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Effect of Clam Shell Powder (*Anadara granosa*) Composition on Physical and Mechanical Properties of Polyester Resin Particle Board Products

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In this work, the produced particle board was one of the panel products that was made by using shells powder as filler and unsaturated polyester resin as matrix with the addition of methyl ethyl ketone peroxide as catalyst using compression molding.The purpose of this study was to investigate the mechanical properties of shells powder compounded with polyester in the manufactured particle board. Shells powder was added with different amounts of concentration (10, 20, 30, 40, 50 and 60 wt %). The addition of clam shell powder as filler was not only to utilize the waste but also to increase the hardness and strength of the particle board. Both physical and mechanical tests were conducted on the particle board. It was observed that the physical properties of the particle board increased as the amount of the filler increased but the mechanical properties decreased with the addition of shells powder up to 30 wt %. The obtained mechanical properties of particle board were modulus of rupture (MOR) 40.911 MPa, modulus of elasticity (MOE) 180.547 MPa and internal bonding (IB) 13.605 MPa. The results of physical and mechanical properties were almost the same as the standard JISA 5908-2003 except for modulus of elasticity.

Keywords: Composition, Clam shell, Particle board, Polyester.

INTRODUCTION

Forests, the major sources of wood supply are declining at the alarming rate of 13 million ha each year in developing country and it relates to the usage of wood for other industry. One of them are using wood to produce composite. The demand for composite wood products such as particle board, plywood, medium density fiber board, hard board and veneer products has recently increased distinguishably throughout the world [1]. The rising cost of wood and timber products and the concern for conservation of natural forests, is creating a dilemma for the majority in population. Moves to utilize agricultural wastes for making particle boards that would replace wood products, are receiving notable attention [2]. In this research, particle board made using non-wood materials such as waste shells as a filler mixed with polyester resin as an adhesive.

The difference between particle board and conventional particle are particle board is a panel product manufactured from lignocellulosic materials primarily in the form of discrete particles combined with a synthetic resin or other suitable binder and bonded together under heat and pressure and conventional particle board is manufactured by mixing wood particles or flakes together with a resin and forming the mix into a sheet [3]. Particle boards are used for sound-proofing, thermal insulation and false ceilings [4]. Many substantial efforts have been put forth to reduce some problems related to particle board manufacture, including reduction of cost, increase in output, optimization of resin content and control of formaldehyde emissions [5].

In this research, the manufacturing of particle board were using shells powder as filler since calcium carbonate is the primary mineral content in seashell [6] and can increase the mechanical properties like better dispersion of the particles in polymeric matrix and ability to improve the rigidity of system [7]. The chemical composition of clam shell powder (*Anadara granosa*) is given in Table-1 [6]:

TABLE-1
CHEMICAL COMPOSITION OF
CLAM SHELL POWDER (*Anadara granosa*)

Oxide	Composition (% wt)	Oxide	Composition (% wt)
CaO	94.1	SO_3	0.4
SiO_2	1.0	SrO	0.3
Na_2O	1.0	MgO	0.3
TiO_2	1.0	Al_2O_3	0.2
Fe_2O_3	0.4	–	–

This study aims to determine the optimum composition of the clam shells were substituted so as to improve the physical and mechanical strength of particle board covering density, moisture content, thickness swelling, modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding strength (IB) and impact strength. The particle board product can be used in a variety of buildings and appliances so that reduced the use of raw materials.

EXPERIMENTAL

The matrix unsaturated polyester resin and catalyst methyl ethyl ketone peroxide (MEKPO) obtained from PT Justus Kimia Raya, Medan, Indonesia. While the filler seashells obtained from the restaurant along Jalan Krakatau, Medan, Indonesia.

Preparation of matrix particle board: Unsaturated polyester resin mixed with methyl ethyl ketone peroxide and 1 % of the resin's weight [8]. The mixture stirred with metal mixer for 10-15 min until prevalent.

Preparation of filler particle board: Clam shells washed with water and dried in the sun for 12 h. The dried clam shells milled with ball mill until the particle in micro powder size for 8 h. After that, filtered with 290 mesh sieve's size.

Manufacturing process particle board: Mixed matrix and filler with a comparison 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 wt % (weight percent) in container. Then put some glycerin as lubricant in the iron molding with the size 250 mm × 250 mm × 15 mm. Poured the mixture of matrix and filler into iron molds which has been formed according to the standard of JIS A 5908-2003 [9]. Flatten the mixture on the surface of the mold and pressed it by using compresion molding with pressure of 125 psi high for 40 min. After compressed, the particle board is left for about 5 days which liberate the voltages on the surface of the sheet. the product of particle board removed from the mold and cut according to standar JIS A 5908-2003.

Physical and mechanical properties particle board: The particle board were formed according to JIS A 5908-2003 then analyzed density, water content and thickness swelling by using physical method. For the mechanical properties like modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB) and impact strength were determined using GOTECH AL-7000M with cross-head speed of 500 mm/min and maximum load 2000 kgf.

Density: The density of the cured sample is determined by calculating first the mass of the specimen in air and then the mass of the specimen immersed in a liquid (water is used as a reference). Its apparent mass upon immersion is determined and its specific gravity (relative density) is then calculated. This test is carried out at room temperature [10].

Moisture content: Each specimen should be weighed immediately, before any drying or reabsorption of moisture has taken place. If the specimen cannot be weighed immediately, it should be placed in a plastic bag or tightly wrapped in metal foil to protect it from moisture change until it can be weighed. After weighing, the specimen is placed in an oven heated to 101 to 105 °C (214 to 221 °F) [11]. The formula for water content [11]:

$$\text{Moisture content (\%)} = \frac{\text{Weight when cut} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

Swelling thickness: Thickness of the specimens was measured at the point where the two diagonals intersect using a dial with 0.01 mm precision. Specimens were submerged in clean in an upright position, at rest. Once the immersion test was finalized, the excess of water was drained and the thickness at the intersection of the diagonals was re-measured [12]. The formula for swelling in thickness [13]:

$$\text{Swelling thickness (\%)} = \frac{T_f - T_i}{T_i} \times 100$$

T_i = initial thickness; T_f = final thickness.

Modulus of rapture (MOR) and modulus of elasticity (MOE): The crosshead speed was set in accordance with standards that require the destruction to occur after 60 ± 30 s. Consequently, the crosshead speed was 7 mm/min for the entire board in the X and Y directions, 5 mm/min for the core layer in X and Y directions and 2.5 mm/min for the face layer in the X and Y directions. For each test series, a linear regression was calculated for the linear range of the deflection force diagram [14]. The formula for modulus of rupture [3]:

$$T_b = \frac{3WL}{2bt^2}$$

where: T_b = Modulus of rupture (N/mm^2); W = max load (N); L = buffer (mm); b = width (mm); t = thick (mm).

The linear regression was the basis for calculating the modulus of elasticity (MOE) formula [14]:

$$E_m = \frac{l^3(F_2 - F_1)}{4bt^3(a_2 - a_1)}$$

where: E_m = Modulus of elasticity (N/mm^2); l = buffer (mm); F_1 = force at 10 % destructive force (kgf); F_2= force at 40 % destructive force (kgf); b = width (mm); t = thick (mm); a_1 = deflection at force F_1 (mm); a_2 = deflection at force F_2 (mm).

Internal bond (IB): The sample was placed on the machine and anchored at both ends. As the machine was pumped manually, both tensioned ends were stretched till it failed. Failure occurred by splitting. Internal bond was calculated using the formula [3]:

$$\delta t = \frac{W_t}{b \times t}$$

where: δt = Internal bond (N/mm^2); W_t = load (N); b = width (mm); t = thick (mm).

Impact strength: Impact test was done to determine the characteristics of the material chisel. Two standardized tests the Charpy and Izod, were designed and were still used to measure the impact energy, sometimes also termed notch toughness. For both Charpy and Izod, the specimen was in the shape of a bar of square cross section, into which a V-notch is machined. The load was applied as an impact blow from a weighted pendulum hammer that is released from a cocked position at a fixed height. Upon release, a knife edge mounted on the pendulum strikes and fractures the specimen at the notch, which acted as a point of stress concentration for this high-velocity [15].

RESULTS AND DISCUSSION

Density test: It aims to see whether the product mass is proportional to the volume materials clam shell powder. Fig. 1 shows values of density of the particle board increased by the addition of filler composition of clam shell powder. This is due to the physical reinforcement between matrix and filler through cavities filled, so it will increase the cohesiveness of the bonds between the particles. Due to the empty space of the board the density decreased and the density will be improved by filler composition of clam shell powder. In addition, the higher composition filler shells powder will add to the total weight of the board produced at the same volume. Theoretically, of particle board is influenced by the density of the raw materials, the concentration of adhesive (matrix) and other additives in the manufacture of particle board [16].

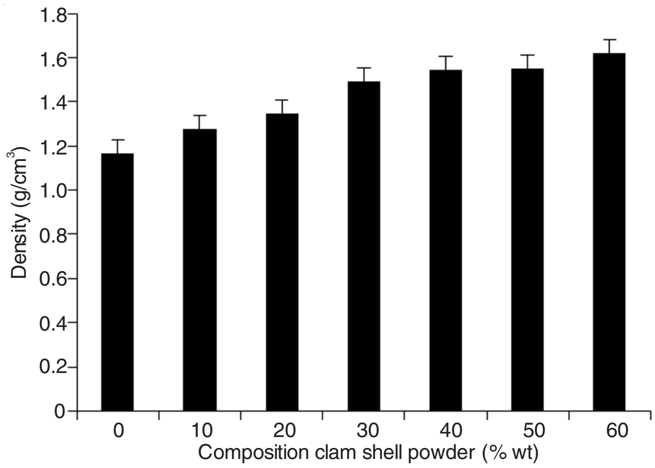

Fig. 1. Effect of the filler composition clam shell powder on the density particle board

Moisture content: it indicates the amount of water content in an object which is expressed as a percent. The purpose of testing moisture content of particle board is to determine the amount of water that remains in the cavity of the cell and the particles during the hardening process matrix. Fig. 2 shows moisture content particle board increased by the addition composition of filler clam shell powder. This is due to the addition of filler composition make the filler particles absorb water easily (hygroscopic), thus the value of the moisture levels will rise. In addition, the increasing moisture content of particle board are also influenced by the dominant composition calcium oxide of the powder shells. Calcium oxide is highly hygroscopic and can absorb water quickly [17]. In this study, density particle board is directly proportional to the value of its water of the content, where the highest density of 1.618 g/cm^3 has the highest moisture content is 0.3235 %. This result was in agreement by Li *et al.* [18]. They showed that the density particle board increased with the improving moisture content raw materials. Moisture content in particle board produced is very low, ranging between 0.20 to 0.33 % and are in accordance with the requirements of the JIS A 5908-2003 which requires water content of particle board < 13 %.

Thickness swelling: It aims to find accretion thickness (%) specimen test after the test sample immersed in water at room temperature. The higher thickness swelling, the lower

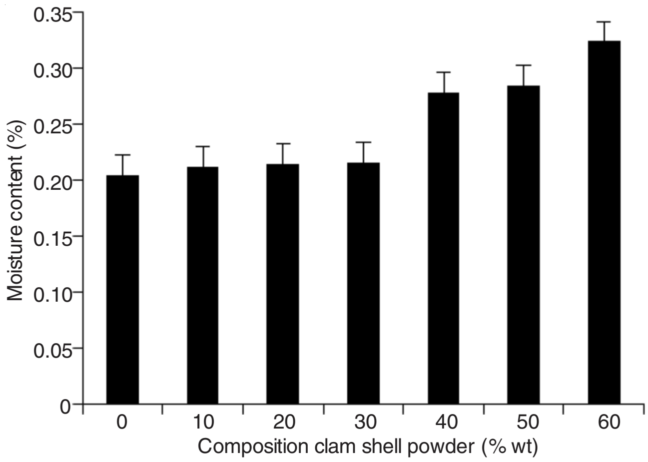

Fig. 2. Effect of the filler composition clam shell powder on the moisture content particle board

stability of the shape because water particles entered into the volume of the board. Fig. 3 shows thickness swell particle board increasing with the addition of filler composition of the clam shell powder. This is caused by the lack of strong connective power between the particles of clam shell with unsaturated polyester resin so that it will accelerate the swelling thick of particle boards when soaking in water. This result is in agreement by Blankenhorn *et al*. [19]. They showed thickness swell is closely related to the adhesive bonding and raw materials, when the bond formed well, the thickness swell will decrease [19]. From this research thickness swell particle board is very low, below 0.5 % and in accordance with the requirements of the JIS A 5908-2003 requiring thickness swell particle board a maximum of 12 %.

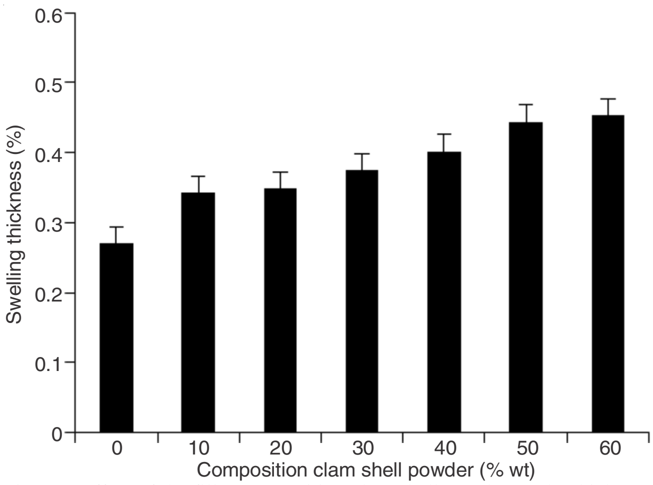

Fig. 3. Effect of the filler composition clam shell powder on the thickness swell particle board

Modulus of rupture: The purpose of modulus of rupture testing is to determine how much the maximum flexural strength of the particle board can accept a given load. Fig. 4(a) shows the addition of filler clam shell powder, modulus of rupture particle board filled clam shell powder had a higher value than modulus of rupture pure particle board (unsaturated polyester). This is because the particle board filled clam shell powder capable of distributing the load applied to the whole part so that a given load is not resting on one point. This is consistent with the statement of Wu *et al.* [20], which states that the addition of fillers can improve the mechanical strength of the composite due to the interaction of the matrix with fillers, these interactions lead to better stress transfer between the filler particles with the matrix. Fig. 4(a) showed that the modulus of rupture particle board filled clam shell powder values increased with addition clam shell powder composition until it reaches a maximum value of 40.94 MPa at a composition of 30 %, but decreased in the composition of 40 to 60 % to reached a value of 30.939 MPa. This is because when the composition of the filler has passed an optimum point, will undergo agglomeration of filler particles to form a larger particle and uneven so that the lower strength of the composite. This is consistent with the statement [21], that agglomeration of particles may decrease the mechanical strength when the addition of too much filler. Based on research [22], also points out that increased filler content (wt %) which has exceeded its limit may decrease the mechanical strength. This is due to lower filler interaction with the matrix caused by particle agglomeration effects fillers that cause early damage/failure.

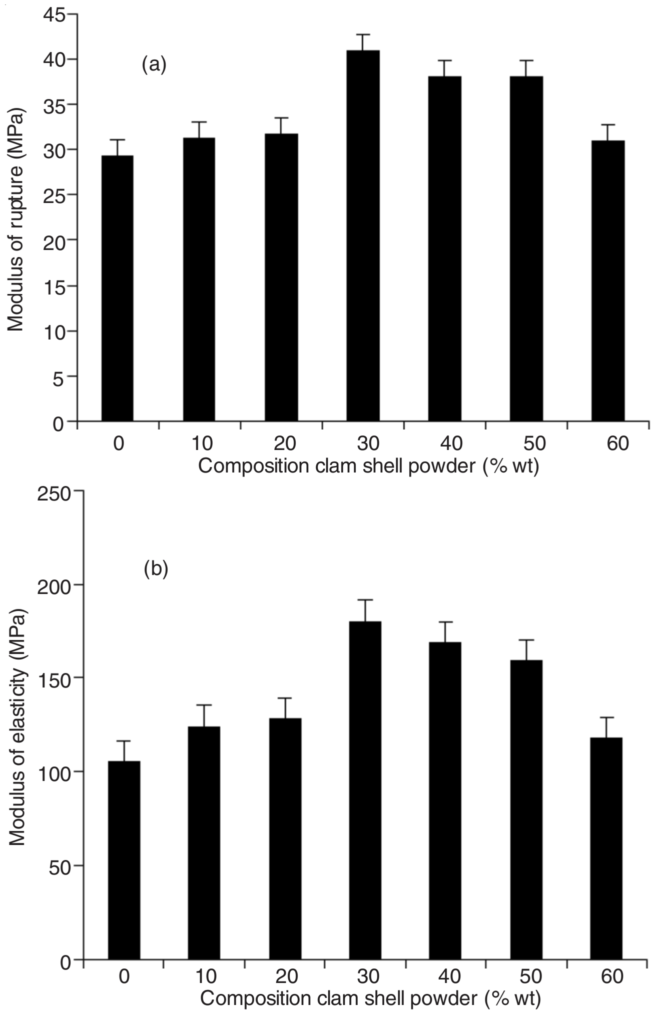

Fig. 4. Effect of the filler composition clam shell powder on the (a) modulus of rupture (MOR) and (b) modulus of elasticity (MOE) particle board

Modulus of elasticity: Fig. 4(b) shows the addition of filler clam shell powder, modulus of elasticity particle board filled clam shell powder had a higher value than modulus of elasticity pure particle board (unsaturated polyester). It is also the same as the modulus of rupture is due to a good interaction between the matrix and filler so as to distribute the applied load. Fig. 4(b) showed that the modulus of elasticity particle board filled clam shell powder values increased with addition clam shell powder composition to the value of 180.457 MPa at a composition of 30 %, but decreased in the composition of 40 to 60 % to the value of 117.931 MPa. This shows that the composition of the powder filler shells that exceeds the optimum, so it will be concentrated in one area and form lumps or agglomeration resulting bending strength is lowered. This is consistent with research done by Kang and Chan [23]. They suggests that at a certain particle size with the addition of filler particles can easily occur clumping/agglomeration and the actual distance between particles become larger than expected, resulting in decreased mechanical strength.

The results showed that the particle board produced has a high modulus of rupture values ranged between 29.3 to 40.9 MPa and in accordance with the JIS A 5908-2003 which requires the value of persistence fracture (modulus of rupture) minimal particle board 82 kgf/cm^2 (8.03 MPa). As for testing the modulus of elasticity, the value obtained is very low, below the 180.5 MPa according to the JIS A 5908-2003 requires persistence fracture value (modulus of rupture) particle board of at least 20,400 kgf/cm^2 (1999.20 MPa). The low value of modulus of elasticity suggests that the ability to resist deformation of particle board under the influence of the load is low. Deformation effects can be minimized if the material is elastic [24].

Internal bond: Analysis of internal bonding strength (IB) aims to determine the value of adhesion and bonding strength between the combined materials to form a composite board. Fig. 5 shows the value of internal bonding particle board filled clam shell powder increased with the addition composition of filler up to 30 %, but decreased in the composition of 40 to 60 %. This is due to their association with the internal bonding and the particle size related to its density. The smaller particle size of the filler will make the density higher and increase the internal bonding. However, to some extent, the higher density will make the contact between the particles becomes non-uniform and less intensively during the compression process and also in forming a stronger bond between the components will decrease [25]. It is also in accordance with the density value obtained, where the value of the highest density 1.618 g/cm^3, yielding a value lower internal bonding strength 8.080 MPa. In addition the smaller particle size (49.7 m) with the addition of fillers can cause agglomeration. It is also supported by Hagstrand *et al.* [26]. They argued that the agglomeration can easily occur because the smaller particles will increase number of filler particles, where the presence of agglomeration in the composite clearly worsen the mechanical properties. The result of internal bonding value from this research are very high and it ranged between 8.1 to 13.6 MPa and has met the JIS A 5908-2003 requiring internal value of the bonding strength of the particle board at least 1.5 kgf/cm^2 (0.147 MPa).

Impact: Fig. 6 shows the value of impact strength particle board filled clam shell powder increased with addition of clam shell powder up to 30 %, but decreased in the composition of

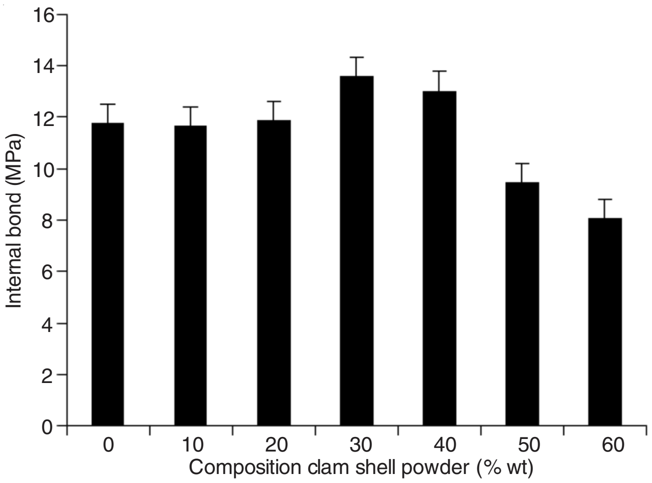

Fig. 5. Effect of the filler composition clam shell powder on the internal bonding particle board

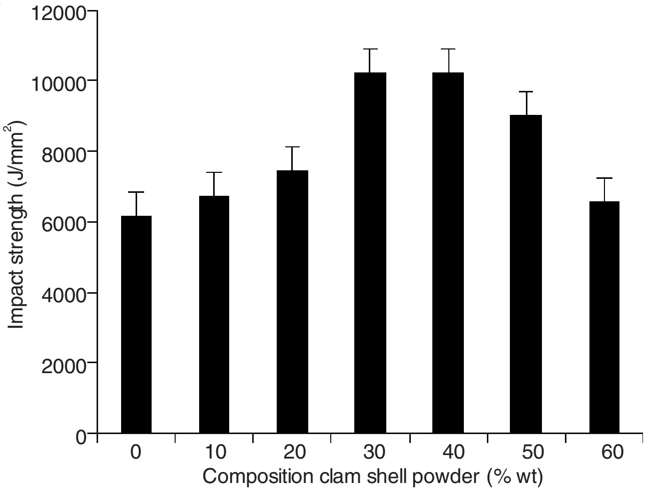

Fig. 6. Effect of the filler composition clam shell powder on the impact strength particle board

40 to 60 %. This shows that the composition of the filler exceed the optimum, so it will reduce the impact strength, which is caused by occurrence of agglomeration. This is consistent with the work of Veena *et al.* [22]. They suggested that the increasing filler content (wt %) has exceeded its limit and decrease the interaction of filler with matrix. Therefore, the mechanical strength will also be decreased and developed early damage (failure).

Conclusion

Extra shells powder filler in particle board can increase the mechanical strength. The addition of filler powder composition of shells 30 % is the optimum limit and produce the highest mechanical strength.

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