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THE BIOCOMPOSITE STRUCTURE OF DECORATIVE LAMINATES

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Summary: *High Pressure Laminates (HPL) are manufactured by pressing thermoset-impregnated wood fiber-based layers together under high pressure and heat. . For development of a given strength, appearance and surface topography of a laminate, the process conditions during pressing, the choice of press plate and the choice of materials and structure of the resin-impregnated wood fiber-based layers are essential. Detailed understanding of the structures of these layers is thus important for improving specific characteristics of laminate structures. The present work includes two decorative laminate samples having the same structural composition, but differing with respect to the surface perception. In addition, the samples were abraded with a rotary abrasion test to create surfaces with different extent of wear. The structural analysis was based on laser profilometry and scanning electron microscopy (SEM) of the laminate surfaces and cross sections. The structural analysis revealed that the difference in perception was primarily due to a roughening effect caused by the pressing conditions. The study also showed visually how the wear gradually removed the surface of the top layer (the overlay) as well as the perceptible roughness, before exposing the lower part of the overlay where ceramic particles were added for abrasion resistance. This insight to the internal architecture of these composite materials will be most valuable for further development of superior laminate surfaces.*

1 INTRODUCTION

High Pressure Laminates (HPL) are manufactured by pressing multiple impregnated paper layers together under high pressure and heat (typically 75 kg/cm² and 110-150 °C). The result is a wood fiber reinforced plastic composite with several distinct functionalities due to adequate choices of fiber grades, thermoset resin grades, process conditions and manufacturing equipment. When used in applications such as flooring or in kitchen worktops the laminates need to be persistent to abrasion, scratch, staining and burns, but it is also important that their appearance (visual, touch and sound) appeal to the end user.

In the HPL process all the layers are placed in a press with the top side facing the pressing plate or an intermediate material. The process conditions during pressing, the choice of press

plate material and structure of the top three melamine-impregnated paper layers (Figure 1) are essential for developing a given strength, appearance and surface topography of a laminate. Detailed understanding of the structures of these three layers is thus essential for improving specific characteristics of the laminate structures.

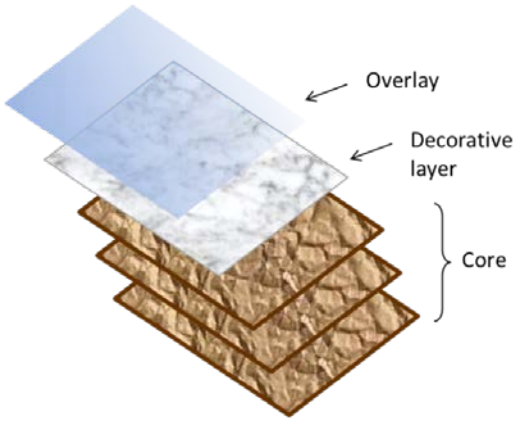

Figure 1: Schematic representation of a high pressure laminate.

A typical paper-based decorative laminate consists (from bottom to top) of a core of several papers impregnated with phenol-formaldehyde (PF) resin, a unicolor or printed decorative paper impregnated with melamine formaldehyde (MF) and a transparent overlay paper or aluminium foil impregnated with MF (Figure 1). In addition to these layers an impregnated barrier paper can be added between the core and the decorative layer to reduce any discoloring of the latter by the core during pressing. To decrease the risk of deformation a balancing paper impregnated with MF may be added on the back of the core [1]. The types of resin, the number of sheets and the paper properties may be altered to optimize the properties of the laminate.

Melamine-formaldehyde (MF) is, due to its hard and transparent properties, the most commonly used resin in laminate surfaces (such as decorative papers and overlays). The surfaces of MF impregnated laminates have been shown to resist staining by ethanol, acetone, soap, coffee, milk and tea as well as scratch and abrasion [4].

The overlay may be an impregnated paper, but it can also be an aluminium foil or a layer of MF. Its main function in flooring is to provide resistance to scratch, abrasion and stains and an attractive appearance through glossiness and transparency. The overlay resin is often filled with solid particles to increase scratch, abrasion, strength and stiffness properties of the laminate. The fillers may be made of ceramic (e.g. Al_2O_3), glass or carbon black. The filler properties that are expected to affect the laminate properties are e.g. size, shape, internal strength, density and surface chemistry (wetting and adhesion).

The decorative paper is thin (e.g. 30 g/m^2) and printed in unicolor or pattern (usually wood or stone patterns). Decorative papers are made from cellulose rich pulp (e.g. alpha cellulose) and need to have the right porosity and enough wet resistance for successful impregnation [5]. It has been reported that decorative papers with different patterns and paper properties affected laminate properties differently [6].

The core layer is made of several PF impregnated papers (e.g. kraft papers). By altering the number of papers in the core its thickness and mechanical properties can be modified.

Impregnated sheets are piled and pressed with heating. The elevated temperatures and

pressures cause the resin to flow and the impregnated papers form a monolithic laminate [3]. A wooden substrate (such as a particleboard) may be attached under the laminate during laminate pressing or the laminate may be glued to the substrate at a later occasion.

The main objective of this work was to study the relationship between pressing conditions and the surface structure of the finished laminate product. The study was based on a detailed examination and comparison of the structure of two laminates presently manufactured commercially.

2 EXPERIMENTAL

Two high pressure laminates referred to as S and OT have been provided by Alloc AS. The laminates had the same structural composition, but differed with regard to the surface perception. The OT laminate had a gloss of 5-6 % whereas the gloss of the S laminate was 11-12 % (Dr. Lange gloss). The individual laminate components from the same series (overlay, decorative paper and core paper were provided by Alloc for comparison.

In addition, the samples OT and S were tested with respect to the wear resistance, using a Taber Rotary Platform Abraser. The wear cycles were 200, 400, 800, 1000, 2000, 9800 (S) and 10200 (OT).

Pieces (10 mm × 20 mm) of each sample were embedded in epoxy resin and prepared for cross-sectional SEM analysis. The embedded samples were hand-held ground, automatically polished with polishing clothes of 9 and 1 μm and coated with a layer of carbon for SEM analysis. The microscope was a Hitachi S-3000 variable pressure SEM (Hitachi High-Technologies Corporation, Minatoku, Tokyo, Japan). SEM cross-sectional images were acquired from each sample, applying the backscatter electron imaging (BEI) mode. The magnifications were 100× and 400×. The acceleration voltage and working distance were 5 kV and 10 mm, respectively. Additionally, samples were coated with carbon for surface SEM analysis. The SEM surface images were acquired in BEI mode.

Samples (10 mm × 10 mm) were coated with a layer of gold for topography analysis. A laser profilometer (LP, Lehmann, Lehman Mess-Systeme AG, Baden-Dättwil, Germany) was used and ten LP topography images were acquired from the top side of each sample. The lateral and z-resolution of the LP system was 1 μm and 10 nm, respectively. The size of the local areas was 1 mm × 1 mm. The surfaces were horizontally levelled. For details on the structural analysis see e.g. Chinga-Carrasco *et al*. [2].

3 RESULTS

3.1 The structure of laminates for flooring

The cross-sectional structures of the individual laminate components are shown in Figure 2. Note the overlay structure (Figure 2A), which is composed of a fiber layer impregnated with melamine formaldehyde and a lower layer dominated by relatively large aluminium oxide particles. The aluminium oxide particles are used to increase the wear resistance of the overlay layer. The decorative paper in the middle layer is printed with a given print to give the visual appearance to the laminates (Figure 2B).

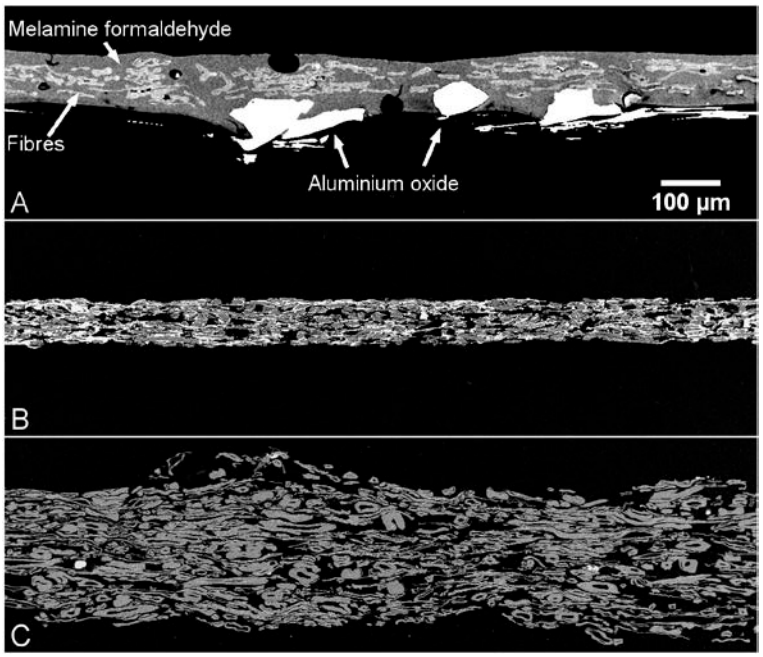

Figure 2: Cross-sectional structure of the three laminate components; the overlay (A), the decorative paper (B) and the core paper (C). All the images were acquired at the same magnification.

The laminate composites are composed of two types of resin, various types of wood pulp fibers, fillers and aluminium oxide particles organized in an advanced laminate structure to meet all the requirements of a modern HPL. The cross-sectional structures of the OT and S laminates are shown in Figure 3. The aluminium oxide particles are relatively large (~100 µm) and positioned between the overlay layer and the decorative paper. The decorative paper has a major fraction of filler material (white areas). The core layer in the lower part of the laminate has a thickness of roughly 400 µm.

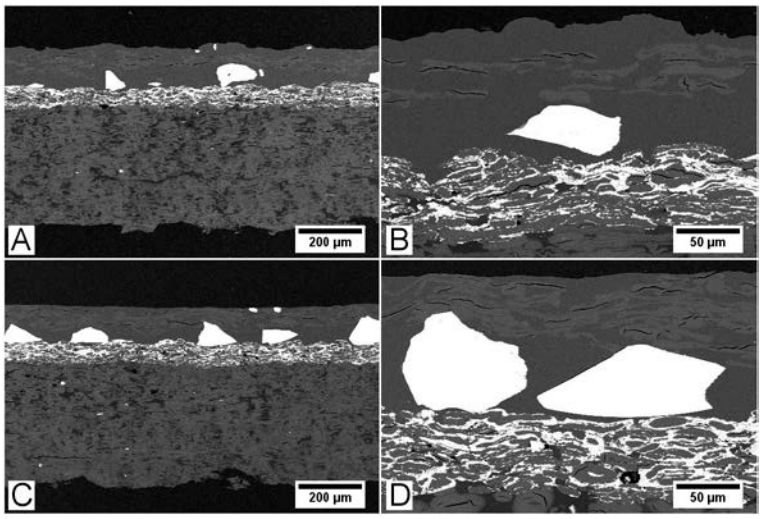

Figure 3: SEM BEI cross-sectional images of the laminates OT (A and B) and S (C and D). The overlay, the decorative paper and the core paper are visualized on the upper, middle and lower parts of the images, respectively. The images were taken at 100x (A and C) and 400x (B and D) magnifications.

3.2 Comparative analysis of the OT and S samples

The surface structure of the samples OT and S shows different roughness characteristics.

The SEM analysis indicates that the sample OT is rougher (Figure 3A and B) compared to sample S (Figure 3C and D). A laser profilometry (LP) analysis was performed to quantify the roughness of the two samples, OT and S. The analysis showed a clear difference between the OT and S laminates, confirming the rougher structure of the OT sample (roughness=8.0 μm), compared to the smoother surface of the S sample (roughness=3.6 μm). Note again that the same laminate components were used in the two samples, which confirms that the differences of the laminate structures are caused by the pressing process.

3.3 Wear analysis

The samples OT and S were tested with respect to the wear resistance, following a Taber Rotary test. The surface development of the samples as a function of the number of revolutions was quantified with laser profilometry (Figure 4). There is a clear difference between the sample OT and S. However, after 200 revolutions the roughness of the samples OT and S are similar. Such a surface development was expected since the two laminate samples are composed of the same structural components, the only difference being the surface roughness created by the pressing conditions. There is no significant difference between the samples tested after an increasing number of revolutions (200 - >9000).

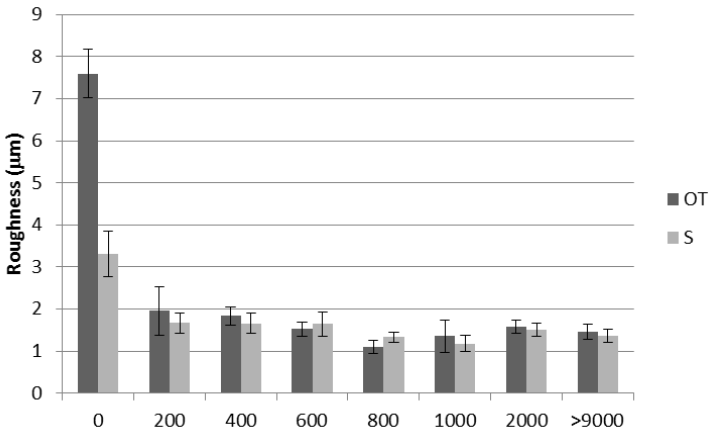

Figure 4 The roughness of samples OT and S as a function of the number of revolutions in a Taber rotary test.

The surfaces of the abraded samples were assessed with SEM (Figure 5). Although the surfaces have similar roughness levels, as revealed by the laser profilometry analysis (Figure 4), it becomes clear that the wear of the samples is gradually removing material from the surface, and penetrating deeper into the lower parts of the overlay. The aluminium oxide particles are thus gradually exposed. Important to note that there were no signs of removal of complete aluminium oxide particles, indicating that the particles are well bonded to the melamine formaldehyde matrix. In addition, note also that scratches seem to be more visible as the wearing progresses. The scratches occur on both the melamine matrix and within the aluminium oxide particles.

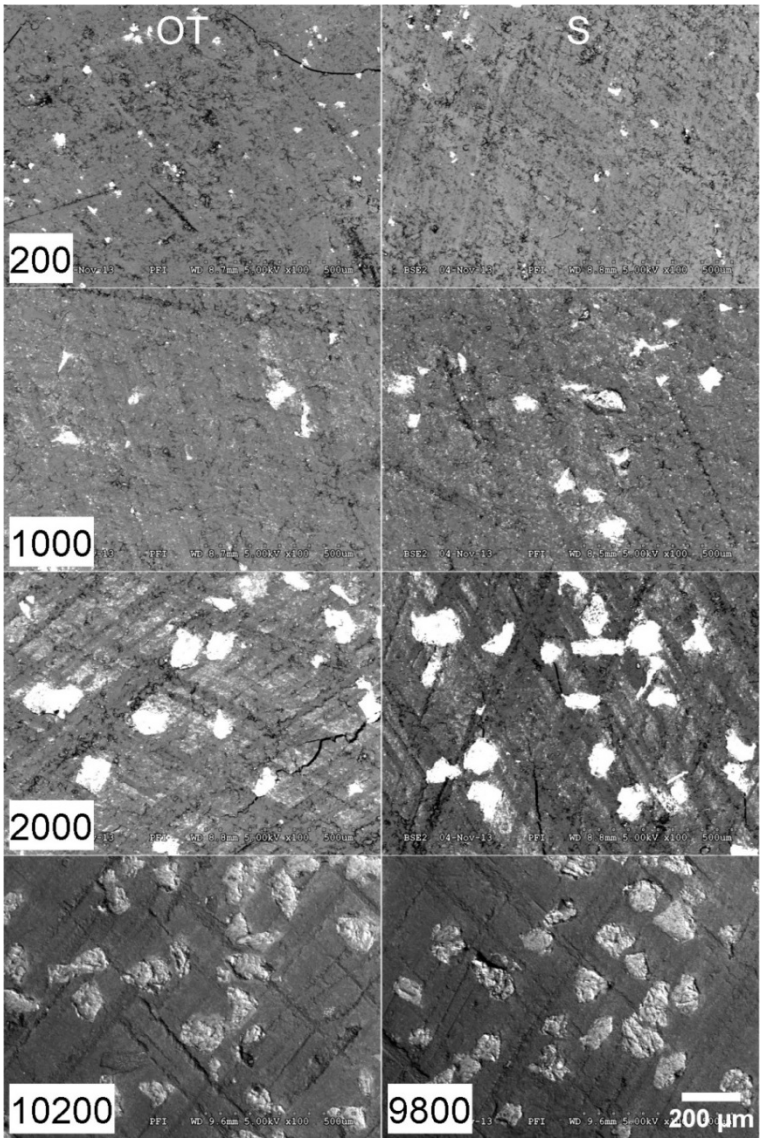

Figure 5 SEM analyses of the samples OT (left) and S (right column). The images are taken after 200, 1000, 2000 revolutions in BEI mode. The images of the OT sample after 10200 and S sample after 9800 revolutions were acquired in BEI 3D mode.

4 CONCLUSIONS

The intention of this report was to assess and quantify the structure of two floor laminates, i.e. an oiled touch (OT) and a silk (S) sample. The OT and S samples have the same structural composition, but differed with respect to the surface perception. The structural analysis revealed that the different perception was primarily due to a roughening effect of the OT samples induced by the pressing conditions.

In addition, the wear of the OT and S samples was assessed. It was demonstrated that after 200 wear revolutions most of the roughness created by the pressing conditions was removed. The roughness of the OT and S samples was thus similar at all the subsequent revolutions during the Taber rotary test. SEM analysis revealed that the wear gradually removed the surface from the overlay layer, thus exposing the lower part of the overlay including the aluminium oxide particles.

In addition to clarifying the causes of the differences between the OT and S samples, the

insight to the internal architecture of these composite materials provided by this structural analysis will be valuable for further development of superior laminate surfaces.

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