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Evaluation of Some Finishing Properties of Oil Palm Particleboard for Furniture Application

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Abstract: The finishing properties of particleboard made from the Empty-Fruit Bunch (EFB) of oil palm (*Elaeis guineensis* Jacq.) were evaluated for its suitability for furniture applications, using different coating and overlay materials. The results found that the thick plastic-formica overlay provided the best surface finish, in terms of surface smoothness, adhesion strength and impact resistance. Although the polyurethane lacquer provided an acceptable finish, its quality and performance is not comparable to that of the thick plastic overlay. Despite the fact that the use of such overlay material may render the material not aesthetically appealing and limit it to concealed applications or where the thick overlay material is tolerated, its cost competitiveness and environmental friendliness may be able to position the oil palm particleboard as a substitute for the conventional wood-based particleboard in the furniture manufacturing industry.

Key words: Finish characteristics, oil palm, particleboard, furniture, adhesion strength, impact resistance

INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the most important plantation tree crops in Malaysia and it covers a land area of almost 3.5 million hectares (Khalil *et al*., 2006). Cultivated primarily for the production of palm oil, the tree crop is an important source of alternative fibers for the manufacture of value-added products. Approximately, 40 million tons of usable fibers from the trunk, frond and empty fruit-bunch of the oil palm is produced annually in the country. The oil palm fiber has high cellulose content and is suitable for the manufacture of a variety of value-added products (Sreekala *et al*., 1997). One of the most promising products manufactured from the empty-fruit bunch fiber is particleboard and the installed production capacity for oil palm particleboard in Malaysia is estimated to be 20,000 m^3 per annum (Khairiah and Khairul, 2006). Although extensive research into the mechanical properties of oil palm particleboard has been undertaken (Chew and Ong, 1985; Yuziah *et al*., 1997), reports on the finishing properties of oil palm particleboard remain scarce. Therefore, a study was undertaken to evaluate the surface finishing characteristics of the oil palm particleboard, which is a pre-requisite to ensure its successful utilization in the furniture manufacturing industry.

MATERIALS AND METHODS

Oil palm particleboards of 700 kg m^{-3} in density and 12 mm in thickness were obtained from a local manufacturer located in Perak, Malaysia. The experimentation was carried out in 2007 at the laboratory of the subsidiary of Coating Industries Inc. in Malaysia. The boards of the dimension 18×1000×1000 mm were conditioned in a controlled environment at a temperature of 20°C and 70% relative humidity for a week prior to experimentation. The boards were sanded using cloth-backed silicone carbide coated abrasives, of two-sanding grits sequence of 80-120 at a feed speed of 4.5 m/min. The resultant surface roughness of the boards was measured in average surface roughness (R_a) over ten sampling points per board, using a MITUTOYO stylus-type profilometer as described by Hiziroglu (1996).

The boards were then applied with different coating and overlay materials, as shown in Table 1. The coating

Table 1: Types of experimental finishing materials

Type of finish	Volume solid content (%)	Thickness of overlay (mm)
Nitro-cellulose (NC) lacquer	35	
Acid curing (AC) lacquer	48	-
Polyurethane (PU) lacquer	48	-
Wood veneer	-	1.5
Melamine paper	-	1.5
Plastic-formica	-	2.0

-: Denote non-availability of figure

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materials were applied using a roller coater, until a wet film thickness of 500 μm was obtained. The boards were then left to cure in a climatic chamber for 7 days, before the final surface roughness and dry film thickness measurements were made. The coating film thicknesses were measured using the 3 M-film thickness gauge.

The overlay materials used were Meranti (*Shorea* sp.) veneer, melamine paper and plastic-formica. The overlays were bonded to the surface of the boards, using a urea-formaldehyde adhesive, spread at a rate of 200 g m^{-2}. The boards were hot pressed at a temperature of 70°C, under a pressure of 8 kg cm^{-2} for 30 min and left for curing in the climatic chamber for 7 days, before surface roughness measurements were made.

A series of tests were conducted on the finished boards to evaluate the adhesion strength, surface wettability and impact resistance of the treated boards. The adhesion of the various coating and overlay materials to the oil palm particleboard were evaluated using the torque-wrench method, as described in Rijckaert *et al.* (2001), which measured the quality of adhesion on the basis of the shearing strength. The surface wettability test which reflects the surface smoothness and integrity was carried out by measuring the contact angle of 10 μL of water droplet over a period of 60 sec using the technique described by Yamamoto *et al.* (1988). A lower contact angle indicates greater surface smoothness and water absorption and vice-versa. The film impact resistance test was conducted in accordance with the BS3962 (1975), by dropping a weighted ball from a height of 2 m and the appearance of the surface rated from a scale of 0-4 denoting the extent of damage. The scale 4 denotes no damage, while the scale 0 denoted more than 25% damaged surface. For each of these tests, eight replicates were used for each coating and overlay materials.

For comparison purpose, parallel experiments were conducted using commercial grade wood-based particleboard, with similar treatments and number of replicates.

RESULTS AND DISCUSSION

Comparative surface roughness of oil palm particleboard: The average surface roughness (R_a) of the raw oil palm particleboard was 315 μm, compared to 210 μm for the sanded oil palm particleboard. On the other hand, the raw wood-based particleboard had an average surface roughness of 245 μm, while the sanded boards had a surface roughness of 165 μm. The marked difference in surface roughness of the un-sanded and sanded oil palm particleboard has been attributed to the morphology of the oil palm fiber, which is significantly tougher than the wood fiber (Sreekala *et al.*, 1997). The thicker cell walls of the oil palm fiber explain its higher coarseness and rigidity (Law *et al.*, 2007). Hence, the two-grits sanding process, which leads to higher stock removal, is necessary to achieve an acceptable level of surface roughness (Ratnasingam and Scholz, 2006). However, the wear of the abrasive sanding belts after sanding the oil palm particleboard were higher compared to that of the wood-based particleboard, resulting in a higher process cost.

Coating characteristics of oil palm particleboard: It is apparent that the coarse fiber morphology and highly cellulosic nature of the oil palm fibers imparts a high degree of hygroscopic properties to the boards (Table 2), which tend to absorb the coating materials applied (Sreekala *et al.*, 1997, 2001; Sreekala and Thomas, 2003). Further, the significantly different densities between the fiber bundles and parenchyma cells in oil palm fibers, creates an inherent density gradient within the material, which leads to a variable texture with a significant degree of porosity (Khalil *et al.*, 2006). This explains the high absorption of coating materials by the oil palm particleboard, which in turn reduces the coating film build on the surface of the board. On the other hand, the wood-based particleboard with its greater board integrity has lower porosity and therefore allows better coating film build-up. In terms of surface smoothness, it is apparent that Nitro-Cellulose (NC) lacquer had the lowest surface smoothness, while the film impact resistance was the highest with the polyurethane (PU) lacquer (Table 3). Against this background, the application of polyurethane (PU) lacquer to the oil palm particleboard is recommended to improve surface smoothness and hardness.

Table 2: Surface roughness and adhesion strength of different finish treatments

Type of finish	Surface roughness (μm) after application of finish material	Amount of lacquer applied (g) to achieve 500 μm wet-film thickness	Final dry-film thickness of lacquer in μm	Adhesion strength of finish material (kN m^{-2})
Nitro-cellulose lacquer	180 (165)	680 (485)	115 (158)	2750 (2980)
Acid curing lacquer	175 (145)	450 (350)	145 (180)	3840 (4050)
Polyurethane lacquer	160 (135)	438 (345)	153 (193)	3957 (4055)
Veneer	151 (135)	-	-	4595 (4705)
Melamine paper	130 (122)	-	-	4410 (4690)
Plastic-formica	117 (115)	-	-	4858 (5150)

*Figures in parentheses indicate values for wood-based particleboard. -: Denote non-availability of figure

Table 3: Comparative surface smoothness and impact resistance measurements

Type of finish	Contact angle (°) after 30 and 60 sec	Impact resistance rating
Nitro-cellulose lacquer	40/38 (35/31)	0 (0)
Acid curing lacquer	60/57 (58/54)	1 (1)
Polyurethane lacquer	82/74 (78/71)	2 (2)
Veneer	65/60 (65/60)	3 (3)
Melamine paper	45/39 (45/37)	3 (3)
Plastic-formica	42/31 (43/32)	4 (4)

*Figures in parentheses indicate values for wood-based particleboard

Overlaying characteristics of oil palm particleboard: It is apparent that the plastic overlay produced the best surface quality, while the veneer and paper overlays did not perform equally well (Table 2). This observation can be attributed to the greater thickness of the plastic overlay, which is able to camouflage the surface roughness of the oil palm particleboard. On the other hand, the thinner veneer and paper overlays were not as successful in concealing the rough surface of the oil palm particleboard. In terms of adhesion strength, the plastic overlay performed better compared to the other coating and overlay materials (Table 2) clearly indicating that thicker finishing material is desirable for oil palm particleboard. This is possibly attributed to the fact that the adhesive used penetrated into the cell structure, especially the parenchyma cells, hence increasing the adhesion strength (Sreekala *et al*., 2001). Further, the performance of the wood-based particleboard was comparable to that of the oil palm particleboard under the application of the different overlay materials (Table 2). In terms of surface integrity and impact resistance, the plastic overlay produced the best results, compared to other coating and overlay materials (Table 3). In this context, it is apparent that the use of thicker overlay materials can improve the finishing and surface smoothness properties of oil palm particleboard and in turn have a far-reaching economic implication on its use for furniture manufacturing.

Industrial implications: The study shows that the most suitable finishing material for oil palm particleboard is the plastic-formica overlay, which gave the best performance in terms of surface smoothness, adhesion strength and impact resistance (Table 4). However, the thick plastic overlay has poor aesthetic appeal and will therefore, minimize the opportunity for the oil palm particleboard to gain market share as a premier furniture raw material. This study also shows that oil palm particleboard has a promising potential to compete with the wood-based particleboard, in applications where surface smoothness is not a priority and overlay application is allowed, especially in niche applications such as school furniture, cabinets, etc., where economics is the primary criterion.

Table 4: Comparative costs of different finishes on oil palm particleboard

Type of finish	Cost (US$ m^{-2})	Comparative quality rating
Nitro-cellulose lacquer	4.50	1
Acid curing lacquer	5.10	2
Polyurethane lacquer	5.90	3
Wood veneer	6.10	3
Melamine paper	5.80	3
Plastic-formica	5.90	5

*Comparative quality rating is based on cost and finish performance factors

CONCLUSIONS

The finishing characteristics of oil palm particleboard were evaluated and it was found that the thick plastic-formica overlay produced the best surface quality and performance, although it may the limit the material's use in concealed applications, or in areas where the use of thick overlay materials are tolerated. However, the oil palm particleboard, which is a cost-effective and greener alternative to the wood-based particleboard, may be able to expand its market share as a furniture raw material, if the correct marketing strategy is employed.

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