International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 07, Issue – 10, October 2022, PP – 32-37

PVAc/Epoxy Resin Ratio as Hybrid Matrix toward Hardness and Thickness Swelling of Particleboards Reinforced of Oil Palm Empty Fruit Bunch (OPEFB)

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Abstract: Indonesia has been the world's largest producer of palm oil since 2006 and the production reached 44.5 million tons in 2021, with an average growth of 3.61% per year. The high production of palm oil will accompany an increase in waste. Utilization of this waste can be a solution for handling waste from the palm oil processing industry. This study used a compaction pressure of 30 bar and a holding time of 120 minutes. The materials used are OPEFB fiber, sengon wood particles, epoxy resin, and PVAc. The composition of each material is calculated based on the volume fraction, namely: 15% OPEFB fiber, 50% sengon wood particles, and 35% combination of epoxy resin - PVAc. The variation of hybrid adhesive between the epoxy resin and PVAc is S1 (20/15), S2 (15/20), and S3 (10/25). The characteristics of particleboard observed were hardness, thickness swelling, and surface morphology. This research shows that PVAc content increases, the hardness and dimensional stability decreases. The best performance of particleboard is S1, with a composition of 20% epoxy resin and 15% PVAc. The thickness swelling and hardness is 4.01% and 103.38HB, respectively. Both of these characteristics meet the requirements of particleboard based on SNI 03-2105-2006.

Keywords: hybrid adhesive, epoxy resin, PVAc, hardness, thickness swelling, SNI.

I. Introduction

Palm oil production in Indonesia continues to increase, and in 2020 it reached 44,759,147 tons (BPS, 2020). This condition causes other impacts in the form of waste, namely empty fruit bunches, shells, and coir. Even though this waste still has the potential to be reused as fertilizer, biomass, animal feed mixtures, and bio composites.

Oil palm empty fruit bunches have good strength. OPEFB fiber composition consists of 28.93% lignin, 55.75% cellulose, and 15.32% hemicellulose [1]. OPEFB single fiber characteristics are fiber diameter 250-550 μm, moisture content 2.2-9.5%, average tensile strength 71 MPa, Young's modulus 1703 MPa, and 11% elongation [2]. Pretreatment of the fiber can improve the mechanical properties of the material. OPEFB fiber treated with 5% NaOH immersion for 2 hours can increase the tensile strength of the fiber [3]. Another method to increase OPEFB fiber's strength is boiling and steaming. This method can slightly increase the tensile strength of the fiber [4]. Izani et al. [5] compared the thermal stability and tensile strength of OPEFB fibers treated with sodium hydroxide, boiling, and combined with NaOH-boiling. This research shows that the tensile strength and thermal stability of OPEFB fiber increased after alkaline treatment and boiling water.

OPEFB fiber length affects the mechanical properties of the composite. Lusiani compared fiber lengths of 5, 10, and 15 mm. This research shows that the longer the fiber increases the density, hardness, impact strength, and flexural strength, but the thickness swelling decreases [6]. Another influential parameter is the fiber volume fraction in particleboard composites. The greater the number of fibers, the higher the composite's hardness, impact strength, and thickness swelling. This research states that the volume fraction of 15% gives the most optimal properties [7].

Some of the particles that can be used as fillers are wood particles and oil palm trunks. Sunardi et al. compared the characteristics of particleboard using sengon wood, mahogany wood, bayur wood, and rice husk ash. This research shows that mahogany particles have the best performance and meet SNI 03-2105-2006 [8]. A study shows that oil palm trunk particles have the potential of particleboard [9].

PVAc adhesive as a bonding material in particleboards produces lower flexural strength and internal bond strength than urea-formaldehyde resin [10]. The other study shows that adding PVAc to the composite can increase compressive strength. The comparison between PVAc and waste at 2:7 resulted in the most optimum mechanical strength [11].

Matrix performance on composites can be improved by using a hybrid matrix. Wang et al. compared phenol formaldehyde (PF) and polyvinyl acetate (PVAc) as wood adhesives. This research shows that the composition of PF/PVAc with a ratio of 1:1 has the same performance as pure PF resin in roll forming or die forming processes [12].

Epoxy resin performance can be improved by adding iron particles with mesh size (48-500) µm, and silicon carbide (150 and 250) µm using steel, polymer, and glass fiber as reinforcement [13]. Calcium silicate particles with the lowest degree of agglomeration and dimensions in the epoxy composites produced the highest tensile strength [14]. The particle's grain size strongly influences the particleboard's bond strength. A study showed that the smaller the particle size of sengon wood increases the hardness and dimensional stability [15].

This paper presents the behavior of particleboard using a hybrid matrix, namely epoxy resin and PVAc adhesive, with a specific ratio. Particleboards using a hybrid matrix have certain characteristics. The use of PVAc adhesive is carried out to reduce the cost of making particleboard with epoxy resin. Combining these two types of adhesives produces particleboard resistant to water at a lower production cost.

II. Methodology

2.1 Materials

1. Reinforcement. This study uses oil palm empty fruit bunches as composite reinforcement. OPEFB fiber is obtained from the palm oil processing industry with a fiber length is 15 mm.
2. Fillers. The filler used to manufacture particleboard is sengon wood obtained from the wood processing industry in the Cilegon region of Indonesia. The wood particle size was filtered using a sieve with a mesh size of 18.
3. Binding. Particleboard uses an epoxy resin binder and a PVAc adhesive. The advantages of epoxy resin are high strength, low shrinkage, excellent adhesion, electrical insulator, low cost, and low toxicity. Epoxy resins are suitable for composite applications. PVAc adhesive is intended to increase the composite's ductility. The advantages of PVAc adhesive are that it is odorless, non-flammable, and solidifies faster.

2.2 Manufacturing Process

1. Pretreatment of fiber. OPEFB fiber was treated with 5% NaOH for 2 hours and continued with rinsing using distilled water.
2. Sample preparation. The composition of the particleboard is 50% sengon wood particles, 15% EPEFB fiber, and the combination of epoxy resin and PVAc becomes the independent variable.
3. Mixing the particleboard components was carried out using an electric mixer at 400 rpm for 20 minutes. After mixing, it was left for 15 minutes, and the compaction process.
4. The compaction process was carried out at the integrated laboratory of bioproduct, BRIN Cibinong-Indonesia. The composite mixture was put into the mold, given pressure of 30 bar, and held for 120 minutes. After that, the material is cooled with atmospheric air until it cools down.

2.3 Composite Characterization

1. Hardness. The particleboard hardness test was carried out according to ASTM E10 using the Brinell method. The indenter used is 10 mm in diameter at a loading of 62.5 kgf and a loading time of 3 seconds. The test sample is in the form of a beam measuring 70 x 35 x 14 mm.
2. Thickness swelling. The thickness swelling test is carried out by referring to SNI 03-2105-2006. Samples were immersed in water at a temperature of 25 ±1 °C for 24 hours. The sample size is 50 x 50 mm. The following equation expresses the measurement of thickness expansion.

   $$Thickness\ swelling\ (\%) = \frac{T2-T1}{T1}\ (100\%)$$

   Where, T_2 is the thickness after immersion in water (mm), T_1 is the thickness before immersion in water (mm).
3. Surface morphology. Surface morphology observations were carried out using a scanning electron microscope with magnifications of 100 and 1000X.

III. Results and Discussion

3.1 Sample Macro Photos

The particleboard composition comprises 15% EFB fiber, 50% sengon wood particles, and 35% a composite matrix of epoxy resin and PVAc adhesive. The manufacturing process is carried out by cold pressing at a pressure of 30 bar and holding time for 120 minutes. Composite samples were made with a size of 120x90x40 mm. A macro photo of a particleboard composite reinforced with OPEFB fiber is shown in Figure 1.

a. Sample 1 (S1) consisted of 20% epoxy resin and 15% PVAc.
b. Sample 2 (S2) consisted of 15% epoxy resin and 20% PVAc.
c. Sample 3 (S3) consisted of 10% epoxy resin and 25% PVAc.

Figure 1: Composite Specimen

3.2 Thickness Swelling

The particleboard thickness swelling test is carried out by referring to the Indonesian National Standard SNI 03-2105-2006. The test procedure was carried out by immersion for 24 hours at 25 °C ±1 °C. The results of the thickness expansion are shown in Figure 2.

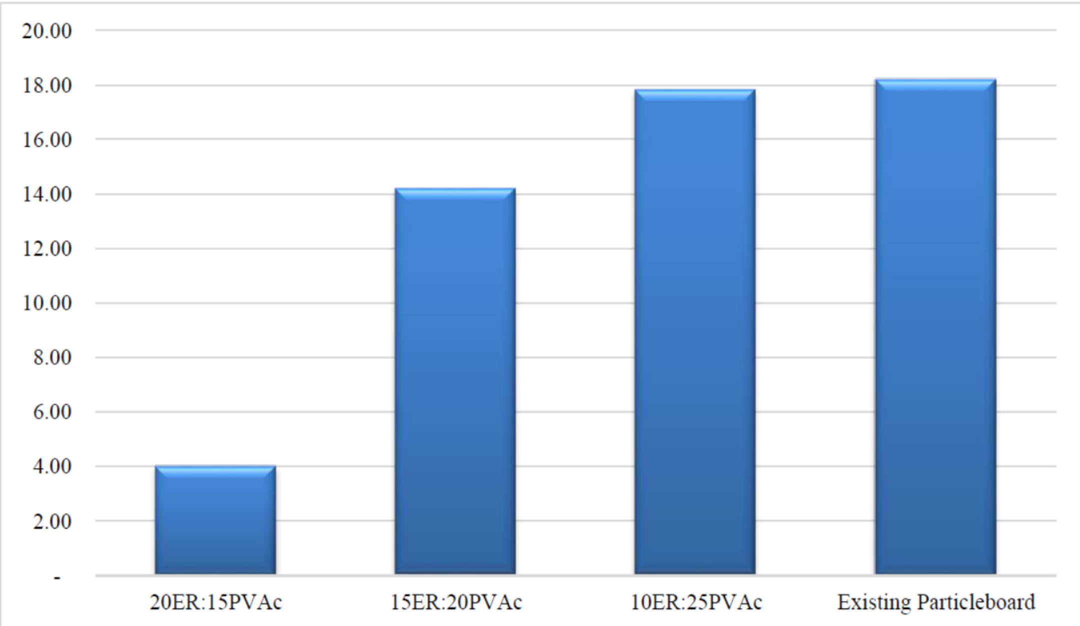


Figure 2: Correlation between epoxy/PVAc ratio and thickness swelling

Figure 2 shows that a more concentration of PVAc adhesive causes an increase in thickness development. Based on SNI 03-2105-2006, the maximum thickness expansion value of structural particle board is 20%. While the particle board in this study, the thickness expansion value reached a maximum value of 17.81% with the addition of 25% PVAc and 10% epoxy resin. That is, the particleboard developed meets the minimum requirements for particleboard

The particleboard's thickness swelling is affected by the characteristics of the PVAc adhesive when in contact with water. PVAc will be hydrolyzed by water so that the bond between particles is weakened so that the dimensional stability of the particle board changes. The character of PVAc is the ability to bind other materials using hydrogen bonding or chemical adsorption. The thickness expansion of the particleboard reached its maximum value at a PVAc concentration of 30% [16].

Essen et al. showed that the combination of polymeric diphenylmethane diisocyanate (pMDI) and PVAc positively impacted thickness changes in the laminated veneer lumber (LVL) of pine wood. The composition of 92% PVAc and 8% pMDI resulted in better dimensional stability. pMDI reacts with active hydrogen atoms so that the wood surface is covered by -OH groups. Thickness development decreased when the hygroscopic properties of wood decreased [17].

3.3 Hardness

The hardness of particleboard is greatly influenced by the matrix used. The adhesive material's characteristics directly affect the particleboard's mechanical properties. Figure 3 shows that the greater the PVAc content, the lower the surface hardness of the particleboard. The bond between particleboard constituents formed by the hybrid adhesive of epoxy resin and PVAc adhesive is strongly influenced by water absorption. PVAc adhesives are very vulnerable when in contact with water, and the internal bond will be weakened. Kowaluk and Fuczek showed that PVAc adhesives produced lower flexural and internal bond strengths when compared to urea-formaldehyde resins [10].

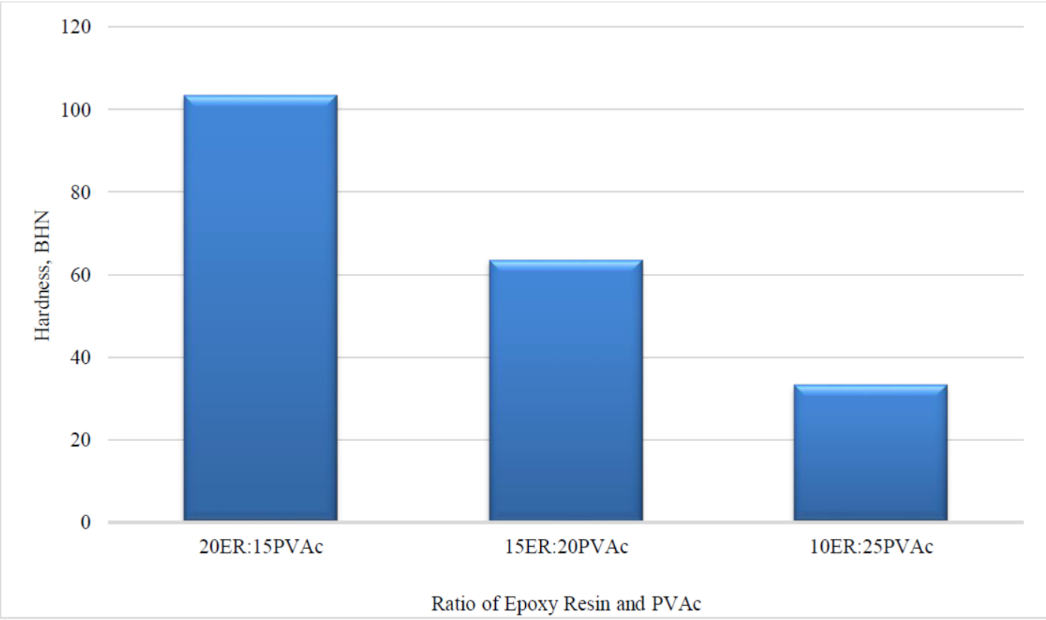


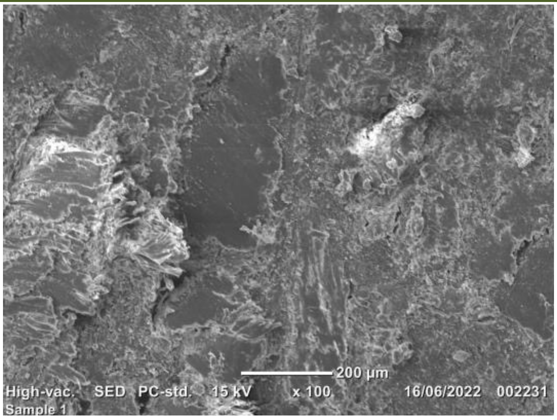
Figure 3: Correlation between epoxy resin-PVAc ratio and hardness

The higher the epoxy resin content in the composite, the higher the particleboard's hardness. This study is in line with Suryawan et al., where the higher the epoxy resin content, the higher the hardness of the glass fiber and nettle fiber reinforced composites [18]. Webo et al. also showed the same phenomenon, namely, the higher the epoxy resin content in the composite, the higher the hardness [19].

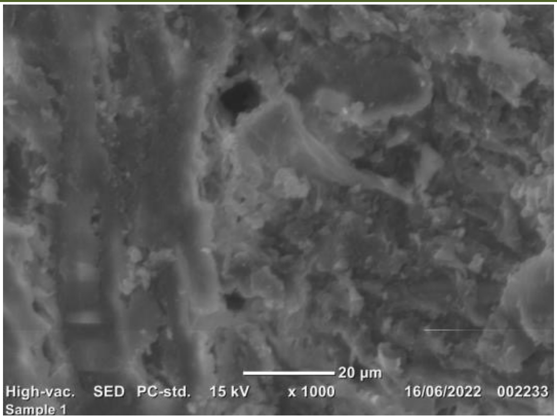
3.4 Surface Morphology

The surface morphology of the particleboard observed with a scanning electron microscope with 100X, and 1000X magnification is shown in Figure 4. Sample 1 (4a and 4d) showed that the epoxy resin dominated the particleboard. From sample 1, it can also be seen the presence of porosity, but porosity is more common in sample 3. Crack features are visible in all samples.

Epoxy resin and PVAc were evenly distributed in all samples. This condition indicates that the epoxy resin can be mixed homogeneously with the PVAc adhesive. The decrease in hardness occurred at higher PVAc compositions. This phenomenon is due to the softer PVAc adhesives characteristics than epoxy resins. The nature of PVAc, which is easily hydrolyzed by water, causes the weakening of the internal bonds between the particleboard constituents so that the thickness swelling and hardness experience performance degradation.



(a)



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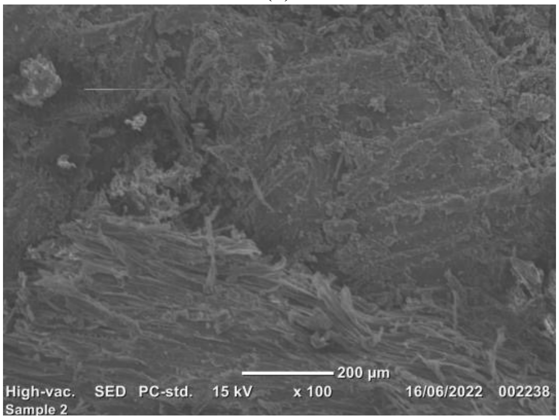

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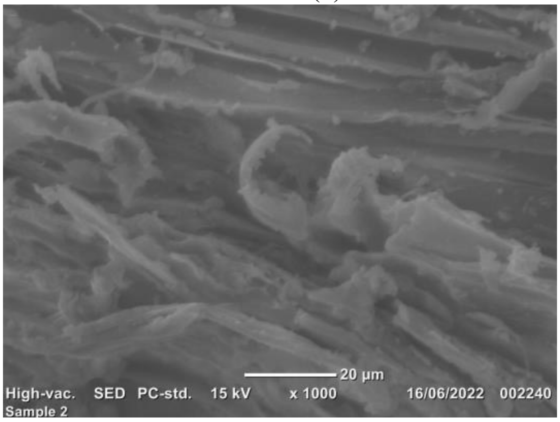

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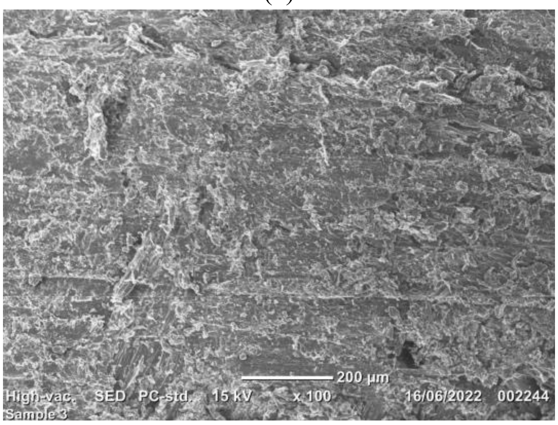
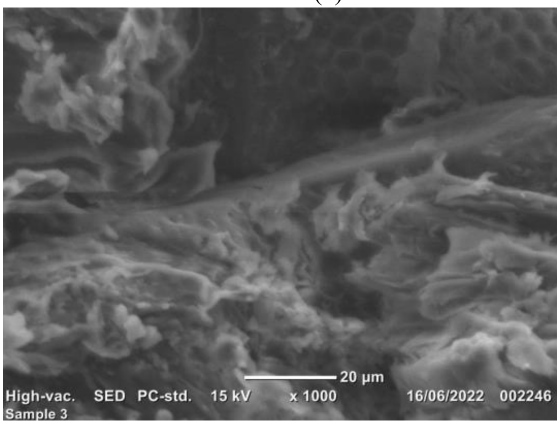


(c)



(f)

Figure 4: Surface morphology of sample (4.a.d) Sample 1 with magnification 100X and 1000X, (4.b.e) Sample 2 with magnification 100X and 1000X, and (4.c.f) Sample 3 with magnification 100X and 1000X

IV. Conclusion

The type of adhesive in manufacturing particleboard significantly influences the hardness and thickness swelling. From this research, it can be concluded that the higher the epoxy resin composition, the higher the dimensional stability and hardness of the particle board. The combination of epoxy resin and PVAc adhesive reaches its maximum value at the composition of 20% epoxy resin and 15% PVAc with a thickness swelling of 4.01% and a hardness of 103.38BHN

References

[1]. N. Hidayah and I.U. Wusko, Characterization and Analysis of Oil Palm Empty Fruit Bunch (OPEFB) Waste of PT Kharisma Alam Persada South Borneo, *Traditional Medicine Journal, 25(3),* 2020, 154-160.

[2]. M.Z.M. Yusoff, M.S. Salit and N. Ismail, Tensile Properties of Single Oil Palm Empty Fruit Bunch (OPEFB) Fibre, *Sains Malaysiana, 38(4)*, 2009, 525-529.

[3]. F. Gultom, H. Supriadi and S. Savetlana, Pengaruh Perlakuan Alkali Terhadap Kekuatan Tarik Serat Tandan Kosong Kelapa Sawit untuk Digunakan pada Komposit Serat TKKS, *Jurnal FEMA*, *2(2)*, 2014, 1-8.

[4]. L. Agustina, Udiantoro and A. Halim, Karakteristik Serat Tandan Kosong Kelapa Sawit (TKKS) dengan Perlakuan Perebusan dan Pengukusan, *Ziraa'ah, 41(1)*, 2016, 97-102.

[5]. M.N. Izani, M. Paridah, U. Anwar, M.M. Nor and P. H'ng, Effects of fiber treatment on morphology, tensile and thermogravimetric analysis of oil palm empty fruit bunches fibers, *Composites: Part B, 45*, 2013, 1251-1257.

[6]. R. Lusiani, Sunardi and Y. Ardiansah, Pemanfaatan Limbah Tandan Kosong Kelapa Sawit sebagai Papan Komposit dengan Variasi Panjang Serat, *Flywheel: Jurnal Teknik Mesin, 1(1)*, 2015, 46-54.

[7]. Sunardi, M. Fawaid and M. Chumaidi, Pemanfaatan Serat Tandan Kosong Kelapa Sawit sebagi Penguat Papan Partikel dengan Variasi Fraksi Volum Serat, *Machine: Jurnal Teknik Mesin, 2(1),* 2016, 36-39.

[8]. Sunardi, R. Lusiani, I. Saefuloh, E. Listijorini, A.E. Sumarna, M. Fawaid and Y. Meliana, Particleboard Characterization Using Sawdust from Sengon Wood, Mahogany Wood, Bayur Wood, and Rice Husk aAsh as Composite Fillers, *IOP Conf. Series: Materials Science and Engineering, 909*, 2020, 1-10.

[9]. Sunardi, R. Lusiani, J. Andrean and M. Fawaid, Karakteristik dan Potensi Limbah Kelapa Sawit sebagai Papan Partikel, *Seminar Nasional Pengelolaan Lingkungan SNPL 2017*, Palembang, 2017, 110-115.

[10]. G. Kowaluk and D. Fuczek, PVAc Glue as a Binding Agent in Partcleboards, *Drewno-Wood, 52(182)*, 2009, 17-24.

[11]. Masturi, Mikrajuddin and Khairurrijal, Efektivitas Polyvinyl Acetate (PVAc) Sebagai Matriks Pada Komposit Sampah, *Berkala Fisika, 13(2)*, 2010, 61-66.

[12]. Y. Wang, V. Yadama, M.-P. Laborie and D. Bhattacharyya, Cure kinetics of PF/PVAc hybrid adhesive for manufacturing profiled wood-strand composites, *Holzforschung, 64*, 2010, 603-608.

[13]. A.S. Abdulaziz, A.N. Rashid and Y.M.A. Hbaite, Adhesive strength improvement of epoxy resin with different reinforcing materials, *Al-Rafidain Engineering, 21(6),* 2013, 116-125.

[14]. A. Jelic, M. Sekulic, M. Travica, J. Gržetic, V. Ugrinovic, A.D. Marinkovic, A. Božic, M. Stamenovic and S. Putic, Determination of Mechanical Properties of Epoxy Composite Materials Reinforced with Silicate Nanofillers Using Digital Image Correlation (DIC), *Polymers, 14(1255)*, 2022, 1-23.

[15]. Sunardi, M. Fawaid, R. Lusiani and R. Parulian, Pengaruh Butiran Filler Kayu Sengon Terhadap Karakteristik Papan Partikel yang Berpenguat Serat Tandan Kosong Kelapa Sawit, *Jurnal Mesin Teknologi, 11(1)*, 2017, 28-32.

[16]. B. Raharjo, Pemanfaatan Limbah Tandan Kosong Kelapa Sawit Sebagai Bahan Pengganti Alternatif Papan Partikel, *Indonesian Journal of Laboratory, 2(2),* 2020, 1-9.

[17]. R. Esen, E. Likos and G. Zengin, The Effects of Using Different Adhesive on the Thickness Swelling Ratio of LVL Produced from Scotch Pine, *Bio Resources, 17(4)*, 2022, 5645-5654.

[18]. I.A. Suryawan, N. Suardana, I.S. Winaya and I. Suyasa, Hardness Analysis of Epoxy Composite Reinforced with Glass Fiber Compared to Nettle Fibers, *International Journal of Engineering and Emerging Technology, 5(1)*, 2020, 1-4.

[19]. W. Webo, L. Masu and M. Maringa, The Impact Toughness and Hardness of Treated and Untreated Sisal Fibre-Epoxy Resin Composites, *Advances in Materials Science and Engineering, 2018*, 2018, 1-10.

