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Modification Of Oil Palm Wood Using Acetylation And Impregnation Process

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Abstract. The purpose of this study is chemical modification by process of acetylation and impregnation of oil palm wood to improve the dimensional stability. Acetylation process aimed at substituting the hydroxyl groups in a timber with an acetyl group. By increasing the acetyl groups in wood is expected to reduce the ability of wood to absorb water vapor which lead to the dimensions of the wood becomes more stable. Studies conducted on oil palm wood (Elaeis guineensis Jacq) by acetylation and impregnation method. The results showed that acetylated and impregnated wood oil palm (E. guineensis Jacq) were changed in their physical properties. Impregnation with coal ashfly provide the greatest response to changes in weight (in wet conditions) and after conditioning (dry) with the average percentage of weight gain of 198.16% and 66.41% respectively. Changes in volume indicates an increase of volume in the wet condition (imbibition) with the coal ashfly treatment gave highest value of 23.04 %, whereas after conditioning (dry) the highest value obtained in the treatment of gum rosin:ethanol with a volume increase of 13:44%. The highest changes of the density with the coal ashfly impregnation in wet condition (imbibition) in value of 142.32% and after conditioning (dry) of 57.87%. The result of reduction in water absorption (RWA) test showed that in the palm oil wood samples most stable by using of gum rosin : ethanol of 0.97%, whereas the increase in oil palm wood dimensional stability (ASE) is the best of 59.42% after acetylation with Acetic Anhydride: Xylene.

INTRODUCTION

Indonesia was the largest crude palm oil (CPO) producer with total production of over 30 million tons on 2015. Oil palm plantations in Indonesia was approximately 10,210,892 hectares. In 2013 areas of oil palm plantations in Kalimantan approximated of 1,115,415 ha [1]. By assume in one hectare of land contains approximately 106 trees, so there are 118,233,990 trees in East Kalimantan. And assumed one oil palm trunk (OTP) produce 1.25 m^3 timber, within period of 20 to 25 years will upcome OTP waste of 147,792,488 m^3. The OTP waste will cause serious environment problems.

On the other hand, in the era of globalization and the rapid growth of science, technology, and art has prompted scientists take advantage of a variety of materials, including waste material converted into useful and economics valuable goods. From the analysis and understanding of the researchers about characteristics of oil palm trunks were believed wood waste can be engineered into a material with high economic value [2].

The use of technologically engineered oil palm trunk waste is expected to replace the role of wood in meeting people's needs for building materials, floor of the house, and a variety of household accessories and other industrial needs[2,3]. In general, the use of wood as buildings or industrial needs has always focused on aspects of the lifetime of wood, wood stability, esthetically value, and environmental health.

Chemical modification is the process to change from hydrophobic to hydrophilic in the wood[4]. Efforts to improve the dimensional stability of oil Palm trunks were conducted with acetylation and impregnation process. In this research, the improvement of oil palm trunk properties by impregnation and acetylation were using acetic anhydride solvent: xylene, toluene: acetic anhydride, ethanol soluble black gum rosin, coal fly ash, acetone soluble

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clear gum rosin, ethanol soluble clear gum rosin. While testing on the properties of the engineered OPT were conducted on the moisture content, density, shrinkage and swelling (RWA and ASE), static bending (MoE & MoR), axial compression, resistance to fungi and termites.

EXPERIMENTAL

Materials

The research material was oil palm trunks (OPT) taken from Sebakung Desa Jaya, District Babulu, Penajam Pasir Utara (PPU), East Bornoe. Chemicals used in this study were the stabilizer urea (technical), acetic anhydride, ammonium sulfate, toluene, xylene, ethanol, acetone, coal fly ash, gum rosin clear, and gum rosin black (GTM).

Methods

a. Treatment before acetylation and impregnation

Acetylation conducted after the OPT were dried to a moisture content of 2-5%. Water content is achieved by predicting the other samples were oven-dried [5,6].

b. Acetylation

Acetylation using solvent of acetic anhydride: xylene at a temperature of 140^{o}C for 4 hours. Acetylation with acetic anhydride: toluene at a temperature of 135 ^{o}C for 1 hour, the wood samples were previously impregnated with a mixture of urea: amonium sulfat for 30 min. After the acetylation, samples were vacuumed at a pressure of 750 mmHg for 1 hour at room temperature [7]. Wood were dried in an oven 60 °C, 80 °C and 95 °C respectively for one day. Then samples were immersed in water for 2 hour. The water sorption and dimensions of the acetylated- and impregnated wood were measured to obtain values of swelling, Reduction of water absorption (RWA) and anti shrink efficiency (ASE) [8].

c. Impregnation process

Palm wood samples were impregnated by soaking with ethanol soluble gum rosin, acetone soluble gum rosin [9,10], NaOH soluble coal fly ash. The impregnation carried out by soaking for 24 hours. After the impregnation process, samples were dried in an oven for 24 hours .

d. Data analysis

Response from this study covered the physical properties of wood and Weight Percent Gain (WPG), due to the acetylation process. Physical properties measured include the value of density, moisture content (MC) of wood, changes in volume and density of the wood due to acetylation, according to ASTM D 2395-69 and ASTM D 2016-65. Reduction in water absorption (RWA) and dimensional stability of wood (anti shrink efficiency, ASE), resistance to fungus and bacteria referred [11,12,13].

RESULTS AND DISCUSSION

In general, the chemical modification of wood is the reaction of chemical reagent with the wood structural polymeric constituents resulting in the formation of a covalent bond between the reagent and the wood substrate[6]. The results obtained from the treatment which gives the highest response to changes in weight (imbibition) and weight changes after conditioning with coal fly ash with the average percentage change in weight of 198.16% and 66.41% respectively (table1). In the treatment of impregnation with a solution of coal fly ash produce the average percentage change in imbibition weight after treatment and the mean percentage change in weight after conditioning tends to be higher. This is caused the coal fly ash containing carbon hydrogen and oxygen, sulfur, nitrogen and other content such as silica, aluminium, iron, calcium and magnesium. At the time of the treatment process, coal fly ash

will leave the ashes into the wood pores thereby increasing the weight change in circumstances imbibition and after conditioning. The acetylated wood obtained weight changes of 33.42% (the second highest). The products obtained contains acetyl group bonded to hydroxyl (OH) sites in the wood cell wall [6,11,12,13]. The extent of reaction of acetic anhydride with wood reported as acetyl weight percentage gain, abbreviated as WPG.

TABLE 1. Mean value of the percentage change in weight on oil palm wood after treatment

Solution	Initial weight (g)	Weight after treatment (imbibition) (g)	Weight after conditioning (g)	Weight changes at imbibition (%)	Weight changes after conditioning (%)
Control	3.60	8.97	3.86	149.33	7.36
Acetic anhydride: xylena	3.85	9.08	5.07	135.74	31.70
Toluene:acetic anhydride	3.64	9.86	4.85	171.62	33.42
Gumrosin (black) : ethanol	3.46	6.26	4.10	82.36	18.68
Coal fly ash	3.73	11.11	6.19	198.16	66.41
Gumrosin (clear):Acetone	3.86	5.64	4.62	45.94	19.47
Gum rosin (clear) : Etanol	3.67	4.74	5.34	29.53	45.43

Testing of volume changes after treatment with different solutions showed that the highest value (imbibition) on treatment with coal fly ash in value of 23.04% and after conditioning the highest value on treatment with gum rosin clear: ethanol solution with the average value of 13.44% (prepared in table 2). Due to the acetylation, the cell wall is occupied by the chemically bonded acetyl groups. Invariably, measuring the external dimensions of oven dried wood samples before and after modification to determine this swelling [6].

TABLE 2. Mean Value of percentage in volume changes (at imbibition) and volume changes after conditioning on oil palm wood after Treatment

Solution	Initial Vol	Vol After treatment	Vol After conditioning	Changes in Vol Imbibition (%)	Changes in Vol after conditioning (%)
Control	10.09	10.84	10.12	7.45	0.33
Anhydride Acetate : Xylena	9.67	10.77	9.53	11.78	-1.21
Toluene:Anhyd acetate	9.15	10.42	9.71	13.95	6.16
Gum rosin (black) : ethanol	9.99	10.61	10.37	6.24	3.89
Coal fly ash	9.53	11.74	10.03	23.04	5.31
Gum rosin (clear) : Acetone	9.49	10.09	9.95	6.33	4.91
Gum rosin (clear) : Ethanol	9.22	9.99	10.46	8.3	13.44

Based on testing of changes in density in a state of imbibition and changes in density after conditioning (table 3), the treatment process with different chemicals showed the highest value in the treatment solution of coal fly ash with the average percentage change in density (imbibition) of 142.32% and after conditioning the highest value on chemicals coal with the average change in the density of 57.87%.

If the wood density is increase, there are changes in the shape regularity structures, flexibility will be lower. Cells in wood filled with chemical agent changed the preferred orientation of wood by replacement of hydroxyl groups with monomer that polymerize with wood [4].

TABLE 3. Mean value of density changes (imbibition) and density changes after conditioning on oil palm wood

Solution	Initial density (gram/cm^3)	Imbibition density (gram/cm^3)	Density after conditioning (gram/cm^3)	Changes in density imbibition (%)	Changes in density after conditioning (%)
Control	0.36	0.83	0.36	132.01	0.68
Anhyd Acetate:Xylena	0.4	0.84	0.51	111.79	28.13
Toluene:Anhyd acetate	0.4	0.95	0.5	138.2	25.75
Gumrosin (b):ethanol	0.35	0.59	0.4	71.77	14.25
Coal fly ash	0.39	0.95	0.62	142.32	57.87
Gumrosin (c):Acetone	0.39	0.56	0.46	44.32	19.72
Gumrosin (c) : Etanol	0.4	0.47	0.51	19.67	28.49

The results from reduction of water absorption (RWA) test for 24 hours on acetylated and impregnated oil palm wood provide value ranges of -0.39 to 5.51(table 4). Reduction of water absorption in the acetylated oil palm wood can be said quite successful, it is evident from the depreciation value of water absorption of about 5.51%. In the oil palm wood undergoing the process of acetylation containing an acetyl group ($COCH_3$) which replaces –OH group in wood, so acetylated wood can reduce the absorption of water. While impregnated-wood with a solution of coal fly ash has a high value of water absorption, showed in RWA (-0.39%). The cause is on the treated wood with coal fly ash contains elements that absorb water. The test results showed that acetylation- and impregnation treatment gives effect to reduce the value of water absorption of the oil palm wood.

TABLE 4. Reduction of water absorption on acetylated- and impregnated oil palm wood

Solution	RWA %
Anhydride Acetate : Xylena	5.51
Toluene : Anhydride acetate	3.91
Gum rosin (black) : ethanol	0.97
Coal fly ash	-0.39
Gum rosin (clear) : Acetone	-0.26
Gum rosin (clear) : Ethanol	4.87

Evaluation on the dimensional stability indicate the highest average value of the dimensional stability by the treatment with acetic anhydride: xylene solvent in value of 59.42% and the lowest value in the treatment of coal fly ash solution of -10.34%. This is due to the coal solution is a concentrated solution, which will result in damage to the cell wall of oil palm wood.

In the presence of atmospheric conditions, acetylated wood is far less susceptible to shrinking and swelling. The chemically bonded acetyl groups filled the cell wall which take up space within the cell wall [6,11].

TABLE 5. Anti-shrink efficiency on acetylated- and impregnated oil palm wood

Solution	ASE (%)
Anhydride Acetate : Xylena	59.42
Toluene : Anhydride acetate	49.81
Gum rosin (black) : ethanol	18.61
Coal fly ash	-10.34
Gum rosin (clear) : Acetone	12.49
Gum rosin (clear) : Ethanol	18.91

Based on these results, it turns out the average value of dimensional stability of acetylated or impregnated oil palm wood with a chemical effect on the difference in dimensional stability of oil palm wood. The differences in the dimensional stability of the oil palm wood caused by acetylation or impregnation. Acetylation or impregnation able

to change the structure of the wood into the cell wall of the wood, because wood cell consists of the cell wall, then solvents or chemicals used will interact with the cell wall and fill the cell cavity.

In addition Acetylation and impregnation not only changing the physical structure, but also alter the molecular structure of constituent chemical components of wood. Acetylation or impregnation resulting -OH is easily substituted to be replaced by an acetyl group. Due to the larger an acetyl group or hail from the -OH group, replacement cluster of small groups to groups larger cause not all of groups replaceable. The -OH groups which are difficult to replace instead will cause parts of crystalline turned into an amorphous part, which even more increase parts of amorphous or decrease crystalline portion.

Table 5 shows that the mixture of acetic anhydride: xylene solvent produce higher dimensional stability compared to other solvents. The differences are caused by the acetic anhydride: xylene solvent gives the density or specific gravity higher compared to other solvents, therefore the oil palm wood tends to be more stable. This is due to the acetyl group from acetic anhydride: xylene replace the OH group on oil palm wood, then the oil palm wood ability to bond water vapor in the air is reduced. Increasing the value of dimensional stability due to acetylation and impregnation caused by the blocking chemically to hydroxyl groups.

CONCLUSIONS

Based on the research results can be concluded as follows:

The percentage of weight changes in imbibition circumstances after-treatment process, the treatment with the highest value of coal fly ash of 198.16%. The lowest value was obtained in the treatment with black gum rosin solution in ethanol with the average percentage of 18.68%.

The percentage of volume change in imbibition circumstances after treatment process, the treatment with the highest value of coal fly ash of 23.04%. The lowest value was obtained in the treatment with solution of acetic anhydride : xylene with the average of volume change of -1.21%.

The results of the percentage of the change in density in imbibition after-treatment process, the treatment with the highest value of coal amounted to 142.32%. And the lowest value obtained on the treatment by black gum rosin in ethanol with the average change in density of 14.25%.

The highest value of RWA and ASE were obtained from the acetylation treatment with solvent Acetate Anhydride: xylene with values of 5.51% and 59.42% respectively.

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