

Surface testing of particleboard and medium density fiberboard for laminating applications

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ABSTRACT: *Evaluation of the surface pull test, one of over 15 methods to evaluate substrate surfaces which are reviewed, indicates the need for standardized testing procedures.*

KEYWORDS: *Fiberboards, lamination, particleboards, softboards, standards, substrates, surface properties, test methods.*

Particleboard and medium density fiberboard (MDF) are the substrates of choice for most wood-based panel laminating applications. Both of these materials are manufactured as uniform, flat panels that provide excellent surfaces for the application of laminating materials such as high-pressure decorative laminates (HPDL), wood veneers, saturated papers, vinyl overlays, and more. These laminated panels are then used in the construction of cabinets, furniture, and other industrial product applications.

While the performance of laminated panel products is dependent on many substrate and overlay material factors including moisture content, response to changes in moisture content, modulus of elasticity (MOE), thickness, and the use of balanced construction, perhaps the single most critical feature to consider when looking at substrates for laminating applications is the substrate surface.

Adhesive application, adhesion of the overlay material, and the finished

appearance of the laminated panel will all be affected by the surface of the substrate. Such substrate characteristics as surface strength, resistance to adhesive strike in, fiber pop, and smoothness are factors that need consideration when using wood-based panels for laminating applications. With the increasing use of thin paper and vinyl laminating materials bonded with aqueous adhesives, the surface of the substrate material has become even more important.

Background

In 1990, the National Particleboard Association (NPA) initiated a project to identify test methods and procedures that were currently being used to evaluate substrate surface characteristics. This report summarizes the progress of that project.

While particleboard and MDF make ideal substrates, the manufacturer must consider the many factors that will affect surface quality in virtu-

ally every step of the manufacturing process. The selection of the raw material as well as milling, forming, pressing, and ultimately the final sanding will all have an effect on the panel surface.

Jay and Tasma (1) identify some of the manufacturing factors that will affect surface quality. Thickness control is crucial both at the press and out of the sander. Finished surface thickness variation can cause wrinkling of paper laminates. Panels that are too thin out of the press will not be properly sanded resulting, in soft over-cured surfaces which will tend to absorb excessive adhesive when laminated and will also have an increased likelihood of pitting. Another problem, fiber pop, occurs when individual particles show through thin laminates. This is best controlled by limiting the maximum size of the particleboard's face material.

Surface performance can also be affected by the manner in which the panels are handled not only at the manufacturing plant but also in transit and at the laminating facility. Failure to follow proper handling practices can lead to problems in the surface of the substrate that will have an impact on the performance of the laminate. Proper handling includes avoiding exposure of the substrate to high humidity or wet conditions.

Even though surface characteristics are important for virtually all laminating applications, there are few widely accepted test methods that are used to evaluate objectively the criti-

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cal surface characteristics of wood-based panels. Instead, surface evaluation test methods have been developed on a mill-by-mill basis or between individual mills and specific customers. Because of this, there are sometimes multiple variations of a single test method. Often it is difficult to relate directly the results of one method to another or even between the different variations of a particular method. Development of standardized test methods would benefit panel producers and laminators alike.

Objective

When NPA initiated a project to identify test methods and procedures that were currently being used to evaluate panel surface characteristics, visual grading was identified as the most often used method of evaluating finished panel surface quality. Surface characteristics—such as thickness tolerance, pitting, sander streaks, and chatter—which were routinely evaluated, controlled, or both at the sander were not considered to be the primary focus of this study. Rather it was determined that the key surface characteristics for consideration were fiber pop, the propensity of strike in or dry out when gluing or coating, and surface strength. These properties are not often readily evaluated through visual inspection at the sander.

Using these criteria, the objective of this project was to identify the test methods currently being used to evaluate the surface quality of particleboard and MDF. Ideally, these tests would be widely used and provide a clear, objective means of evaluating differences between panel surfaces. Those test methods judged as having the potential to be drafted into standards or those already widely adopted in standards would be further analyzed, including laboratory evaluation where it was appropriate.

Procedure

The test methods included in this study were identified through mill contacts,

a literature search which included a search of existing surface test standards, and direct contacts with individuals who had demonstrated experience with laminating applications and surface evaluation and test methods. NPA staff often visited the plant or laboratory sites to witness a demonstration of the test procedure or to view the test equipment.

The most significant test methods identified by this study are described below. Minor variations of a test method are not listed as separate test methods but, instead, are considered as variations on a genre of test methods. Each test is considered on a basis of its objectivity, ease of use, and potential value as a surface evaluation tool. Criteria for judging the value of a test method included overall acceptance of the method, the amount of product surface that is tested, and the ease of interpreting the results.

Surface pull testing was evaluated at three industry laboratories belonging to Boise Cascade Corp.; Willamette Industries, Inc.; and Temple-Inland Forest Products Co. All of the laboratories are located at manufacturing facilities. Test evaluation included three variations of the same general test procedure. Two laboratories performed the test according to the most widely recognized standard. One of these laboratories performed side-by-side testing using a variation of the surface pull test now under consideration by the European Committee for Standardization (CEN) (2). The third laboratory looked at still another variation of the test method.

The samples for all of the test laboratories were selected from the same source and included product from 10 plants. Four were MDF and six were particleboard. Data was analyzed using analysis of variance (ANOVA) to determine if variations in the test methods and the product source had a significant effect on the surface pull strength data.

Survey results

More than 15 different surface tests were identified, and several of these were found in multiple forms. Eleven surface test methods were found in various international standards, though some of these were only variations of the same test method. The test methods which were identified are described in the following section.

Black lacquer draw down—gloss retention test

The black lacquer gloss test involves the application of 2 mils of a standard black lacquer to a test sample using a draw down bar to apply a uniform coating. After air drying, the panel is visually evaluated for its gloss retention and variation from a standard panel. The test enhances visibility of surface imperfections such as fiber pop and pitting and provides a means of evaluating panel coatability. Although evaluation is subjective, it has been suggested that inclusion of a gloss meter reading of the surface would provide an objective measure of gloss retention.

Unfortunately the test is very sensitive to application technique and comparisons between test sites may be difficult. Problems with the test include uniform and consistent application of the lacquer and potential variation in the lacquer gloss. One laminator who was familiar with gloss meters suggested that lacquer variability might also be a shortcoming of this method. The test provides a measurement on a relatively large area of the panel surface. There are no known standards for this test procedure.

Boiling water resistance

This test measures the ability of the surface of an HPDL to maintain its color and surface texture when subjected to boiling water. A variation of this test is applied by some manufacturers to evaluate surface properties of panel substrates directly. A specified amount of boiling water is placed

Testing

directly on the panel and then a beaker of hot water is set in this puddle for a specified time. Surface change is subjectively evaluated. The test is part of the standard National Electrical Manufacturers Association (NEMA) test protocol for HPDL surfaces (3), but it is not appropriate for unfinished materials—especially substrates bonded with interior-type adhesives.

Cellophane rub

This test method involves using a piece of cellophane to increase the sensitivity of the fingertips to surface imperfections. The test is an entirely subjective measure of surface smoothness and pitting. It is effective only for relative evaluations between panels by a single individual.

Coin surface hardness test

This test method involves taking a coin and scraping it against the surface of a panel. The degree of penetration or wear on the surface of the panel is a subjective measure of surface hardness. With experience, the test may be useful to individuals looking for a soft surface as an indication of thin panels out of the press.

Durometer

The durometer is a device that provides a quick, simple measure of panel surface hardness. The durometer is held against the panel surface and actuated. A bearing pin strikes the panel surface and a dial gauge indicates the hardness at the contact point. Durometers are typically used in the rubber industry where there are specific durometer standards.

The test provides an objective evaluation of surface hardness that may directly relate to the dive in characteristics of glues and finishes. The test instrument provides rapid results and is relatively inexpensive, compact, and easy to use. Due to the relatively small impact surface area durometers can be expected to perform best on surfaces with fine, uniform faces. Because of this, durometers

find wider use on MDF than particleboard.

Hot oven test

This test involves subjective evaluation of panel surface response to cycles of steaming and subsequent oven drying at 158°F for 22 hours. This test is a rigorous method of evaluating fiber pop characteristics and may not accurately represent expected performance in laminating applications. The performance evaluation is entirely subjective.

Low angle lighting

Evaluation of the panel surface smoothness using low angle lighting to enhance the visibility of surface features is the most common of all evaluation techniques. This test is generally a subjective measure of panel surface quality. Standards based on acceptable surface uniformity criteria (4) have been established, however, and many mills have clearly defined acceptable surface criteria.

Performed as a standard quality control or grading procedure during final finishing, this evaluation primarily identifies surface smoothness and pitting. The test has the advantage of evaluating the entire surface of the graded panel. Some grading stations have the capability of evaluating both sides of the panels.

Panel thickness density profile

This technique utilizes X ray or a gamma source as a high-energy radiation measurement to provide through panel, vertical density profiling as an evaluation for surface layer densification. Since particleboard and MDF density varies through the thickness, this technique is of increasing utility in the area of process monitoring and control. The surface density information provides a characteristic product profile that can be used to evaluate operational variation that may have an impact on surface quality. At the present time, the test equipment is expensive, the sample size is limited,

and no standardized procedures have been developed. Also no quantitative relationship between density profiles and surface quality have been established.

Surface roughness tests

Surface roughness testing is commonly used in the paper industry to evaluate fiber pop and surface uniformity. International standards for wood-based panel products have also been developed. These roughness tests evaluate surface profiles by measuring air leakage between a panel surface and a contact surface of the roughness test device (5, 6). A surface roughness test that includes high humidity exposure cycles may offer a direct means of characterizing fiber pop.

There is a considerable body of experience in the paper industry with Sheffield surface roughness testers. Through adaptation, this test may be suitable for wood-based panels. Surface roughness devices provide a quick, relatively easy measurement and may warrant further consideration. A previous publication evaluated a custom surface roughness tester and reported that it differentiated between different particleboard and MDF panel surfaces (7).

Stylus profilometer

The NPA worked on the concept of using a stylus profilometer to make surface measurements, including use of a high-humidity exposure cycle almost 20 years ago. Although the work was promising, no final procedures or recommendations were ever made. Generally the lack of commercially available equipment suitable for measuring particleboard and MDF made industrial application of these devices impractical. Commercially available profilometers are designed for use on metals, and output information is based on the metal industry surface standards (8). Resolution is too fine and the evaluated surface too short to be practical for particleboard and MDF surface evaluation.

Custom-built profilometers have been used for very specific surface evaluation applications. The American Plywood Association (APA) uses profilometer testing to evaluate the performance of siding products in accelerated exposure testing. A stylus profilometer is used to measure directly the panel surface characteristics before and after cycling.

Researchers at Michigan State University are evaluating the use of a stylus profilometer to measure the surface quality of laminated panels. Their objective is to determine surface stability through exposure to a high relative humidity exposure cycle. This work is continuing and may hold promise for the use of surface profilometers for measuring finished panel surface characteristics.

Noncontact profilometer

The University of California Forest Products Laboratory conducted preliminary evaluations for the NPA on noncontact profilometer techniques using laser measurement equipment. In general, the results were not very promising. In evaluating a coated and finely finished surface which was clearly smoother than the surface of an uncoated sample, the laser device did not make a definitive distinction between the different surfaces. It was suggested that the laser actually responded to the below surface characteristics of the transparent fill finish. Clearly these tests were preliminary, and further consideration of laser or other noncontact techniques may be warranted if these problems can be isolated and overcome.

Solvent dive

Versions of this simple test are widely used. Testing is easy to perform, involves little equipment, and provides instant results. A drop of methanol or other solvent is placed on the panel surface, and the time required for the droplet to penetrate the surface is measured. The test results are influenced by the choice of solvent. Alcohol, toluene, and mineral oil are

currently being used at different locations.

The test is generally subjective, but individual experience provides relative uniformity in measurements. There is no standard for the volume of solvent applied to the panel, and the test is very limited in the amount of panel surface evaluated.

Surface absorption for hardboards

In this test, a steel ring is mounted to the panel surface in a water tight fashion and filled with a fixed amount of water. After a period of time, the water and the ring are removed. Then the panel is reweighed. This test is typically used in hardboard operations. A version of this test is presently cited in the appendix to the Australian Standards for Flat Pressed Particleboard (9). A similar test procedure has been drafted by CEN (10).

The test provides an objective evaluation of panel response to standing water, but it represents a rigorous test for standard urea formaldehyde resin-bonded particleboard and MDF. It is not clear exactly how this test could be applied to evaluating these products, however. Since water and water vapor are usually associated with fiber pop, the test may have some merit in this area.

Surface absorption with toluene or solvent

A widely used group of test methods are solvent surface absorption tests. A sample is typically mounted at a fixed angle, and a measured portion of a solvent is dropped onto the panel. Evaluation is based on measurements of the length and the width of the solvent runoff. Versions of this test are commonly used to evaluate MDF. Variations in the test include solvent type, solvent volume, and sample angle.

The British Standards Institution (BSI) has a standard method that specifies toluene as the solvent (11), and a similar version is being consid-

ered by CEN (12). Individual companies and mills have developed standard test procedures using different solvents including xylene, mineral spirits, and ethanol with varying runoff angles. The only standard method identified uses toluene. Methods using other solvents should be correlated to the toluene test to establish a common reference.

The test provides a quantitative measure that may provide an objective means to evaluate products. The relationship between the runoff results and panel surface characteristics is not clearly established, however. In addition, the use of solvents for testing requires additional safety and environmental considerations.

Surface pull

In the United States, surface pull testing is the most widely used, objective surface evaluation test method. Typically, a circular metal block with a specified surface area is glued to one surface of a small panel specimen, and a tension load is applied until the surface fails. The maximum tension load is recorded as a measure of the panel surface strength. The test is widely used, though techniques were found to vary. Some laminate applicators set minimum surface strength requirements based on surface pull testing. They have found that the panel products that do not meet their criteria are more likely to have crazing and cracking of the laminate surface (13).

Surface pull test methods standards have been developed in several countries including Canada and the United Kingdom (14,15) and a draft standard is under consideration by CEN. Though many U.S. panel manufacturers use surface pull tests to evaluate their products, there is no U.S. standard. Instead, U.S. manufacturers commonly use variations of the test method as defined in the Canadian standard.

Problems with the test method relate to the character of the bond between the test material (substrate surface) and the metal test block. Con-

cern has been expressed about the possibility of hot-melt adhesives diving into the board surface and affecting the surface strength. At least one procedure calls for cold-set epoxies which are less inclined to dive in but are slow to set (12). Expedience encourages the use of hot melts for bonding the blocks to the wood. The most recent CEN draft standard recommends using a precise amount of a hot-melt adhesive in an effort to control the uniformity of the test (2).

One secondary manufacturer uses this test in conjunction with application of a polyester surface laminate. The laminate is applied to the sample using a small lab press. The block is then bonded to the surface of the laminate which can now be done without the problem of the hot-melt dive in. The sample is surface-scored around the perimeter of the test block to further ensure that the test is a measure of one square inch of the panel surface.

Surface wettability

Tests that evaluate the surface wettability properties should provide excellent information pertinent to the glueability and fiber pop characteristics. Quantitative measures of the wettability can be made using surface contact angles. One technique that has shown promise uses video camera equipment to freeze the image while the contact angle measurements are made. This overcomes the problem of a moving contact angle due to strike in (16). There is no known standard equipment or procedure for routinely making these measurements.

Test results

Table I lists surface pull test results by product source. Variation by product source was found to be significant. **Table II** lists average test results by test site. Variation by test site was also found to be significant. Surface strengths were not significantly different at sites 1 and 2, using the same test method. At site 5, however, where

a distinct variation of the test method was used, results were found to be significantly different and lower in all cases.

Table III lists the performance of two distinct variations of surface pull test methods. In this instance, both tests were performed at the same test site. Again the differences between test methods were found to be significant. Generally, samples that were not surface-scored had higher surface strength values than those samples that were scored.

The variation between product source was evaluated to determine the effect of product type. On average, MDF surface strengths were found to be higher than particleboard (PB) at all three test sites. **Table IV** lists test results for PB and MDF. Variation by product type was found to be significant. Variation by product source was still significant, however, even when product type was factored out.

Discussion

Most of the existing, commonly used tests are measures of the surface glueability. Several tests in this genre that are defined by standards include toluene surface absorption, the water surface absorption test, and the surface pull test. The most widely used of these in the United States is the surface pull test. Variations of this test method can be found in the standards of at least four organizations. Two surface absorption tests are standards in various countries, and both are being developed into CEN Standards. There are no comparable U.S. standards. Many U.S. manufacturers, however, use modified versions of a solvent surface absorption test.

There was a decided lack of tests for evaluating fiber pop. Those tests that seemed to hold the most promise fall into the genre of surface roughness measurements. The International Organization of Standardization (ISO) standards describing surface roughness testing (5, 6) should provide a model for any further development of surface roughness test procedures.

I. Table of means for surface pull strength, kPa, by product sample source with 95% confidence interval for the mean

Product source	Average	95% confidence interval for the mean	
0	1630	1521	1742
1	1601	1490	1711
2	1764	1654	1874
3	1357	1247	1468
4	1755	1644	1865
5	1486	1375	1596
6	1191	1080	1302
7	1247	1137	1357
8	1502	1392	1612
9	1797	1687	1908

II. Table of means for surface pull strength, kPa, by test site with 95% confidence interval for the mean.

Test site	Average	95% confidence interval for the mean	
1	1636	1576	1697
2	1640	1580	1700
5	1322	1262	1383

III. Table of means for surface pull strength, kPa, by test method with 95% confidence interval for the mean

Test method	Average	95% confidence interval for the mean	
1	1636	1585	1689
2	1377	1326	1430

IV. Table of means for surface pull strength, kPa, by product type with 95% confidence interval for the mean

Product type	Average	95% confidence interval for the mean	
PB	1476	1393	1559
MDF	1619	1518	1720

There are several different surface roughness devices available that are used in a similar fashion as described in the two ISO surface roughness tests. One such device is described by Bonac (7) who designed a pneumatic device that utilized a flexible reference surface that was found effective in separating low-order surface irregularities. Sheffield roughness testers are commonly used in the paper industry and are being used by some manufacturers to evaluate panel surface roughness. Others have designed simple test instruments that incorporate similar principles.

Conclusions and recommendations

Based on this survey and the limited evaluation of test methods that are currently being used to characterize the surface quality of particleboard and MDF, the following conclusions can be made:

- In this study, several test methods were identified that provide objective measurements for evaluating surface quality characteristics. It is not always clear, however, how these tests related to the actual surface performance of laminated panels.
- Evaluation of surface pull testing clearly indicated that minor differences between two variations of the same test method resulted in significantly different absolute strengths.
- Substrate surface quality characteristics are a key to laminated panel performance. Objective test methods to characterize these surface criteria have not been satisfactorily standardized.

Performance of many of the tests described above within a laboratory is generally presumed to be adequate. When needs arise to compare differences between products and product performance, however, clearly standard methods would be helpful. Seem-

ingly small differences between the procedures of routinely used test methods often provide significantly different results. This complicates comparisons between products and the expected product performance. Obviously everyone would benefit from objective, widely used, standardized test procedures.

This study to characterize surface test methods is continuing and will include additional laboratory evaluation of other tests to include surface absorption, roughness, and black lacquer gloss retention. Results of this work will help to identify the suitability of specific tests and help standardize testing procedures. ▢

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