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The effect of particle immersing in acetic acid solution on dimensional stability and strength properties of particleboard

Apri Heri Iswanto, Samuel Hermanto and Tito Sucipto
Department of Forest Product, Faculty of Forestry, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia
E-mail: apri@usu.ac.id and apriheri@yahoo.com

Abstract. The objective of the research was to evaluate the effect of particle immersing treatments in acetic acid (AA) solution on dimensional stability and strength properties of particleboard. Particle was immersed in various level AA solution namely 0 (untreated), 1, 2, 3, 4% for 24 hours. Afterward, the particle was oven dried up to 5% moisture content. The amount of 12% UF resin level used for binding in manufacturing particleboard. Board size, thickness and density target in this experiment was 25 by 25 cm$^2$, 1 cm, and 0.75 g/cm$^3$ respectively. After mat forming, board pressed using 130°C temperature, 30 kg/cm$^2$, and pressure for 10 minutes. The results showed that particles immersing in AA solution provide enhancement of thickness swelling (TS) parameters. Overall, 1% AA solution is the best treatment to improve dimensional stability. The similar results also showed by internal bond value. In general, the excess of 1% acetic acid level resulted in decreasing of IB value. A similar trend also occurs in modulus of rupture (MoR) and modulus of elasticity (MoE) parameters.

1. Introduction
Market demand for wood product keeps increasing, while wood supply as raw materials keeps decreasing. Wood shaving from sawmill industries is a potential material to produce a decent quality of particleboard and could be the solution to wood demand. Bowyer et al. [1] stated that wood shavings are irregular particles produced by shaving the thick part of the wood.

Dimensional stability and strength properties are a weakness of particleboard products, in particular, those who using urea formaldehyde (UF) adhesive [2,3]. The particleboard thickness swelling from dry to wet was 10-25% and exceeded whole wood swelling, while the linear swelling reached 0.35% [1].

Previous studies to enhance dimensional stability through to particle and strand pretreatment had been done [4,5,6,7,8,2,9,10]. The objective of this research was to improve of particleboard dimensional stability through particle treatments in acetic acid solution at various level.

2. Materials and Methods

2.1. Materials
Materials used in this study were particle waste in the form of wood shavings obtained from sawmill industries in the city of Medan, urea formaldehyde (UF) adhesive and acetic acid.
2.2. Methods

2.2.1. Materials preparation
The acetic acid solution made on namely 1, 2, 3, and 4%. Wood shavings were immersed in the acetic acid solutions for 24 hours, drained and dried oven up to 5% moisture content.

2.2.2. Particleboard manufacturing
The amount of 12% UF (SC: 63%) resin level used for binding in manufacturing particleboard. Mat formed into a size of 25 by 25cm, then hot pressed on 130 °C of temperature and 30 kg/cm² of pressure for 10 minutes. Conditioning was conducted around seven days, followed by board cuttings referred to JIS A 5908 (2003).

2.2.3. Evaluation of particleboard
The parameters were density and moisture content, water absorption, thickness swelling, internal bond, Modulus of Elasticity (MoE), and Modulus of Rupture (MoR). The physical and mechanical test of particles referred to JIS A 5908 (2003) standard.

2.2.4. Data analysis
This research was using Completed Randomized Design (CDR). The treatments were soaking the samples in acetic acid solution at 0, 1, 2, 3, and 4%. Particleboard in each treatment produced in triplicate.

3. Results and discussion

3.1. Physical properties
The parameter study of physical properties in this research shown in Table 1.

| Acetic acid Level | Density (g/cm³) | MC (%) | WA (%)   | TS (%)   |
|-------------------|----------------|--------|----------|----------|
|                   |                |        | 2H       | 24H      | 2H       | 24H      |
| 0%                | 0.53           | 5.34   | 84.36    | 91.05    | 17.67    | 19.76    |
| 1%                | 0.55           | 5.56   | 41.65    | 80.96    | 10.01    | 11.03    |
| 2%                | 0.52           | 5.21   | 43.89    | 83.46    | 10.06    | 11.19    |
| 3%                | 0.55           | 5.55   | 60.56    | 84.13    | 12.59    | 14.03    |
| 4%                | 0.54           | 5.96   | 71.67    | 86.35    | 12.99    | 15.46    |

We haven’t been able to reach the targeted particle density value of 0.75 g/cm³. We assumed that this was caused by particleboard spring back that was 36.5% on the average. As shown in figure 1, the lower spring back value would increase the density value. The result showed that the treatments did not significantly influence the particle density on the confidence level of 95%. The moisture content value was 5%. The treatments did not significantly influence the particle moisture content parameter on the confidence level of 95%.
Figure 1. The correlation between of spring back and density

The treatment of 2% concentration caused the thickness swelling value to increase compared to control. However, concentration > 2% caused the decrease of thickness swelling value. Sjostrom [11] stated that acid condition is able to degrade chemical component of wood. According to Fengel and Wegener [12], hemicellulose has non-crystalline properties, easy to swell, soluble in alkali and easily hydrolyzed by acids. Degraded hemicellulose lowered the OH group on the polymer. The acetic acid immersion raised the particle acidity. However it reduced extractive substances of the wood particle. Maloney [13] stated that extractive was influencing the adhesive consumption and maturation rate, preventing wetting and causing blowing on compression. Variance showed that treatments resulted significant influence to the thickness swelling value on the confidence level of 95%. According to Harmsen et al. [14], chemical modification using weak acid caused hydrolysis on hemicellulose and impacted on the increase of porosity. The increase of substrate porosity will enhance the penetration, resulting in better strength properties and distribution. Water absorption parameter depended on thickness swelling. We assumed that the increase of particle acidity would enhance UF adhesive maturation process.

3.2. Mechanical properties

The parameter study of mechanical properties in this research showed in Table 2.

| Acetic acid Level | Mechanical Parameters |
|-------------------|-----------------------|
|                   | MoE (x1000) (kg/cm²) | MoR (kg/cm²) | IB (kg/cm²) |
| 0%                | 6.31                  | 52.57        | 2.38        |
| 1%                | 8.74                  | 73.75        | 4.27        |
| 2%                | 7.74                  | 68.51        | 2.68        |
| 3%                | 7.39                  | 59.00        | 2.74        |
| 4%                | 5.31                  | 48.31        | 1.36        |

Overall, particle immersing in 2% acetic acid solution provides the best enhancement of MoR value. Concentration above the level of 2% decreased the MoR value. We assumed it was caused by cellulose hydrolytic as the result of acid use. Previous studies showed that acetylation treatment was causing MoE and MoR values [15, 16, 17, 18]. Variance on the confidence level of 95% did not significantly influence the MoR value.

A similar trend was also occurred on MoE value. Overall, MoE value had not met the standard due to the particleboard had a low slenderness ratio (SR) and aspect ratio (AR) values. The SR and AR values were 27.00 and 1.69, respectively. Maloney [13] declared that the ideal SR ratio for flake particle is 150 and to obtain good board orientation the aspect ratio should reach the minimum of three.
Therefore, we haven’t been able to reach the ideal SR value. Misran [19] stated that aspect ratio of 2 was enough to produce particleboard with good properties.

The optimum condition for mechanical properties included internal bond was the treatment in 2% of concentration. Xing et al. [20] stated that the maturation time during hot compression differs depending on pH level. Furthermore, Paridah et al. [21] stated that to obtain optimum strength properties, the optimization of adhesive polymerization rate could be done through temperature regulation and compressing time. Malanit et al. [22] described that the strength properties value of UF increases with the increasing of wood acidity. Xing et al. [23] stated that level pH below 5 resulted in lower IB value. The result showed that the treatments provided the significant influence on the confidence level of 95%

4. Conclusions
Wood shavings immersion on 1% acetic acid solution is the best treatment to improve physical and mechanical properties of particleboard. Overall, immersion treatments on acetic acid were able to improve dimensional stability parameter. The optimum point of acetic acid is on concentration level 1%. Higher concentration of acetic acid could cause the negative effect in dimensional stability value and internal bond strength properties of particleboard.

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