Effect of Nanofiller on Properties of Poly Vinyl Chloride/Teak Sawdust Nanocomposites

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Abstract. Nanocomposites based on poly vinyl chloride (PVC), teak sawdust, and nano-precipitated calcium carbonate (NPCC) are made by melt compounding in the Laboplastomill internal mixer. The objective of this research was to study the effect of different amount of nanofiller NPCC to the properties of nanocomposites at different amounts of teak sawdust. Composites prepared in three different amount of NPCC 0, 5, and 10 phr (per hundred resin), and three different amount of teak sawdust 40, 50, and 60 phr, The amount of PVC was fixed at 100 phr for all formulation. The physical properties test results showed that the tensile strength, elongation at break, and slip resistance of nanocomposite were improved by addition of nanofiller NPCC, this improvement were observed up to 5 phr of NPCC content and then decreased. Termite resistance test results conducted for 21 days showed that nanocomposites were very resistant to subterranean termites. SEM micrographs showed better dispersion with 5 phr of NPCC.

Keywords: Nanocomposites; PVC; teak sawdust; NPCC

Introduction

Wood/polyvinylchloride composite (WPVC) is a composite, suitable for building and other construction products. WPVC has high sittness, strong chemical resistance, and good flame retardation due to chlorine atoms in the PVC molecules [1]. Wood as a filler presents lower density, less abrasiveness, lower cost and is renewable and biodegradable [2]. Wood plastic composite (WPC) can be made from many wood species, the wood species can affect the properties WPC [3,4] also the tensile strength [5], but no report the use of teak wood in WPC. In Indonesia, teak wood is one of the most widely used woods for construction and furniture because it has unique properties and characteristics. The growing of the use of teak wood cause of industrial waste such as teak wood sawdust has also increased and has not been utilized properly. One of the utilization of teak sawdust is made wood plastic composite (WPC).

Nanotechnology is a very promising field for improving the properties of WPCs using nanosized fillers. This improvements include tensile stregth, thermal stability, flammibility properties and biodegrafability [5]. The use of nanoscale fillers in WPCs has been reported in literature. The focus has been mainly on the effect of nanoclay filler on the mechanical properties of PP or PE based WPC [6-10]. Calcium carbonate (CC) is one of the most abundant and stable minerals, generally divided into natural calcium carbonate (NCC) and precipitated calcium carbonate (PCC). Application PCC as a filler in PCC-bamboo-polymer hybrid composites has been reported in the literature [11], but no reports related to nanoprecipitated calcium carbonate (NPCC) as a filler in the PVC based WPC. The addition of NPCC in WPVC is expected to improve the mechanical properties of WPC.

The main purpose of this research was to evaluate the effect of nanofiller NPCC on the properties of PVC/teak wood sawdust nanocomposite. The samples were prepared with various contents of nanoclay and teak sawdust. Wood and plastic are incompatible because the polar constituents in wood make it hydrophilic, and plastic is hydrophobic. Therefore, compatibilizer are often added in order to increase the wood-plastic compatibility [9]. In this research another additives were also added to WPC formulations that aid in processing and end use applications.

Experimental

Materials

Suspension of poly vinyl chloride (PVC) used in this research was purchased from supplier, in the form of PVC powder and having a K value of 65. The PVC powder was dry-blended with various additive as listed in Table 1, to give PVC compound. Nano precipitated calcium carbonate (NPCC), surface coated with coupling agent was purchased from supplier with trade name of SHENGKE (NPCCA-602).

Teak sawdust was obtained from Asri Jati Meubel Yogyakarta. Firstly, teak sawdust was soaked in the hot water for 24 h to remove the extractive substances, then dried by exposed to sun rays until equilibrium moisture content ~~is~~ was reached. The dried teak sawdust was grinded followed by sieved using standard mesh to get particle sizes of 50 mesh.

Other additives were commercial product and purchased from supplier includeing maleic anhydride as a compatibilizer, dicumyl peroxide (DCP) as a initiator, dioctyl phthalate (DOP) as a plasticizer, antioxidant AOX, calcium stearate as a thermal stabilizer, stearic acid as a lubricant, biocide as a fungus resistance, and titanium dioxide.

Nanocomposite preparation

Nanocomposites based on poly vinyl chloride (PVC), teak sawdust, and nano-precipitated calcium carbonate (NPCC) were made by melt compounding in a *Laboplastomill internal mixer* (Toyoseiki) at 200^{o}C, 50 RPM for 10 min. The amount of teak sawdust in the PVC composite was varied from 40 to 60 per hundred resins (phr). NPCC amount was varied 0; 5; and 10 phr. Nanocomposites then were pressed to test specimens by *Hydraulic Press* at 200^{o}C.

Table 1. The Ingredients of PVC compounds and composites.

Ingredient	Concentration (phr)
Suspension PVC	100
DOP	20
Calcium stearat	1.5
Stearic acid	1
Antioxidant AOX	0.1
Biocide	6
titanium dioxide	1
maleic anhydride	5
DCP	0.75
NPCC	Varied for study (0; 5; 10)
Teak wood sawdust	Varied for study (40; 50; 60)

Characterization

Density was determined by using *Electro Densimeter* in accordance with ASTM D792. Tensile and elongation at break properties were measured using the *Troning Alberttesting machine*, type QC II-M-18 in accordance to ASTM 638. The hardness was evaluated using a *Toyoseiki –Durometer Shore D* in accordance with ASTM D2240.The slip resistance test was conducted using a testing apparatus for shoes test, whereas every speciments subjected to a load of 5 kg and a speed of 20mm/min for dry and wet surface conditions, and the obtained sliding distance was noted. The termite resistance test procedure followed Indonesian National Standard (SNI) 01-7207-2006 (duration of the test was 21days). Durability of specimen against the attack of termites were observed based on weight loss of the specimen. Morphological characterization was determined by using a Jeol Scanning Electron Microscope (SEM). The speciment surfaces were coated with a thin layer of gold and then the images were recorded.

Results and Discussion

Effect of NPCC on the density of nanocomposites

The influence of nanofiller NPCC and teak wood sawdust contents on the density of the composites are shown in Fig. 1. All the samples had density in the range of 0.978-1.074. The density increased with increasing amounts of nanofiller NPCC at different content of teak wood sawdust. This is due to the fact that NPCC has a density higher than density of PVC and teak wood sawdust.

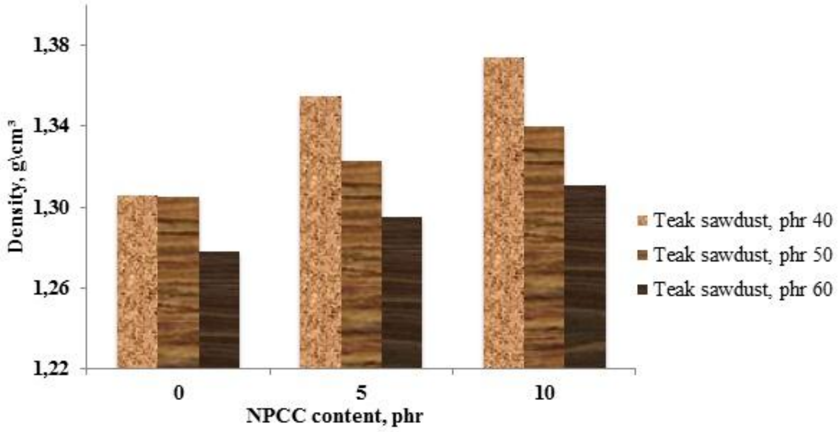

Figure 1. Effect of NPCC on the density of nanocomposites.

Effect of NPCC on the tensile strength and elongation at break of nanocomposites

Figure 2 and 3 shows the tensile strength and elongation at break of PVC/teak sawdust nanocomposites. The tensile strength and the elongation at break of nanocomposites increases with addition of 5 phr nanofiller at different content of teak sawdust and then decreases.

The addition of 5 phr nanofiller NPCC increasing of the tensile strength at 40, 50, and 60 phr teak sawdust content are approximately 25.027%, 25.033%, and 5.261%, respectively. When 5 phr of NPCC was added, the elongation at break increased 18.182% (40 phr teak wood content), 25% (50 phr teak sawdust content), and 27.778% (60 phr teak sawdust content). The decrease of tensile strength is also due to the weakness of interfacial adhesion between PVC matrix and NPCC.

The highest tensile strength of approximately 254.93 kgf/cm^2 was obtained from 50 phr teak sawdust, 100 phr PVC, and 5 phr NPCC. The highest elongation at break of approximately 26% was obtained from nanocomposites containing 5 phr NPCC and 40 phr teak sawdust.

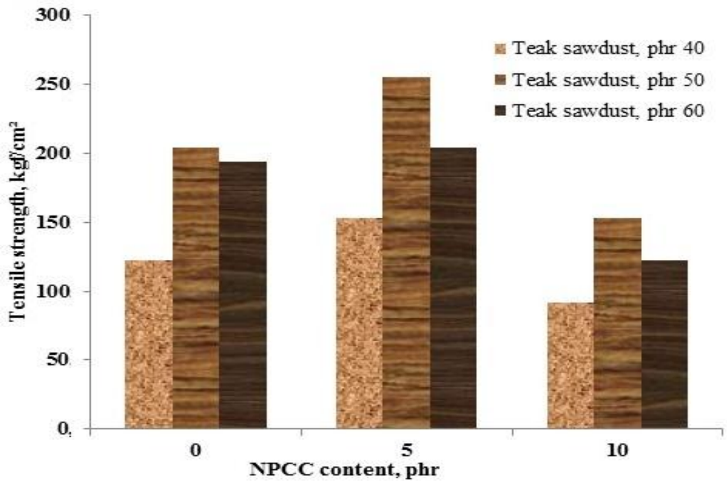

Figure 2. Effect of NPCC on the tensile strength of nanocomposites.

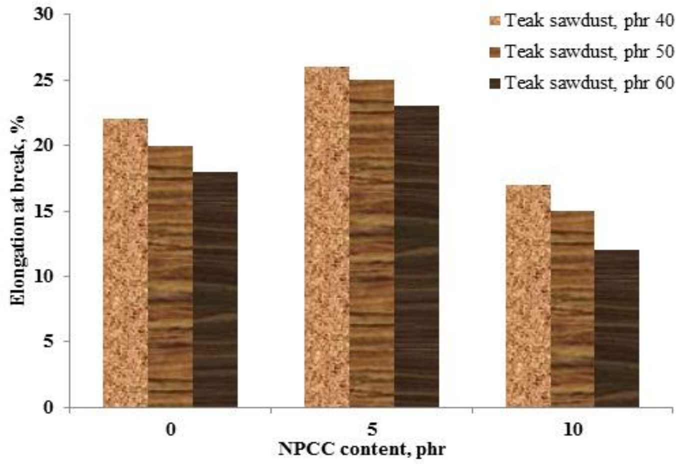

Figure 3. Effect of NPCC on the elongation at break of nanocomposites.

Effect of NPCC on the slip resistance of nanocomposites

Slip resistance of a nano composites surface ~~is~~ was quantitatively characterized by sliding distance. The influence of nanofiller NPCC and teak sawdust contents on the sliding distance of the composites are shown in Fig. 4 (dry conditions) and Fig. 5 (wet conditions).

Composites without nanofillerNPCC showed that the increasing of sawdust content decrease the sliding distance. Composites with nanofiller at various amounts of sawdust have the lower sliding distance than composites without nanofiller NPCC. It means that nanofiller NPCC showed the positive effect to the slip resistance. The higher slip resistance for dry and wet condition was obtained from nanocomposite containing containing 5 phr NPCC and 40 phr teak sawdust

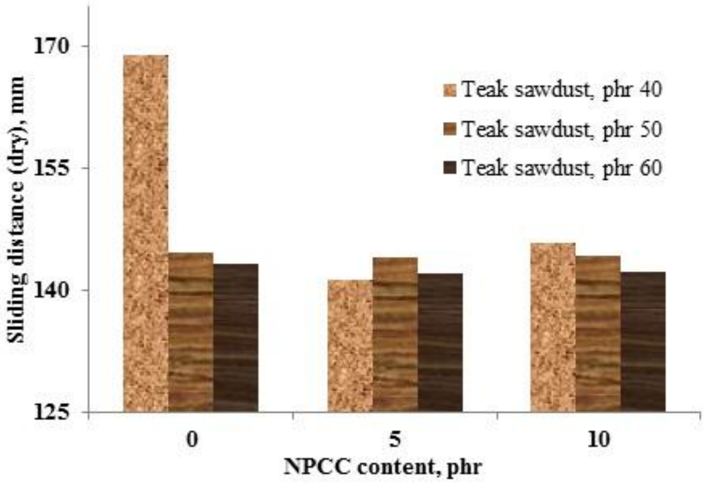

Figure 4. Effect of NPCC on the sliding distance (dry) of nanocomposites.

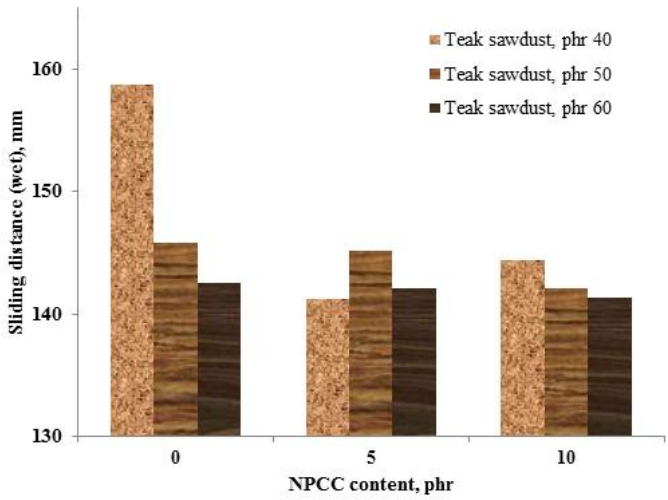

Figure 5**.** Effect of NPCC on the sliding distance (wet) of nanocomposites.

Termite Resistance

Termites are wood and buildings destroying insects that result in substantial economic losses. The termite resistance test results based on the classification according to SNI 01-7207-2006 (Table 2). The influence of nanofiller NPCC and teak sawdust contents on the termit resistance of the composites are shown in Table 3. Test results showed that all the samples had highly termite resistance.

Table 2. Termite resistance classification of wood based on SNI 01-7207-2006.

Level ofresistance	Percent of weight loss (%)
I. Highly resistant	<3.52
II. Resistant	3.52-7.50

III. Moderately resistant	7.30-10.96
IV. Nonresistant	10.96-18.94
V. Susceptible	18.94-31.89

Table 3. Effect of NPCC on the termiteresistance of PVC/teak sawdust nanocomposites.

NPCC content, phr	Teak wood sawdust content, phr	Percent of weight loss, %	Level of resistance
0	40	0	Highly resistant
5	40	0	Highly resistant
10	40	0	Highly resistant
0	50	0	Highly resistant
5	50	0	Highly resistant
10	50	0	Highly resistant
0	60	0	Highly resistant
5	60	0	Highly resistant
10	60	0	Highly resistant

Morphological characterization

The dispersion of NPCC and teak sawdust in the PVC matrix, and the interfacial adhesion between the fillers and the matrix were observed by scanning electron microscopy.

Fig. 6 shows microstructure of the neat PVC and teak sawdust. Fig. 7 (a), (b) and (c) show SEM images of fracture surface of the 0.5 and 10 phr NPCC incorporated composites filled with 40, 50, and 60 wt. % teak sawdust respectivelly.

SEM image showed that there are no clear gap between teak wood sawdust, NPCC and PVC matrix, indicating the good interface bonding. However, an agglomeration of NPCC was seen at higher NPCC loading (Fig. 7c).

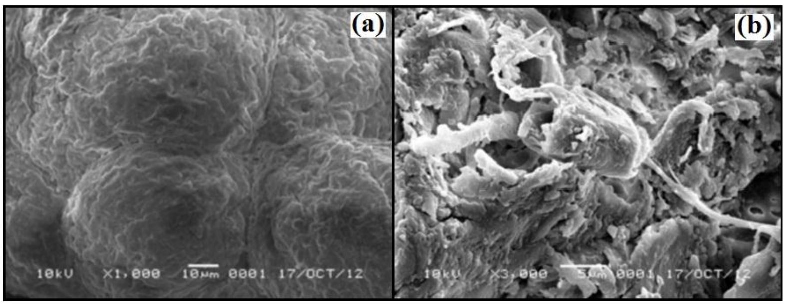

Figure 6. Scanning electron micrograph of (a) PVC (magnification x1000), and teak

sawdust (magnification x 3000.

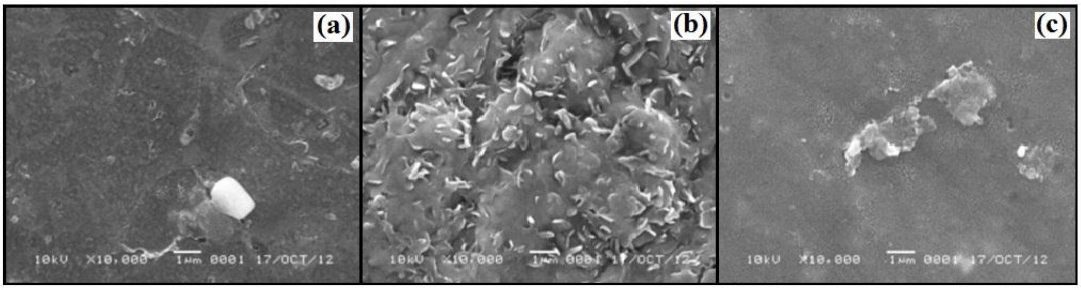

Figure 7. Scanning electron micrograph of PVC/teak wood sawdust nanocomposites with (a) no NPCC (40 phr teak sawdust), (b) 5 phr NPCC (50 phr teak sawdust), and (c) 10 phr NPCC (60 phr teak sawdust) of magnification x 10000.

Conclusion

Nanofiller NPCC showed a positive effect on the physical properties of PVC/teak sawdust nanocomposite. The density increased with increasing amounts of nanofiller NPCC of different content of teak sawdust. The tensile strength and the elongation at break of nanocomposites increases with the addition of 5% nanofillerof different content of teak sawdust and then decreases at 10 phr NPCC. Nanocomposites containing 5 phr of NPCC showed anti-slip properties higher than other composites at various amounts of sawdust. All the PVC/teak wood sawdust nanocomposites had highly termite resistance.

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[1] K. Chaochanchaikul, V. Rosarpitak, N. Sombastsompop, *Bioresources*, **2011**, *6(3)*, 3115.
[2] G. Lulianelli, M. B. Tavares and L. Luetkmeyer, *Chem. Technol.* **2010**, *4(3)*, 225.
[3] J.W. Kim, D.P. Harper, and A.M. Yaylor, *J. Appl. Polym. Sci.*, **2009**, *112(3)*,1378.
[4] J.S. Fabiyi, and A.G. McDonald, *Composites Part A: Appl. Sci. Manuf.* 2010, *41(10)*, 1434.
[5] Ashori andA. Nourbakhsh, *Compos. Mater*, **2009**, *43(18)*, 1869.
[6] Q. Wu, Y.Lei, C.M. Clemons, F.Yao, Y. Xu, K. Lian, K.,*J.Plast.Technol*. **2007**, *27*, 108.
[7] Y. Lei, Q. Wu, C.M. Clemons, F. Yao, Y. Xu, *J. Appl. Polym. Sci*. **2007**, *106*, 3958.
[8] B. Kord, A. Hemmasi, I. Ghasemi, I. *Wood Sci Technol*. **2010**, *45*, 111.
[9] O. Faruk, L.M. Matuana, *Compos Sci Technol*. **2008**, *68(9)*, 2073.
[10] H.Z. Tabari, H.A. Khademieslam, *World Appl. Sci. J.* **2012**, *16 (2)*, 275.
[11] B. Kim, F. Yao, G. Han, Q, Wu, *Polym.Compos.* **2012**. *33(1)*, 68.