SURFACE CHARACTERISTICS OF OVERLAID WOOD COMPOSITES

S Hiziroglu[1] & S Suzuki[2]

[1] *Department of Natural Resource, Ecology and Management, Oklahoma State University, Stillwater, OK 75078-6013, USA. E-mail: salim.hiziroglu@okstate.edu*
[2] *Faculty of Agriculture, Wood Science, Shizuoka University, 836-Ohya, Shizuoka-shi, 422-8529 Japan*

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HIZIROGLU S & SUZUKI S. 2009. Surface characteristics of overlaid wood composites. In this study, surface characteristics of commercially manufactured overlaid medium density fibreboard (MDF) and particleboard panels were evaluated. Roughness was measured randomly from the surface of overlaid samples conditioned at 55 and 93% relative humidity (RH) levels using a fine stylus profilometer. Three roughness parameters, namely, average roughness (R_a), mean peak-to-valley height (R_z) and maximum roughness (R_{max}) were used to determine surface profiles of samples. Statistical analysis revealed that no significant difference was found between roughness values of MDF and particleboard panels exposed to 55% RH. However, when samples were exposed to 93% RH, significant difference between initial and final roughness values was observed. Janka hardness values of samples exposed to 93% RH were significantly lower than those exposed to 55% RH. It appears that roughness of overlaid samples due to humidity exposures can be quantified using stylus type equipment and such data along with hardness characteristics may be used to improve overall quality of panels for further processes.

Keywords: Overlaying, relative humidity, roughness, hardness

HIZIROGLU S & SUZUKI S. 2009. Ciri permukaan komposit kayu berlaminasi. Dalam kajian ini, penilaian dibuat ke atas ciri permukaan papan gentian berketumpatan sederhana (MDF) dan papan serpai komersial yang berlaminasi. Dengan menggunakan profilometer berjarum halus, nilai kekasaran diukur secara rambang bagi permukaan sampel berlaminasi yang disesuaikan pada kelembapan relatif (RH) 55% dan 93%. Tiga parameter kekasaran iaitu kekasaran purata (R_a), min tinggi puncak ke lurah (R_z) dan kekasaran maksimum (R_{max}) diguna untuk menentukan profil permukaan sampel. Analisis statistik menunjukkan tidak terdapat perbezaan signifikan antara nilai kekasaran panel MDF dengan panel papan serpai yang didedahkan kepada RH 55%. Bagaimanapun, apabila sampel didedahkan kepada RH 93%, terdapat perbezaan signifikan antara nilai kekasaran awal dengan nilai akhir. Nilai kekerasan Janka bagi sampel yang terdedah kepada RH 93% adalah lebih rendah secara signifikan berbanding sampel yang terdedah kepada RH 55%. Nampaknya kekasaran sampel berlaminasi yang terdedah kepada kelembapan dapat diukur menggunakan alat berjarum halus. Tambahan lagi data yang diperoleh serta ciri kekasaran dapat diguna untuk menambah baik kualiti keseluruhan panel bagi proses selanjutnya.

INTRODUCTION

Wood-based panel composites including particleboard and medium density fibreboard (MDF) are manufactured in great quantities in Japan for use in the furniture and cabinet industry as substrate for thin overlays (Anonymous 2007). For the last several years, the market for particleboard in Japan is considered stable with little fluctuations, as with MDF. Development in housing and supply of raw material are the main parameters influencing the overall market of these products. Currently the production capacities for particleboard and MDF in Japan are 1 234 000 and 420 000 m^3 respectively (Anonymous 2007).

Much has been written about the utilization of different raw materials to produce particleboard and MDF as well as evaluation of their physical and mechanical properties in many countries including Japan. Particleboard and MDF panels can be sensitive to fluctuations of relative humidity (RH) in surrounding environment. In low humidity conditions, roughness of substrate panels is a latent property. Roughness of panels overlaid with thin papers will be deteriorated in terms of their surface quality if such panels are exposed to high humidity levels. This is known as the telegraphing effect. Although generally used for interior applications the hygroscopic nature of wood composites plays an important role in the performance of MDF and particleboard panels due to changes in RH over a period of time (Hiziroglu 1996). Currently there are no universally accepted standard numerical values about surface roughness of composite panels. However, such values developed from experimental studies can be employed to establish in-house upper and lower control limits to accept or reject panels from the production line. Therefore, it is important to determine surface roughness of overlaid samples using a quantitative method to have a better understanding of their hygroscopic behaviour during their service life and use such data as a possible quality control tool to enhance efficient use of overlaid panels.

No study has been done to evaluate overlaying properties of commercially produced particleboard and MDF panels in Japan (Hiziroglu *et al.* 2005). Several methods for quantifying the surface roughness of composite panels and solid wood are available but none of them has been widely used in the industry (Sandak & Tanaka 2003, Fujiwara 2004, Gurau *et al.* 2005). Currently there are also no acceptable standards and methods to evaluate surface quality of wood composites. The stylus method has been used for many years in the plastic and metal industries. One of the main advantages of this method which has been employed in this work is that it provides an actual profile of the surface, from which the standard numerical roughness parameters can be calculated (Funck *et al.* 1992, Lemaster & Beal 1993, Hecker 1995, Hiziroglu *et al.* 2004, Sandak *et al.* 2004). Any kind of irregularities and magnitude of show-through on the overlaid substrate can be objectively quantified. In addition, the influence of RH on hardness of samples will also provide useful information related to how these panels can be used more effectively during their service life without any deterioration.

MATERIALS AND METHODS

Commercially manufactured MDF and particleboard panels were used for this study. The particleboard was a mixture of sugi, also called Japanese cedar (*Crytomeria japonica*), and hinoki (*Chamaecyparis obtuse*), also known as cypress, while MDF panels were made from the same species as well as imported tropical wood including launa (*Shorea* spp.). Table 1 displays the characteristics of panels used in the study. A total of six samples measuring 12 × 12 cm were used for each hardness and roughness measurement.

The specimens were conditioned in a room with RH of 55% and temperature of 20 °C before they were overlaid using a Carver handpress. Both surfaces of each sample were covered with melamine impregnated paper (120 g m^{-2}) and pressed using a pressure of 2.5 MPa and a temperature of 148 °C for 40 s. Samples were assembled using a combination of stainless steel printing plates with mirror-like surface facing the overlays. Steel press cauls (0.25 cm thick) were put above the plates in the form of sandwich configuration during the pressing process. Density of each sample was calculated by measuring its dimension and weight at accuracy levels of 0.01 mm and 0.01 g respectively. Specimens were conditioned at 55% RH before initial roughness and hardness measurements were taken from their surfaces.

The Hommel T-500 stylus profilometer unit used in this study comprised the main unit and the pick-up model TkE. The pick-up has a skid-type diamond stylus with 5 μm tip radius and a

Table 1 Characteristics of panels used in the study

Panel type	Panel thickness (mm)	Panel density (g cm^{-3})	Raw material of panel
MDF	9	0.78	Sugi and hinoki
MDF	18	0.70	Sugi and hinoki
MDF	24	0.76	Imported mixed tropical hardwoods
MDF	30	0.70	Imported mixed tropical hardwoods
Particleboard	10	0.77	Sugi and hinoki
Particleboard	15	0.82	Sugi and hinoki
Particleboard	25	0.78	Sugi and hinoki

90° tip angle. The stylus moves on the surface at a constant speed of 1 mm s^{-1} over 15.2 mm tracing length. Three roughness parameters, namely, average roughness (R_a), mean peak-to-valley height (R_z) and maximum roughness (R_{max}) were calculated from the digital information obtained. Definition of these parameters has been discussed in detail in ANSI (1985), Faust and Rice (1986), Faust (1987) and Drew (1992). The calibration of the instrument was checked after every 150 measurements by using a standard reference plate with R_a values of 3.02 and 0.48 µm. The cut-off length for the test, i.e the parameter that differentiates roughness and waviness profiles from each other, was 2.54 mm (Mummery 1993, Mitchell & Lemaster 2002). A total of 25 roughness measurements were randomly taken from both sides of each overlaid sample over 15.2 mm tracing length using the profilometer.

After initial measurements were taken at 55% RH, the samples were then placed in a conditioning chamber at 93% RH and temperature of 20 °C until they reached the equilibrium moisture content which took approximately three months. Measurements were repeated from the same points on the samples at final condition. A typical comparison of roughness profiles of samples taken at 55 and 93% RH is shown in Figure 1. Student's *t*-test was used to evaluate differences between treatments of samples.

The Janka ball hardness test (Doyle & Walker 1985, Green & Ewans 1990, Green *et al.* 2006) was used to measure the hardness of samples conditioned at 55 and 93% RH. Load was continuously applied at a uniform cross-head speed of 6 mm min^{-1} until the ball was embedded to one half of its diameter. Comten testing unit

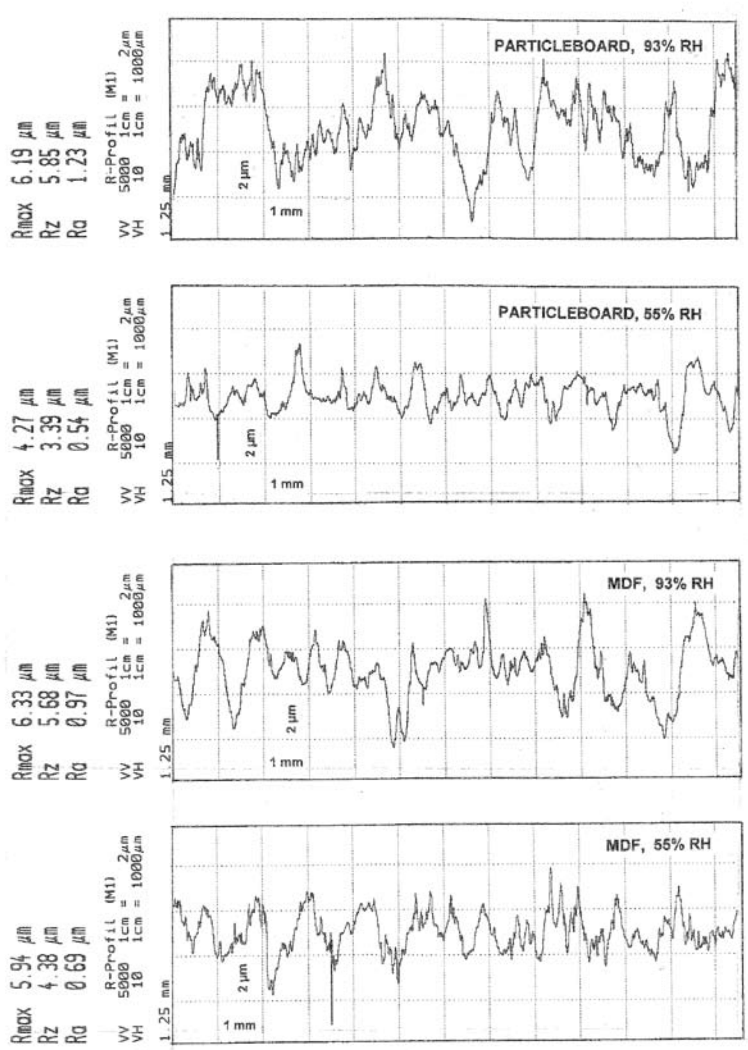

Figure 1 Typical roughness profiles of samples studied

with a 1000 kg load cell capacity was used for the hardness test. Four hardness measurements were taken from each side of the samples, giving a total of eight measurements for each sample.

RESULTS AND DISCUSSION

The roughness and hardness values of the samples are presented in Table 2. At 55% RH, the smoothest surface was observed in MDF panels of thickness 24 mm (R_a = 0.50 µm). With an R_a value of 0.83, the particleboard of 25-mm thickness had the highest roughness value. At 55% RH, average R_a value of particleboard panels was 18% higher than that of MDF samples which resulted in no significant difference at $p > 0.05$. However, when samples were exposed to 93% RH both types of samples showed significantly higher roughness values than those taken at 55% RH. At 93% RH, R_a values of particleboard (average 1.74 µm) were 58% higher that those of MDF (1.10 µm). This is due to the different furnish types and manufacturing processes of the two panel products. In a previous study R_a values of overlaid particleboard and MDF samples were found to be 7.33 and 3.01 µm respectively (Hiziroglu *et al.* 2004). It should be noted that the original surface quality of samples used in this work were better than those used in two of our previous studies (Hiziroglu *et al.* 2004, 2005). This could be due to the geometry of raw materials as well as some of the manufacturing parameters such as more homogeneous mix of resin with particles, better quality of press cauls and the use of higher resin content on the face layers resulting in more densification surface of the panels.

Based on values of three roughness parameters in this work the show-through effect of having fine particles on the face layer of particleboard samples were more pronounced compared with MDF samples. With regard to characteristics of surfaces as a result of high humidity exposure, both R_z and R_{max} values had similar trends as R_a for both types of composite panels. Overall densities of particleboard and MDF samples were similar. Therefore, it appears that density is not responsible for roughness values of overlaid samples. Average R_a values of samples increased ranging from 0.90 to 2.36 times when exposed to 93% RH. Unlike MDF, particleboard samples showed less dimensional stability and this can be related to two different raw materials, namely, fibre and particle used in the manufacture of composite products.

Our study proves that telegraphing or show-through effect of surface irregularities, which may be difficult to objectively determine and quantify using visual observation, can be numerically evaluated with application of the stylus method. The samples did not show any delamination or separation neither from the overlays nor within the panels as a result of high humidity exposure. Initial data determined in this study may provide some kind of starting point for wood composite industry in Japan to evaluate surface roughness of overlaid panel products. It is

Table 2 Average roughness and hardness values of samples at 55 and 93% relative humidity (RH)

Panel type	55% RH					93% RH				
	MC (%)	R_a (µm)	R_z (µm)	R_{max} (µm)	Janka hardness (lb)	MC (%)	R_a (µm)	R_z (µm)	R_{max} (µm)	Janka hardness (lb)
1	12.1	0.61*	3.71	5.05	1710*	18.1	1.25**	5.91	6.10	1100**
2	11.9	0.70*	4.28	5.78	949*	18.4	1.14**	6.08	6.94	733**
3	12.0	0.50*	3.89	4.57	1243*	17.3	0.96**	5.11	7.13	852**
4	12.3	0.72*	5.20	6.83	1032*	19.0	1.06**	6.27	8.21	676**
5	12.1	0.73*	4.52	6.23	1867*	18.9	1.77**	8.38	11.37	775**
6	11.9	0.68*	4.45	5.71	993*	19.2	1.50**	7.87	6.92	622**
7	10.9	0.83*	5.01	6.78	902*	19.0	1.96**	8.96	12.77	630**

1 = MDF, thickness 9 mm; 2 = MDF, thickness 18 mm; 3 = MDF, thickness 24 mm; 4 = MDF, thickness 30 mm; 5 = particleboard, thickness 10 mm; 6 = particleboard, thickness 15 mm; 7 = particleboard, thickness 25 mm; * = $p \leq 0.01$ (no significance difference among the samples at 55% RH; ** = $p < 0.01$ (significant difference between the values of the samples exposed to two RH levels

possible that in-house roughness values of panels be established for various applications with the purpose of product quality improvement and better customer service.

High RH exposure also adversely influenced the hardness of samples. In general higher density and surface compaction ratio combined with brittleness of the overlay paper on MDF sample would show higher values of Janka hardness. MDF panel of 9-mm thickness had the greatest hardness both at 55 and 93% RH, with values of 1710 and 1100 lb respectively (Table 2). For particleboards, the hardness was highest in the 10-mm thick panels at 55 (1867 lb) and 93% (775 lb) RH. Overall average hardness values of particleboard and MDF at initial condition did not show any significant difference. However, as soon as samples reached equilibrium moisture content at 93% RH their hardness substantially reduced ranging from 1.2 to 2.4 times. In general, initially harder samples showed higher reduction in their hardness when exposed to 93% RH in contrast to softer samples. This is due to the higher densification on the face layers of samples resulting in harder surface.

CONCLUSIONS

This study briefly evaluated surface roughness and hardness of seven types of commercially produced composite panels as a function of relative humidity exposure. Our findings suggest that any fluctuation on surface quality of overlaid samples can objectively be quantified using the stylus technique. Such data can be applied for practical use in manufacturing overlaid panels with higher quality. Further studies should include cyclic humidity exposure of samples which would provide better understanding of their dimensional stability behaviour. Also it would be desirable to use more than one type of overlay paper and direct finishing application to the panel surface.

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