TECHNICAL NOTE: A TOOL FOR EVALUATING THE QUALITY OF LAMINATED PARTICLEBOARD COUNTERTOP

X. M. Liu

Graduate Research Assistant
E-mail: xl257@msstate.edu

G. Miller

Research Associate II
Department of Sustainable Bioproducts
Mississippi State University
Mississippi State, MS 39762-9820
E-mail: gdm5@msstate.edu

X. D. (Alice) Wang

Assistant Professor
Wood Products Engineering
Luleå University of Technology
Forskargatan 1, SE-931 87 Skellefteå, Sweden
E-mail: alice.wang@ltu.se

*H. Wan**†

Associate Professor
Department of Sustainable Bioproducts
Mississippi State University
Mississippi State, MS 39762-9820
E-mail: hw2@msstate.edu

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Abstract. To evaluate the quality of laminated particleboard (PB), a typical type of laminate was used in laminating PB with operational parameters similar to industry operational ones. Pull-off tests using Elcometer 510 were conducted. In addition, panel vertical density profiles and the pH of PB at different layers were tested. The results showed that the laminated panel bonded by polyvinyl acetate (PVA) resin had higher pull-off strength than that of the phenol formaldehyde resin within corresponding sanding thickness. Sanding off 0.0762 mm resulted in higher pull-off strength than sanding off 0.0254 mm. The laminates had the highest pull-off strength when the PBs were sanded off 0.0762 mm and glued by PVA. This has provided a solution to improve lamination pull-off strength for industry. The test results have also shown that the laminated panels produced by the manufacturers have the potential to be improved. It also indicates that Elcometer 510 is a good tool to evaluate the PB lamination quality.

Keywords: Phenol formaldehyde resin, polyvinyl acetate resin, laminated particleboard, pull-off strength, Elcometer 510.

INTRODUCTION

Particleboard (PB) is a panel product manufactured by pressing particles of wood or other lingocellulosic materials together with a binder (Nemli and Çolakoğlu 2005). There are several typical binders used in this process, including phenol formaldehyde (PF), melamine formaldehyde, and urea-formaldehyde (UF) adhesive. Laminates are used for decoration of wood-based panels for value-added application. Uniform and flat surfaces are ideal for the application of coating materials. Primarily, the performance of laminated panels depends on the surface quality of PB, the

* Corresponding author
† SWST member

coating or laminate materials, and the type of suitable binder, which should provide an excellent interface between PB and laminates (Hoag 1993).

The Elcometer 510 Automatic Pull-Off Adhesion Gauge was developed by Elcometer Inspection Equipment (Rochester Hills, MI), which accurately measures the strength of the bond between the coating and substrate. The automatic hydraulic pump ensures continuous pressure application for consistent and repeatable results. User-definable measurement ranges with an accuracy of $\pm 1\%$ of the full scale (Elcometer Inspection Equipment 2013). For many years, the Elcometer 510 has been widely used in coating and adhesion-testing areas.

In this study, according to the manufacturing process requirements, PF and polyvinyl acetate (PVA) resins, and 80-grit sandpapers were selected. Sanding thickness of 0.0254 mm (1 mil) and 0.0762 mm (3 mil), respectively, were chosen by a countertop manufacturer. The objective of this study was to evaluate the influence of resins as well as the thickness of sanding on the pull-off strength of a laminated PB.

MATERIALS AND METHODS

A piece of commercial available PB, a piece of Formica laminate sheet (8% of MC) (The Diller Corporation, Cincinnati, OH), PF and PVA resins from Wilsonart (Temple, TX), and two laminated commercial available countertop control panels were used in this experiment. The PB panel from a PB mill was divided into two parts to apply PF and PVA adhesives, respectively. The PF adhesive was Wilsonart 800 with 19% and the PVA adhesive was Wilsonart 3000 with 58% solids.

PB/Laminate Manufacturing

The PB panel with 19.05 mm thickness was cut into four samples with dimensions of 0.3048 m by 0.3048 m, which were then sanded with 80-grit sandpaper. Two of the panel samples were sanded off 0.0254 mm (1 mil) and the other two were sanded off 0.0762 mm (3 mil). The four panel samples and four pieces of laminate sheets were heated in an oven at 47°C for 30 min and then the PF and PVA adhesives were applied at 0.93×10^{-3} kg/m^2 resin load to laminate sheet and the PB sample surfaces, respectively. Afterward, the glued laminate sheets were put onto the heated panels within 5 min. Then, the panel samples with laminates coated with PF and PVA adhesive were pressed together at 88°C and 1.5 MPa for 90 s (daylight to daylight) at 30 s hot press close speed and 30 s open speed with a plywood hot press, to avoid any possible variation during hot press. Finally, after pressing, the laminated PBs were conditioned at a temperature of 20°C and 65% RH for at least 3 wk before test.

Vertical Density Profile Test

In this test, five samples with the dimension of 0.05 m $\times$ 0.05 m were cut from available commercial PB countertop specimens bonded by PF and PVA adhesives. The PB panels were produced at the same time as the one used for laminating operation shown above. The vertical density profiles (VDPs) of both control and tested panel samples were measured using a Quadrupole Mass Spectrometer (Hiden Inc., Livonia, MI) X-ray density profile tester at a scan speed of 0.6 mm/s. The scanning resolution was approximately 0.06 mm across-thickness. During scanning, the X-ray beam, parallel to the plane of the panel, passed across the thickness of the specimen, and this technique averaged the in-plane density of the panel samples.

pH Test

In this test, the pH of PB samples for above lamination process obtained from the panel sample surface, subsurface, and the core layer were tested using the pHs-3E digital pH meter (Yoke Instrument, Shanghai, China). The positions of surface, subsurface, and the core layer of the PB samples are shown in Fig 1. Each of the samples weighed 100 g, and three samples were tested for each position.

Pull-off Test

To test the quality of glue line between PB surface and laminate sheets, the surface soundness

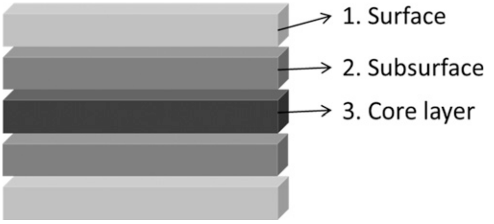


Figure 1. Surface, subsurface, and core layer definition of the particleboard from the client.

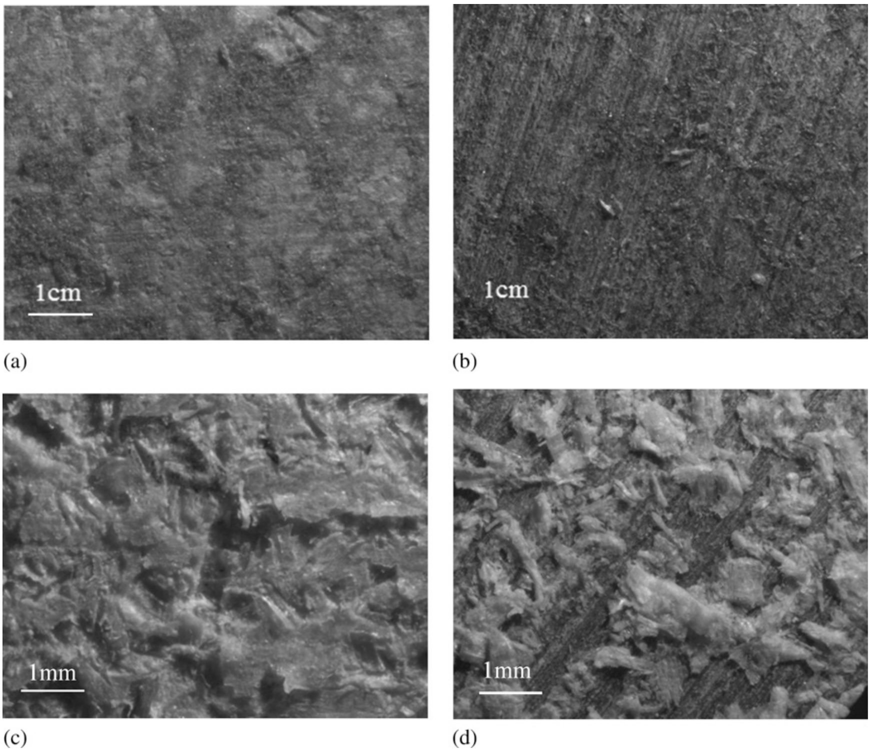
test method was applied according to American Society for Testing and Materials (ASTM) D4541 (ASTM 2009). After more than 3 wk conditioning at 20°C/65% RH, aluminum dollies of 20-mm diameters were bonded to the test pieces of PB samples with the two-part epoxy adhesive of Araldite (Huntsman Advanced Materials, Basel, Switzerland). After 24 h of curing at room temperature of 20°C, a dolly cutter was used to score around the dollies to separate the test area from the rest laminate. The test was conducted with Elcometer 510 Model S, automatic adhesion tester at 1 MPa/s pull rate. The PB surface soundness or pull-off strength was also recorded. For each glued specimen, five samples were tested. The MC of PVA- and PF adhesive–bonded PB samples were 8.4% and 8.2%, respectively. All the test specimens were chosen randomly.

Statistical Analysis

The means and standard deviations of the tested panel pH data and the mean of the pull-off strength were calculated. The pull-off strength data were analyzed statistically using orthogonal linear contrasts through SAS® 9.4 (SAS, Cary, NC).

RESULTS AND DISCUSSION

Generally, Fig 2a-d show the adhesive distribution on industrial control panels. It indicates that PF adhesive coating was not evenly



(a) (b) (c) (d)

Figure 2. Morphology of (a and b) phenol formaldehyde adhesive and (c and d) polyvinyl acetate adhesive on laminated particleboard.

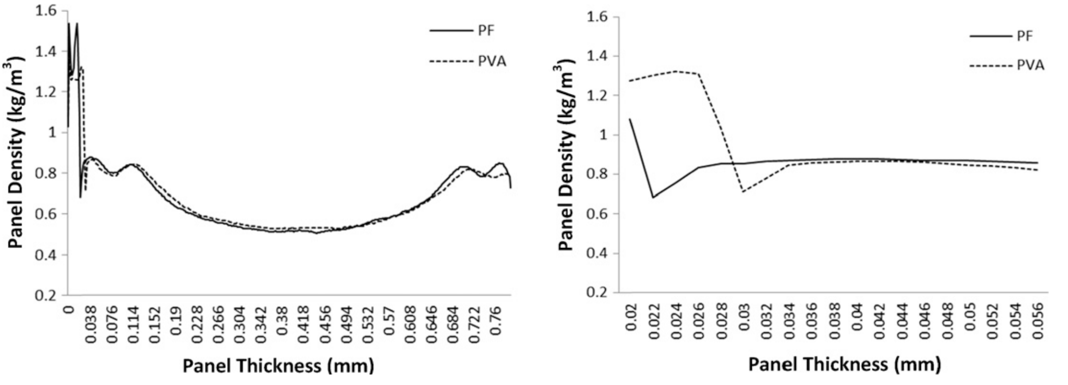


Figure 3. Panel vertical density profiles (a) particleboard with no laminate and (b) PB with laminate).

distributed either on PB panel surface (Fig 2a) or on laminate (Fig 2b). Figure 2c and d show that PVA adhesives were well applied to the PB surface and laminate, which may explain why PVA-bonded panels had high pull-off strength. Detailed discussion follows.

VDP Test

Figure 3a and b are the VDP of PB samples used in this study. They show that the panels used for lamination were identical, indicating the good quality of PB product used. Figure 3b also shows that, at the interface between laminate and panel surface, PF adhesive–bonded laminated panel had low density around 0.68×10^3 kg/m^3 at panel thickness around 0.022 mm, whereas PVA-bonded laminated panel had a density around 0.72×103 kg/m^3. Since low density usually indicates low internal bonding strength, this implies that PF adhesive–bonded laminated panels might have lower pull-off strength than PVA adhesive.

pH Test

Table 1 indicates that the pH of PB at different layers was different: the surface layer had the highest pH and the core layer had the lowest pH.

Table 1. pH of PB panel at different locations.

Position	Surface	Subsurface	Core layer
pH	7.3 (0.2)	5.2 (0.1)	4.24 (0.1)

PB, particleboard. Value in parentheses is the sample standard deviation.

Since the PB panels used in this experiment was UF resin–bonded ones, which indicates that UF adhesive on PB surfaces had experienced more severe decomposition than inner and core layer (Wan et al 2014), which might affect laminated panel quality if adhesive used were not be compatible to the resin's pH change.

Pull-off Strength

Table 2 indicates the pulling off strengths of PF and PVA adhesive with different sanding thicknesses were different. As measured, if the laminates were glued by the industrial client, the means pull-off strengths of laminates glued by PF and PVA resins are 0.5134 and 1.3938 MPa, respectively.

Of the samples laminated at lab, the pull-off strengths were all greater than the laminated controls with the same resin. Statistical analysis shows that all the samples have significant higher pull-off strength than the controls, but not the

Table 2. Pull-off strength (MPa) of PF and PVA adhesives with different sanding thicknesses.

Sanding thickness	Resins	Pull- strength (MPa)[a]
0.0762 mm (3 mil)	PVA	2.0314 A
	PF	1.9498 A
0.0254 mm (1 mil)	PVA	1.9348 A
	PF	0.5708 C
The controls	PVA	1.3980 B
	PF	0.5134 C

PF = phenol formaldehyde; PVA, polyvinyl acetate. The samples of the control experiment were provided by the client.

[a] Means with the different letters are significantly different at the 5% level.

sample using PF adhesive which had been sanded off 0.0254 mm. It is clear that the laminated panels produced by the manufacturers have room to be improved significantly. Since all the data show the same trend, this may indicate that Elcometer 510 is a good tool to evaluate the PB lamination quality.

On the basis of statistical analysis, PF adhesive–bonded laminated PB samples normally had lower pull-off strength than that of PVA adhesive within corresponding sanding off thickness. This shows that adhesive used in the process affected panel pull-off strength. The reason why PF adhesive had a lower pull-off strength needs to be found. Sanding PB 0.0762 mm off helped to improve the laminate's pull-off strength. The highest pull-off strengths was from the PB sample laminated with PVA adhesive, which was sanded off 0.0762 mm, whereas the lowest was from the laminates glued by PF resins which was sanded off 0.0254 mm. The lowest one is significantly different from others at the 5% significance level. This indicated that not only the adhesives chosen but also the sanding thickness affected panel pull-off strength. The reason for this has to be found with further research. However, this has provided a solution to lamination quality for industry, especially related to poor pull-off strength.

CONCLUSIONS

The laminated PB panel bonded with PVA appeared to have higher density than PF adhesive. The PF adhesive–bonded laminated PB panels had lower pull-off strength than PVA adhesive within corresponding sanding thickness. The laminate pull-off strength of sanding 0.0762 mm off was higher than that of sanding 0.0254 mm off, especially in the case of PF adhesive–bonded PB samples. The laminated PBs had the highest pull-off strength when the PBs were sanded off 0.0762 mm and glued by PVA, indicating possible synergy of adhesive and sanding thickness selection. The laminated panels produced in the industrial manufactures have room to be improved significantly. This study indicates that Elcometer 510 seems to be a good tool for PB lamination quality control.

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