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Surface gloss of lacquered medium density fibreboard panels veneered with thermally compressed birch wood

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ABSTRACT

Wood surfaces are typically sanded before the lacquer coatings technological processes. This article discusses the aesthetic properties of lacquer coatings formed on medium density fibreboard (MDF) panels, veneered with thermally compressed birch wood. The effect of thermal compression temperature, veneer side (loose vs. tight), the number of lacquer layers and spread rates on the gloss unit (GU) of lacquer coatings were determined. Rotary-cut birch veneer sheets were thermally compressed at various temperatures (150, 180 and 210 °C) and afterwards they were bonded to the surfaces of MDF panels. The lacquer was applied to the surface of veneered MDF panels in 1, 2 and 3 layers at the various spread rates, appropriate 50, 75 and 100 g/m^2. The values of GU parameter were measured at three angles − 20, 60 and 85°. Statistical evaluation of GU parameter showed, that the number of layers, the amount of lacquer, the direction of wood fibers, the side of veneer and compression temperature significantly affect gloss of the surfaces of veneered MDF panels. Gloss increased with the number of layers and the amount of applied lacquer. Brightness decreases with the increase in temperature from 150 to 180 °C, while a further increase in temperature from 180 to 210 °C enhances GU. There is a significant difference between values of gloss (except for the 20° angle) measured along and across grain direction. The values of gloss measured along the wood fibers are higher than those measured across the grains. Thermal compression of veneer homogenises the surface and as a result the gloss of the loose and tight sides is uniform. Thermal compression of birch wood surface instead of its sanding before finishing improves aesthetic properties of wood, in particular surface gloss as well as reduces the required lacquer application rate. These findings make it possible to improve the technology of lacquer coatings of thermally compressed wood.

1. Introduction

Wooden material protected with lacquer coatings are mainly used to improve aesthetics of furniture and decorative items made from wood and protect them against various factors such as heat, light, temperature, air humidity, abrasion as well as extend the economic life of wood material surfaces. In addition, the coatings (in particular, transparent coatings) can add beauty by enhancing the aesthetic and decorative properties of wood and improving its gloss unit (GU).

Gloss is a surface property connected with the reflection of light and is used to evaluate the quality of wooden finished products. Lacquer products form coatings with a various values of gloss. Although gloss is mainly determined by the chemical composition of the lacquer coatings, the gloss quality of coatings also depends on several factors, such as the wooden substrate itself [1], wood species [2,3], surface roughness [4,5], the type of lacquer products [2,6,7], the number of layers [7], application method [6,8], thermal ageing [9], humidity [3], moisture content of wood [9,10], substrate preparation [1,5,7], and the method of wood treatment [2,11–13]. Therefore, because of the multitude of chemical and mechanical interactions the effect of the surface structure of a coating on its gloss may be different depending on the specific combination of wood species and lacquer products.

Surface preparation processes, including planing and sanding, of wood/wood based materials before lacquer finishing are usually performed to remove machining imperfections (e.g. scratches, raised fibers, knife marks, torn fibers, adhesive residues, and other defects) and to produce a homogeneous, flattened and cleaned surface, as a prerequisite for a quality interaction between the coating and the substrate. Smooth surface is essential for good appearance because the finish accentuates any irregularities of roughness in the surface [14]. Moreover, Richter et al. [15] stated that without preparation, the amount of lacquer products required to impregnate wood surfaces tends to increase, which leads to excessive consumption of these materials. During the planing/sanding processes a layer of wood (very often of a

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valuable species) is removed and this portion of wood irreversibly goes to waste, namely, generates economic losses. Moreover, sander dust creates unfavourable conditions for workers and pollutes the environment. Additionally, the requirement and benefit of the sanding process, which is difficult to control, and which is one of the most skill-based, time-consuming and expensive operations in the woodworking industry, are disputable [4].

Wood veneer, particularly in the case of valuable wood species with an attractive texture and colour, can be used not only in the production of plywood or LVL, but also for veenering of particleboard and medium density fiberboard panels in the furniture industry [16]. However, resources of valuable wood species, which may be used as a veneering material, are becoming dramatically depleted and as such − increasingly more expensive. Less valuable wood species are characterised by various defects, mechanical damage, and less decorative appearance than valuable wood species. This causes the need to improve the aesthetic properties of such wood veneer.

In recent years a rapid increase has been observed in the application of various modification methods (in particular, thermal, thermo-mechanical and thermo-hygro-mechanical treatments) to wood and wood based materials in order to improve their properties [17–19]. These treatments of wood are an eco-friendly method to modify wood without the use of any toxic chemicals. In particular, thermo-mechanical densification of wood veneer was developed to enhance surface quality [5,20,21] and improve bondability and lacquerability of densified veneer [22]. Furthermore, it was also found [22,23], that thermo-mechanical compression of veneers before adhesive application in the manufacture of veneer-based products facilitates a significant reduction of adhesive consumption − 45–50%. Since veneers may also be used as a cladding material for particleboard and MDF panels, it could be expected that the implementation of thermal compression of wood (veneer) surface before lacquers application may also reduce its consumption.

Thermal compression differs from other commonly used processes (planning or sanding) of surface preparation before lacquer finishing of wood, because wood is compressed between heated press plates or is rolled between heated polishing drums to smooth out wood surface.

Because of the application of the proposed surface preparation process before coating the surface layer of wood is exposed to short-term effects of pressure and temperature. Consequently, as it was shown in previous studies [5,18,20,21], wood surface undergoes several changes. These changes relate to both chemical and physical properties, as well as morphological characteristics of wood surfaces, including gloss, colour, surface roughness, hardness and surface texture. Thermo-mechanical compression leading to densification and filling of pores results in softening of wood components and their plastic deformation. The obtained high-density surface is flat and smooth. After such treatment the sanding of the surface of compressed wood before finishing/coating is no longer required. The surface of the wood is aesthetically attractive in itself; additionally, thermal compression gives it an attractive darker colour with clearly distinct features of its texture. Our previous studies [20,21] showed an enhancement of aesthetic properties in thermally densified veneer of various wood species. Gloss values of densified wood increased with an increase in densification temperature and pressure for all investigated species. The colour and gloss of wood are important characteristics for its application and transparent coatings allow the gained good aesthetic properties of wood to remain visible. Together, this may increase the demand for such wood/wood-based materials as well as determine their value, and thus also their price.

The purpose of this study was to assess the potential influence of the new substrate surface preparation method by its thermo-mechanical compression on the quality of the wood finishing. The quality of the lacquer coatings surface was evaluated by measuring its gloss. The influence of the number of layers, lacquer consumption and the temperature of thermal wood compression on the gloss of obtained coatings was also investigated.

2. Materials and methods

2.1. Materials

Rotary-peeled birch (*Betula verrucosa* Ehrh.) trade wood veneers (PLYWOOD MULTI S.A., Bydgoszcz) with the nominal thickness of 1.5 mm and moisture content of ~5% were used as cladding materials. Commercially manufactured (SWISS KRONO Sp. z o.o., Żary) medium density fibreboard (MDF), with thickness 16 mm and density 750 ± 10 kg/m^3 was used as the substrate material. Single-component waterborne Jowacoll® 148.00 adhesive (supplied by Jowat SE Corporation, Detmold) based on EVA copolymer with density 1.35 g/cm^3, apparent viscosity of 13.000 mPa.s (Brookfield), solids content 70%, and pH value 7.0 was used in the veneering operation of MDF panels.

2.2. Short-term thermo-mechanical compression

Veneer sheets were compressed using an automatically controlled single-opening hot press. To avoid surface contamination during compression, veneer samples were placed between smooth and carefully cleaned thin stainless-steel sheets. Then, the veneer samples held between steel sheets were placed between the heated press plates and when the pressure reached 3.0 MPa, it was held under compression perpendicular to the grain (thickness direction) at the temperatures of 150, 180, or 210 °C for time 3 min. After this period the press was opened, the compressed veneer was removed from the press and allowed to cool at a temperature of 20 ± 2 °C and a relative humidity of 65 ± 5%. The weight and dimensions of the samples were measured before and after compression. Thickness of each veneer was measured at four corners accurate to 0.01 mm before and after they were compressed to determine reduction of thickness as a function of temperature values.

2.3. Veneering of MDF panels

Panels (300 × 300 × 16 mm) were veneered with non-compressed (control) and compressed veneer sheets using Jowacoll® 148.00 adhesive. Adhesive was spread on the surface of the MDF samples with a glue roller taking into consideration the loose and tight sides of veneer at a rate of 180 g/m^2 prior to curing using a cold press at a temperature of 20 ± 1 °C and a unit pressure of 0.8 MPa for time 3 min. In a half of produced panels (Group A) the veneer sheet fits in the sandwich packet so that its loose side is opposite to the adhesive layer applied on the surface of MDF samples and is adjacent to the lacquer coating layer (Fig. 1). In the other batch of produced panels (Group B) the veneer sheet fits in the sandwich packet so that its tight side is opposite to the adhesive layer applied on the surface of MDF samples and is adjacent to the coating layer (Fig. 1). Therefore, a half of veneered MDF panels had their outer layers formed by the loose side of veneer, while the other half of veneered MDF panels had their outer layers formed by the tight side of veneer. After the gluing process, the samples were removed from the press and were conditioned in a climate chamber with a temperature of 20 ± 2 °C and a relative humidity of 65 ± 5% before any tests were carried out.

2.4. Surface lacquer finishing process

MDF panels veneered with densified and non-densified veneers were used as substrate for lacquer coating (Fig. 1). A solvent-based lacquer product (trade name OLI-KS Parkettsiegel 7600), based on alkyd-urethane copolymer, full transparent colour, density 0.98 g/cm^3, convencional viscosity 80 s (Ford cup 4/20), solid content 45% was commercially obtained from a supplier (OLI LACKE GmbH, Lichtenau) and was used for the finishing application on the veneered MDF substrates. Samples were conditioned in a climate room before they were