 24, 25 and 27 N/mm², respectively. This hardness value has exceeded the hardness of the manufacturer's particle board which has a hardness of 21 N/mm². This result agrees with that reported by Xiao et al. [8].

SNI 03-2105-2006 does not specify the surface hardness of the particle board. This hardness test is carried out by considering that the particleboard is very likely to collide with other objects, so hardness is estimated to be an essential parameter.

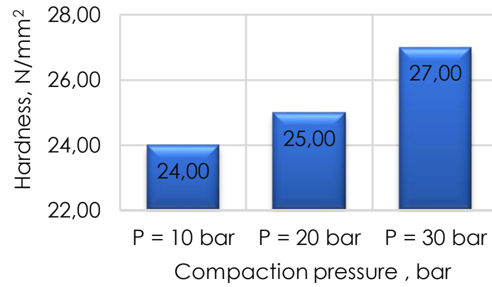


Figure 5. Correlation between compaction pressure and composite hardness

3.4 Strength Impact

Figure 6 shows that the compaction pressure applied to the composite sample when making particle board greatly influences its impact strength. The impact toughness of particleboard increases with compaction pressure.

The impact toughness of the developed particle board is relatively high, an increase of 87.38-129.30% from the toughness of manufactured particle board widely used as furniture.

This phenomenon indicates that the particle board has physical and mechanical properties that exceed the particle board on the market.

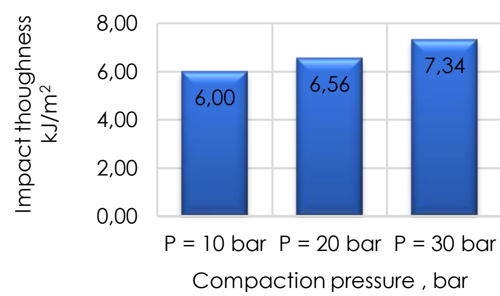


Figure 6 Correlation between compaction stress and composite impact strength

3.5 Bending strength of particleboard

The flexural strength testing used the three-point bending method on beam specimens with ASTM D790 standard testing. The results of the flexural strength test are shown in Figure 7. The flexural strength of the particle board is inversely proportional to the compaction pressure. This decrease in flexural strength is also inversely proportional to the density of the composite. This phenomenon is because the higher the density, the more brittle the material.

The experimental results show that compaction pressure of 10, 30, and 50 bar produce the particle board's flexural strength of 840.05, 781.87, and 684.16 N/mm², respectively. The value of the flexural strength of the manufacturer's particle board was found to be 704.56 N/mm².

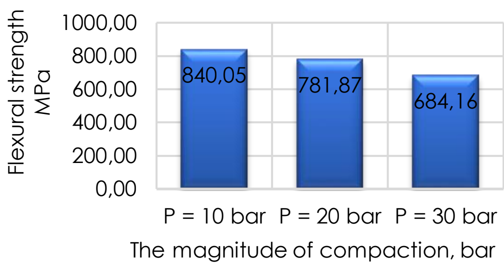


Figure 7 Correlation between compaction stress and composite impact strength

3.6 Observation of Surface Morphology

The composite surface morphology was observed using an optical microscope with 50X magnification. Figure 8 shows that the distribution of the particle board composite material is quite good. This performance causes a reasonably good increase in particle board's physical and mechanical properties.

Figure 8 shows the materials that make up the particle board: resin that looks black, white PVAc glue lumps, wood particles that look gray, and shiny white fibers. This figure shows the bond in the form of *trapping between epoxy* resin, *PVAc adessive,* palm fiber, and wood particles so that the particle board performs better than the properties of the individual constituent materials.

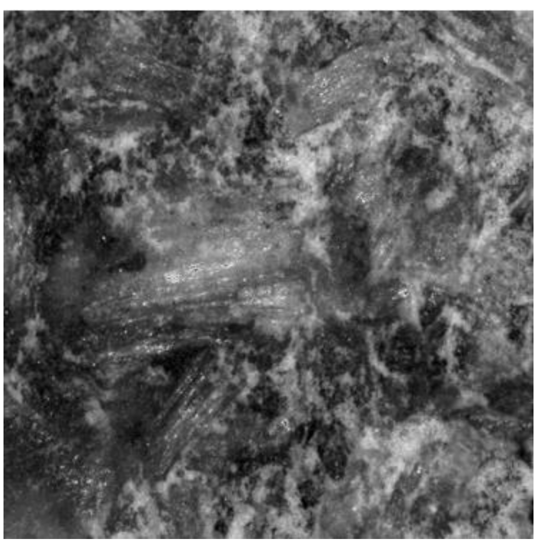


Figure 8 Morphology of particle board's surface

4.0 CONCLUSION

The manufacturing process on particle board manufacturing process has a significant influence. This research shows that the ideal compaction pressure to produce particle board according to SNI 03-2105-2006 is 10 bar with a characteristic density of 0.93 gram/cm^3, thickness expansion of 2.52%, hardness of 24 N/mm^2, a flexural strength of 840.05 N/mm^2, and an impact strength of 6.00 kJ/m^2. Another interesting finding is that the materials that make up the particle board are compatible with producing the best performance.

Acknowledgement

The author would like to thank all stakeholders who have assisted in this research, especially the Metallurgical Laboratory of Sultan Ageng Tirtayasa University and the Center for Polymer Technology Laboratory, LIPI

References

[1] Lusiani, R., Sunardi, S., Ardiansah, Y. 2015. Pemanfaatan limbah tandan kosong kelapa sawit sebagai papan partikel komposit dengan variasi panjang serat. Flywheel: Jurnal Teknik Mesin Untirta. 1(1): 46-54.

[2] Raharjo, B. 2020. Pemanfaatan limbah tandan kosong kelapa sawit sebagai bahan pengganti alternatif papan partikel. Indonesian Journal of Laboratory. 2(2): 1-9.

[3] Sunardi, S., Lusiani, R., Andrean, J., Fawaid, M. 2017. Karakteristik dan potensi limbah kelapa sawit sebagai papan partikel. Prosiding Seminar Nasional Pengelolaan Lingkungan SNPL 2017, Palembang.

[4] Sunardi, S., Fawaid, M., Lusiani, R., Parulian, R. 2017. Pengaruh butiran filler kayu sengon terhadap karakteristik papan partikel yang berpenguat serat tandan kosong kelapa sawit. Jurnal Mesin Teknologi. 11(1): 28-32.

[5] Fithriani, D., Nugroho, T., Basmal, J. 2006. Pengaruh waktu pengempaan terhadap karakteristik papan partikel dari limbah padat pengolahan Gracilaria sp. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan. 1(2): 125-133.

[6] Mbakop, R.S., Lebrun, G., Brouillette, F. 2019. Effect of compaction parameters on preform permeability and mechanical properties of unidirectional flax fiber composites. Composite Part B. 176: 1-10.

[7] Gharaibeh, S.F., Obeidat, W.M., Al-Zoubi, N. 2022, Effect of post-compaction heating on characteristics of microcrystalline cellulose compacts. e-Polymers. 22: 536–543.

[8] Xiao, L., Sun, Y., Yu, L. 2011. The effect of compaction parameters and dielectric composition on properties of soft magnetic composites. Journal of Physics: Conference Series. 303: 1-6.

[9] Sunardi, S., Lusiani, R., Nugraha, A.Y., Fawaid, M. 2018. Perlakuan alkali pada serat tandan kosong kelapa sawit terhadap mutu papan partikel. Prosiding Seminar Nasional Sains dan Terapan IV, Manado.

[10] Lusiani, R., Sunardi, S., Ardiansah, Y. 2015. Pemanfaatan limbah tandan kosong kelapa sawit sebagai papan komposit dengan variasi panjang serat. Flywheel: Jurnal Teknik Mesin. I(1): 46-54.

[11] Sunardi, S., Lusiani, R., Saefuloh, I., Listijorini, E., Sumarna, A.E., Fawaid, M., Meliana, Y. 2020. Particleboard characterization using sawdust from sengon wood, mahogany wood, bayur wood, and rice husk ash as composite fillers. IOP Conf. Series: Materials Science and Engineering. 909: 1-10.

[12] Sunardi, S., Fawaid, M., Chumaidi, M. 2016. Pemanfaatan serat tandan kosong kelapa sawit sebagai penguat papan partikel dengan variasi fraksi volume serat. Machine: Jurnal Teknik Mesin. 2(1): 36-39.

[13] Viel, M., Collet, F., Lanos, C. 2020. Effect of compaction on multi-physical properties of hemp-black liquor composites. Journal of Material Research and Technology. 9(2): 2487-2494.

[14] Dixit, M., Srivastava, R. 2018. Effect of compaction pressure on microstructure, density and hardness of Copper prepared by Powder Metallurgy route. IOP Conf. Series: Materials Science and Engineering. 377: 1-9.

[15] Asfarizal, Kasim, A., Gunawarman, Santosa. 2019. Efek Tekanan dan Temperatur pada Pembuatan Papan Partikel Berbahan Tandan Kosong Kelapa Sawit dan Kulit Pinus. Jurnal Teknik Mesin Institut Teknologi Padang. 9(1): 1-5.