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Effect of Compression Wood on Surface Roughness and Surface Absorption of Medium Density Fiberboard

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Compression wood is undoubtedly one of the most important raw material variables in wood based panel manufacturing. This study evaluated effect of compression wood on surface roughness and surface absorption (flow distance) of medium density fiberboards (MDF) manufactured from furnishes of pine (*Pinus nigra* Arnold var. *pallasiana*) containing compression wood. Panels were manufactured from two different portions of the furnish, one of the portions having a compression wood / normal wood ratio of 75/25, and the other having a ratio of 10/90. Surface absorption and surface roughness were determined according to (EN 382-1) and (ISO 4287), respectively. It was found that panels made from furnish with a 75/25 ratio had a significantly lower surface absorption value (255.78 mm) than panels made from furnish with a 10/90 ratio (317.95 mm). Surface roughness measurements based on three roughness parameters, average roughness (R_a), mean peak-to-valley height (R_z), and maximum peak-to-valley height (R_y) were considered to evaluate the surface characteristics of the panels and supported the above findings as the panels made from furnish with a 75/25 ratio had slightly rougher surface with average values of 4.15 μm (R_a). From the tests performed, we conclude that increasing of the compression wood portion increased the surface roughness and decreased the surface absorption value.

Keywords surface properties, surface analysis, compression wood, medium density fiberboard
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1 Introduction

Finishing properties of medium density fiberboard (MDF) are mainly dependent upon the properties of the raw materials (e.g. species, wood quality and fiber characteristics) and manufacturing parameters. Wood quality is one of the most important variables among these. It has strong relationships with virtually every other variable (Akbulut and Koc 2004).

Clearly, the brash nature of compression wood tracheids can be attributed to several factors, most important of which are their high lignin content, the orientation of the micro fibrils in the S_2, spiral checks or fissures in the cell wall, and the presence of the deep, helical cavities in this layer (Timell 1986). Nicholls (1982) pointed out that in fiberboard that is dried under pressure (hardboard) the short tracheids of compression wood are no disadvantage. In insulation board, by contrast, which is formed under low pressure, the short compression wood tracheids can be expected to bond poorly. The requirements are less exacting for particleboard, and the presence of compression wood should present few problems. Keays in 1971 reviewed the literature dealing with the use of branches for composition board and building materials, including building blocks, fiberboard, particleboard, and wallboard.

Gunther et al. (1972) studied the utilization of branch wood from *Pinus sylvestris* with a high content of compression wood. They found that particleboards could be manufactured from such wood but that the physical properties, and especially the density, of the boards varied considerably. They recommended that in triple layer boards, branch wood particles be used for the middle layer only. Lehmann and Geimer (1974) examined the properties of structural particleboards made from *Pseudotsuga menziesii* residues. Panels made from small branches with bark still attached were of very low quality. Unlike panels from other residues, they also expanded two to six times more than control specimens on absorption of water. The reason for this was probably a higher content of compression wood.

Compression wood (CW) is obviously inferior to normal wood for manufacture of fiberboard. For preparation of fiber, compression wood produces fiber fragments between defibrator discs. The reasons for the inability of compression wood chips to be converted into fiber in a defibrator are to be sought in the chemical, physical, and anatomical properties of its tracheids. Akbulut et al. (2004) reported that physical and mechanical properties of MDF made from pine (*Pinus nigra* Arnold var. *pallasiana*) furnish with 10% CW content were better than those of MDF made from furnish with 75% CW content. They found that thickness swell, modulus of rupture, modulus of elasticity, and internal bond strength values of panels made from furnish with 10% CW content were 5.18%, 38.84 N/mm^2, 3278.05 N/mm^2, and 0.60 N/mm^2, respectively, while the same properties of panels made from furnish with 75% CW content were 6.07%, 37.67 N/mm^2, 3070.74 N/mm^2, and 0.57 N/mm^2, respectively.

For the direct painting and other surface finishing treatments of MDF to be successful, especially in furniture industry, the surfaces have to be smooth, stable, and not highly absorbent. An increase in the surface roughness of the MDF decreased the flow distance (surface absorption). The mentioned studies, generally, investigated some mechanical and physical properties of wood-based panels made from furnish containing compression wood. To our knowledge, there is no information about effect of compression wood on surface characteristics of MDF. In this study, influence of the compression wood on surface roughness and surface absorption of MDF were investigated.

2 Materials and Methods

2.1 Materials

Pine stem wood (*Pinus nigra* Arnold var. *pallasiana* grown naturally in Turkey) containing large amounts of compression wood and normal wood was used to manufacture experimental panels. The pine stems were obtained from slope region of Kastamonu forests in Northern Turkey. The stems were between 25 cm and 40 cm in diameter. The stems were divided into logs of 1-m average length. In the logs that contain compression wood, ratios of compression wood and normal wood were determined on cross-section of butt-end of log (Fig. 1).

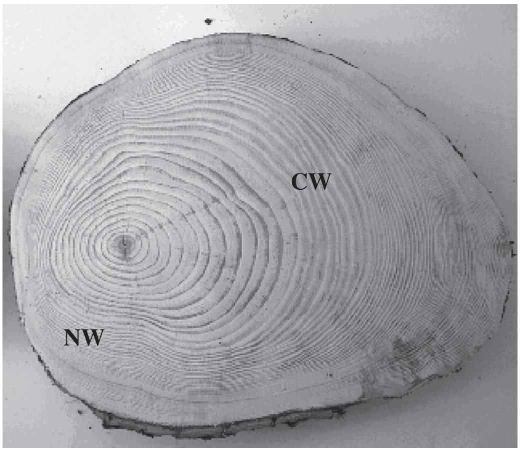

Fig. 1. Cross section of the leaning *Pinus nigra* Arnold var. *pallasiana* stem with compression wood (CW) and normal wood (NW).

The ratios of compression wood and normal wood were calculated from percentages of area measurements on the cross sections. The compression wood and normal wood were not separated from each other in panel manufacturing. Table 1 presents portions of compression wood and normal wood of the experimental panels manufactured.

2.2 MDF Manufacturing

Experimental MDF panels (3660 × 1830 × 10 mm) were manufactured at SFC Integrated Wood Company located in Kastamonu, Turkey. A total of 8 panels, 4 for each type of furnish, were manufactured. The chips having an average size of 20 × 25 × 5 mm were produced from round wood. Raw material was converted into fiber furnish in a *Sunds* defibrator using a steam pressure of 7.5 bar at a temperature of 178 °C for 5 minutes. The following were added to the fiber furnish: 1 percent wax, 0.8 percent NH_4CL as hardener, and 11 percent urea-formaldehyde resin. Mats with average moisture content of 10.5 percent were pressed at temperature of 205 °C for 220 seconds at a pressure of 3.7 $N\,mm^{-2}$. The panels were sanded with a sequence of 50, 60, 80 and 120 grit size following the cooling process. It was determined that air-dry density values of the panels A and B was 0.81 $g\,cm^{-3}$ and 0.79 $g\,cm^{-3}$, respectively, according to EN 323 (1993).

Table 1. Composition of the experimental panels.

Panel type	Compression wood and normal wood portions of the panels	
	Compression wood (%)	Normal wood (%)
A	75	25
B	10	90

2.3 Surface Absorption Test

Surface absorption test specimens with dimensions of 400 × 100 × 10 mm were prepared from MDF panels in accordance with EN 382-1 (1993) standard, which uses toluene as a surface liquid. 30 surface absorption test specimens were cut from each type of panel. 20 of the specimens were taken at a distance of 10 cm from from edges and 10 specimens were taken from the center of the panel. The specimens were conditioned in a climate chamber until they attained a 12 percent equilibrium moisture content. Each individual specimen was put on the test apparatus with a 60° angle and 1 g toluene was dropped from

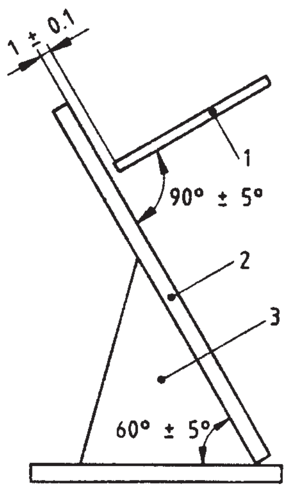

Fig. 2. Surface absorption test set-up (from EN 382-1-1993).

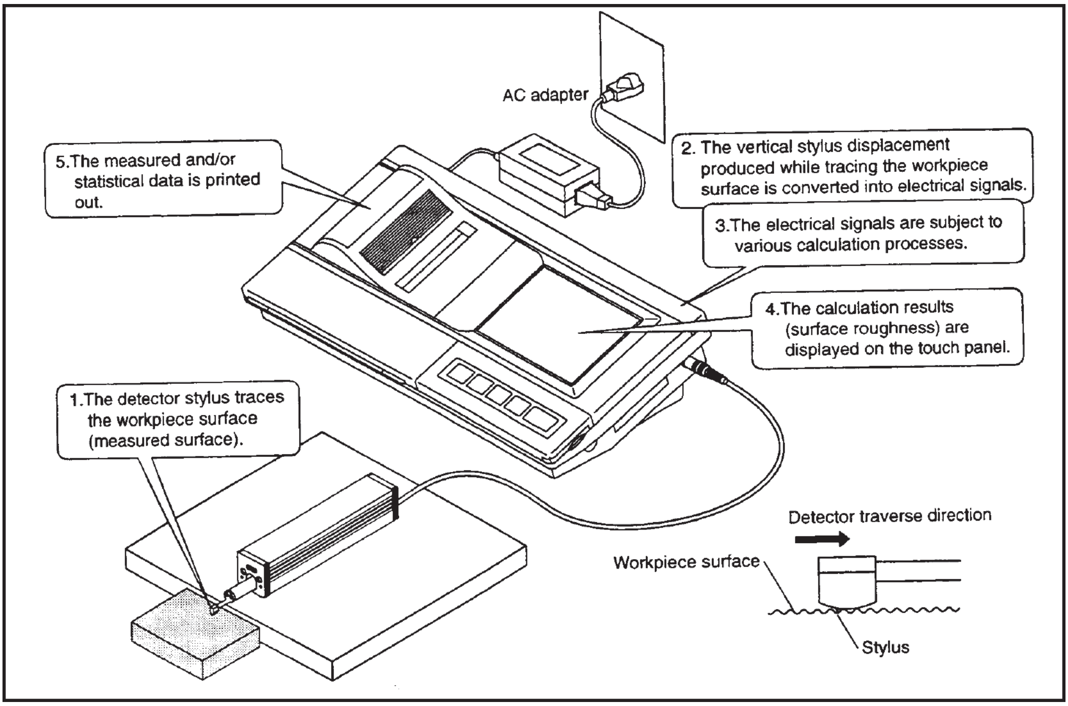

Fig. 3. Outline of the Mitutoyo surftest SJ-301.

1 cm above the surface at a 90° angle to the panel surface (Fig. 2). The maximum distance in which the toluene drop spread on the panel surface was measured from the starting point, and this value was used as a measure of absorption ability of the specimens. The shorter the spreading distance, the lower the surface absorption value (i.e., the greater the absorption). The maximum spread of toluene drops on the panel surface should be at least 150 mm based on the Euro MDF Board (EMB-1993) industrial standard.

2.4 Surface Roughness Test

Surface roughness test specimens with dimensions of 150×75×10 mm were conditioned in a climate chamber until they attained at 12 percent equilibrium moisture content. The points of roughness measurements were randomly marked on the surface of test specimens. Surface roughness were measured by using a stylus type profilometer (Mitutoyo SJ-301) (Fig. 3). A total of 250 measurements, 125 along the sand marks and 125 across the sand marks, were taken from each face of the specimens. Measuring speed, pin diameter and pin top angle of the tool were 10 mm/min, 4 μm and 90°, respectively. Three roughness parameters characterized by ISO 4287 (1997) standard, respectively, average roughness (R_a), mean peak-to-valley height (R_z), and maximum peak-to-valley height (R_y) were considered to evaluate the surface characteristics of the panels. However, statistical comparisons were made on the basis of R_a only. The average roughness is by far the most commonly used parameter in surface finish measurement. R_a is the arithmetic mean of the absolute values of the profile deviations from the mean line. Specification of this parameter is described by Hiziroglu (1996) and Hiziroglu and Graham (1998). Roughness values were measured with a sensitivity of 0.5 μm. The length of tracing line (L_t) was 15 mm and the cut-off was $\lambda = 2.5$mm. Measuring force of the scanning arm on the samples was 4 mN (0.4 gf). Measurements were done at room temperature

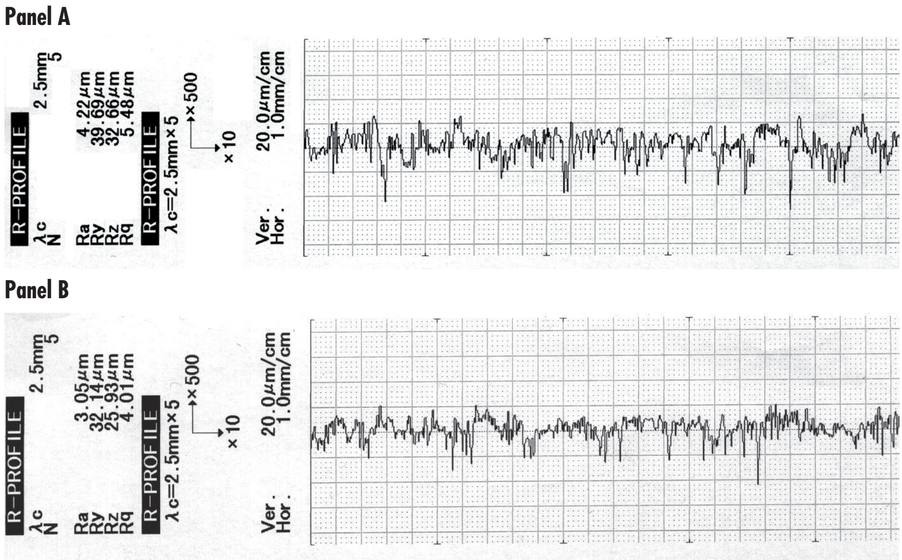

Fig. 4. Typical surface roughness profiles of panels A and B.

Table 2. Arithmetic means of surface roughness and surface absorption values of the panels. Numbers in parentheses show standard deviation.

Property	Panel A	Panel B	Quality requirement [a)]
Surface absorption, mm	255.78 a (39.07)	317.95 b (47.28)	Minimum 150.00
Surface roughness, μm			
R_a	4.15 a (0.54)	3.96 b (0.67)	-
R_z	31.68 (4.42)	29.91 (4.89)	
R_y	40.20 (7.70)	38.14 (8.26)	

a, b There is a significant difference among the arithmetical means according to the t-test.
[a)] Quality requirement according to Euro MDF Board (EMB), Industrial Standard 1993.

and pin was calibrated before the tests. Differences of the means of the surface roughness and the surface absorption in panels A and B were analysed by the t-test.

3 Results and Discussion

Table 2 displays the results of surface absorption and surface roughness of panels A and B. As seen in Table 2, specimens of panel A were more absorbent with an average value of 255.78 mm than specimens of panel B with an average value of 317.95 mm. A significant difference ($p=0.001$ confidence level) was found between two panel types according to the t-test. Both panels A and B exceeded the requirement for surface absorption (min. 150 mm) test by Euro MDF Board (EMB) Industrial Standard 1993. EMB standard was used here for comparison of surface absorption property since there are no established minimum values for MDF in European Norm.

Surface roughness values of panel A were significantly higher than those of panel B. Results of the t-test indicate a significant difference between

R_a values of panels A and B. Average R_a, R_z, and R_y values were found to be 4.15 μm, 31.68 μm, and 40.20 for panel A and 3.96 μm, 29.91 μm, and 38.14 μm for panel B, respectively. Fig. 4 shows typical surface roughness profiles of panels A and B.

In general, surface characteristics of MDF are determined by the anatomical structure of wood, cutting tool geometry, and crushing conditions during the cutting process (Bekhta and Hiziroglu 2002). Surface absorption and surface roughness of individual anatomical elements was created by a variety of voids in tracheids and fibers. The high lignin content of compression wood tracheids makes them hard, brittle, and inflexible, causing them to break rather than separate from one another on grinding. Compression wood tracheids, in addition, have helical cavities or checks penetrating deeply into S_2. Compression wood fiber is the presence of the helical cavities in the secondary wall (Timell 1986). Undoubtedly, penetration of toluene occurs through the numerous inter-cellular spaces. As a result, the spreading distance of toluene was shorter on the panel surface. Tracheids of compression wood are often distorted at their tips and are usually shorter in length than normal wood tracheids. The thick cell walls and wide latewood contribute to specific gravity much higher than that of normal wood tracheids. Although panel A had higher air-dry density (0.81 $g\,cm^{-3}$) than that (0.79 $g\,cm^{-3}$) of panel B, surface characteristics of panel A were inferior to those of the panel B.

Compression failures profoundly affect the ultra structure of pine fibers involved, causing disruption of their individual cell wall layers. The ordered arrangement of the cellulose microfibrils is disturbed, and it is possible that the middle lamella is also affected. Of importance is probably the fact that the cellulose chain lattice becomes disordered and thus accessible to hydrolytic attack (Timell 1986). Besides, in longitudinal sections of compression wood a striking feature is the presence of spiral checks or fissures in the cell walls (FPRL 1956). As a result, toluene was able to penetrate throughout the cell wall and result in shorter distance of toluene on panel A surface than that of panel B.

It should be noted that the lower absorption value of rough surfaces may be due to the higher amount of peaks and valley points on the surface where liquid can be captured by capillary force (Akbulut et al. 2000).

4 Conclusions

MDF made from furnish having a compression wood / normal wood ratio of 75/25 showed lower surface absorption value and slightly rougher surface than the panels made from furnish having a ratio of 10/90. It appears that pine CW fibers are a prime factor influencing the surface characteristics of the panel because of anatomical and morphological properties of CW fibers. Results revealed that MDF could be manufactured from the pine furnish containing 75% of compression wood but surface characteristics of the panels varied negatively as compared with the furnish containing 10% of compression wood. We recommend that compression wood fibers be used for the middle layer of panels (if there is a multi-layer forming) for higher surface absorption value and lower surface roughness value. However, use of compression wood fibers in the middle layer of panels is not suitable for profiled MDF.

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