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Surface characteristics and hardness of MDF panels laminated with thermally compressed veneer

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ABSTRACT

The aim of this study was to investigate surface characteristic (surface roughness and wettability) and hardness of sandwiched panels produced from medium density fiberboard and thermally compressed wood veneer. Oriental beech (*Fagus orientalis Lipsky*) veneers were compressed at temperature levels of 150 °C, 180 °C, and 200 °C using 4 MPa and 6 MPa pressure for 8 min. Commercially produced MDF samples were laminated with such thermally compressed veneer sheets. Contact angle (CA) of the panels were measured with a goniometer. The surface roughness (SR) of the samples was determined fine stylus tracing technique and Janka hardness was determined according to ASTM D 1037 standard. The results showed that the SR value of the panels decreased with increasing press pressure and temperature. Press pressure had no significant effect on the CA values of the panels while temperature significantly affected. All of the compressed veneer laminated panels had higher hardness value compared to non-compressed veneer laminated panel. The hardness value of the panels increased with increasing press pressure and temperature. This study showed that press pressure and temperature can be used to improve surface characteristics of non-laminated and laminated MDF panels. Thermally compressed veneer laminated MDF panels can be utilized for structural purposes due to higher hardness. It also would provide more efficient use of adhesive to manufacture plywood and LVL and better surfaces for surface treatments such as painting.

1. Introduction

Thermal compression process has been used for many years in different applications [1–3]. This process is used to enhance physical and mechanical properties of wood materials. In addition to the enhancement of mechanical properties of wood products, surface quality can also be improved as a result of compression process. Compressed veneer sheets with a smoother surface can be used for plywood and laminated veneer lumber (LVL) manufacturing while reducing consumption of the adhesive amount so that the overall production cost can be positively controlled. Surface roughness of veneer plays an important role on depth of penetration of adhesive into the veneer, uniform distribution of adhesive as well as having improved bonding quality between veneer sheets [2].

Results of some past studies also suggested that press temperature played an important role on surface quality of compressed and heat treated veneer sheets [4–7]. Various studies also have been carried out to determine the surface roughness of compressed veneer sheets [1,2,7]. Bekhta et al. [1] evaluated that effect of compression ratio on surface roughness of birch and alder veneers compressed using a cold rolling process. They showed that surface roughness of veneer improved as the compression degree increased. Candan et al. [2] investigated that surface quality of thermally compressed Douglas fir veneer. They compressed veneer samples using press pressure levels of 1.0 N/mm^2, 2.0 N/mm^2, and 2.5 N/mm^2 at two temperatures of 180 °C and 210 °C for 3 min. They reported that surface of the veneers become smoother when press pressure and temperature increased.

Compressed veneers also supply higher thermal conductivity and lower glue consumption in plywood production compared to non-compressed veneers [4,8]. Asako et al. [4] reported that effective thermal conductivity of Japanese cedar increased after radial compression. Bekhta and Marutzky [8] investigated glue saving possibilities in plywood production by using previously compressed veneers. They concluded that using these veneers in the plywood production enable higher shear strength with lower glue consumption.

Medium density fiberboard (MDF) is one of the most widely used interior wood composite substrates for cabinet and other furniture manufacture. Solid veneer is also used as prime overlay for MDF to manufacture expensive furniture units. Among the other species beech is widely used to laminate substrate particleboard and MDF panels in many European countries. Buyuksari et al. [9]

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evaluated physical and mechanical properties of MDF panels laminated with compressed veneer. They stated that compressed veneer using different press temperature and pressure levels could be considered as an alternative way to develop sandwich type products with satisfactory structural properties. However currently there is no information on surface characteristics and hardness of MDF panels laminated with compressed veneer in the form of sandwich panel. Therefore, the objective of this work was to evaluate effect of laminating with thermally compressed veneer on the surface roughness, wettability and hardness of MDF panels.

2. Materials and methods

2.1. Materials

Oriental beech (*Fagus orientalis Lipsky*) veneer sheets with 1.5 mm thickness produced by rotary peeling technique and commercially manufactured MDF panels with a thickness of 12 mm were cut into 500 mm by 500 mm sections. The veneers were compressed in a laboratory type hot press. A total of 4 veneer samples were compressed for each trial. Thickness of each veneer was measured at four corners at an accuracy of 0.01 mm before and after they were compressed to determine reduction of thickness as function of pressure and temperature. MDF panels were laminated with control (non-compressed) and compressed veneer sheets using urea formaldehyde adhesive with 65% solid content and 1.25 urea/formaldehyde ratio at a spread rate of 160 g/m^2. Ammonium chloride (NH_4Cl) solution with 20% solid content was also added at a level of 1% based on dry weight of wood into the adhesive mix. Sandwiched panels with two sheet of veneer were compressed in a computer controlled hot press. Specimens were conditioned in a climate chamber with a temperature of 20 °C and a relative humidity of 65% for three weeks before any tests were carried out. Experimental design, veneer compression and sandwich panel production parameters are shown in Table 1.

2.2. Determination of surface roughness

Test specimens with 50 mm × 50 mm dimensions were conditioned in a climate chamber until they attained 12% equilibrium moisture content. The surface roughness measurement points were randomly marked on the sample surfaces and twenty measurements for each type of panel were accomplished. A Mitutoyo SJ-301 surface roughness tester, stylus type profilometer, was employed for the surface roughness tests. Three roughness parameters, average roughness (R_a), mean peak-to-valley height (R_z), and maximum roughness ($R_{\max}$) characterized by ISO 4287 standard [10] were determined to evaluate the surface characteristics of the panels. R_a is the arithmetic mean of the absolute values of the profile deviations from the mean line and is by far the most commonly used parameter in surface finish measurement. The roughness values were measured with a sensitivity of 0.5 μm. The length of tracing line (L_t) was 4 mm and the cut-off was $\lambda = 0.8$ mm. Measurements were done at room temperature and pin was calibrated before the tests.

2.3. Determination of wettability

The wetting behavior of the samples conditioned at 65% relative humidity at 20 °C was characterized by the contact angle method (goniometer technique). Contact angles (CA) were measured using KSV Cam-101 Scientific Instrument (Helsinki, Finland). The sessile drop method is the most widely used procedure. The CA was determined simply by aligning a tangent with the sessile drop profile at the point of contact with the solid surface. The drop image was stored by a video camera. An imaging system was used to measure CA, shape and size of water droplets for the tested surfaces of the samples at room temperatures. After the 5 μL droplet of distilled water was placed on the sample surface, contact angles from the images were measured at 1-s time intervals up to 30 s total and average CA was calculated. Twenty samples with a size of 50 mm × 50 mm were used from each type of panel for CA measurements. Surface roughness and wettability samples of the produced panels are shown in Fig. 1.

2.4. Determination of surface hardness

Janka hardness value was determined by using a Janka ball with 11.28 mm in diameter according to ASTM D 1037 [11]. The load was continuously applied throughout the test at a uniform rate of motion of the movable crosshead of the universal testing machine of 5 mm/min. The maximum load required to embed the ball to one half its diameter was recorded the measure of hardness.

2.5. Data analyses and statistical methods

For the surface roughness, wettability and hardness, all multiple comparisons were first subjected to an analysis of variance (ANOVA) at $p < 0.01$ and significant differences between mean values of the panel groups were determined using Duncan's multiple range test.

3. Results and discussion

The results of ANOVA and Duncan's mean separation tests for surface roughness parameters, contact angle and hardness values of panels are illustrated in Tables 2 and 3. Statistical analysis showed significant differences ($p < 0.01$) between surface roughness, wettability and hardness values of produced panels.

The non-laminated MDF panels had the lowest R_a value while MDF panels laminated with non-compressed veneer had the highest R_a value. All of the compressed veneer laminated panels had lower R_a value compared to non-compressed veneer laminated panel. The R_a value of the panels decreased with increasing press

Table 1
Experimental design, veneer compression and sandwich panel production parameters.

Panel type	Process	Veneer compression			Sandwiched panels		
		Pressure (MPa)	Temp. (°C)	Time (min)	Pressure (MPa)	Temp. (°C)	Time (min)
A	MDF/Control	–	–	–	–	–	–
B	Laminated	–	–	–	2.6	110	4
C	Laminated	4	150	8	2.6	110	4
D	Laminated	6	150	8	2.6	110	4
E	Laminated	4	180	8	2.6	110	4
F	Laminated	6	180	8	2.6	110	4
G	Laminated	4	200	8	2.6	110	4
H	Laminated	6	200	8	2.6	110	4