

## **MOISTURE CONTENT DISTRIBUTION OF MULTIPLE EUCALYPTUS VENEERS DURING HOT-PRESS-DRYING**

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### **ABSTRACT**

Ten Eucalyptus veneers were dried using a hot-press with a pressure of 0.2 MPa, temperature of 120°C and pressing time of 30 mins. The horizontal and vertical moisture content (MC) fields of the veneers were examined during the hot-press-drying. The results showed that, in the horizontal direction, MC on the center of the veneers was slightly higher than that on the edge during the drying process. However, there was no significant difference between them. In the vertical direction, the MC field taking NO.4, NO.5, NO.6, NO.7 veneers as center were symmetrical. MC of veneers near the platen was low, while middle veneers' MC was high. 10 veneers were divided into 4 groups by symmetric position. There was a significant difference in veneers' MC of different groups, while the difference of veneers' MC in same group was not significant. Final MC of 10 veneers still had significant difference, while the range had reduced from 10.62 to 3.56 %, which meet the veneer drying requirement.

**KEYWORDS:** Eucalyptus veneers, hot-press drying, moisture content field, horizontal direction, vertical direction.

### **INTRODUCTION**

Hot-press drying, in which the material is dried by pressing between two hot plates, has been used for many years to dry thin decorative veneers. Since 1950th this process has also been investigated periodically as a means for drying thicker veneers and lumber for structural products (Heebink 1952; Hittmeier et al. 1968; Lutz 1974). Hot-press drying is faster than hot-air drying because the veneer is dried by direct contact, and the intermediate step of heating air is eliminated. Compared to hot-air dryers, the veneer dries flatter and shrinks less because it is restrained by the press platens (Loehnertz 1988).

At present, many plywood mills (mainly in north China) purchase air-dried veneers and carry out the hot-press drying (Han et al. 2013). Usually multi-veneers were placed in a hot-press to be dried at a time. Cited studies applied only single veneer (Steinhagen et al. 1995, 1999), no reports are available concerning hot-press drying used for multi-veneers drying. Because the thickness of single veneer is small (usually 0.8-2.0 mm), the moisture content (MC) gradient in thickness can be ignored. When many veneers (example 10 and more) are placed together for hot-press drying, the temperature gradient and MC difference in thickness should be taken into account. As a piece of lumber is dried using a hot-press, MC on the surface of the lumber is lower than in the center during hot-press drying (Mataki and Miura 1986). However, the drying of multi-veneers is different from the drying of lumber. Water in veneer removes out easier than lumber because veneer has a loose structure with many checks exist on the surface as veneer peeled from a log.

The aim of the present study was to examine MC change in horizontal and vertical directions of multi-veneers during hot-press drying.

## MATERIAL AND METHODS

### Experimental material

The air-dried *Eucalyptus saligna* veneers were obtained from a plywood mill in Guang xi, China. 30 defect-free veneer sheets with an initial moisture content ranging from 20-22 % and a size of 300 × 300 × 2.3 mm were randomly selected as specimens. In order to make veneers have uniform moisture content, the sheets were placed in a conditioning chamber with a temperature of 25°C and relative humidity (RH) of 90 % until the equilibrium moisture content of about 21 % was reached.

### Equipment

DHG-9053A drying oven was used for storing the veneers, a 0.001 g scale balance to weight and a needle-type MC meter was used for measuring MC. The hot-press with a size of 300 × 300 mm, oil-heated and single-opening platen was used for drying.

### Procedure

#### *MC tester correction*

Before drying, each veneer was weighted and the MC values were measured at 9 points (Fig. 1), then, the veneer put into 103°C drying oven after weighted. The process repeated every 30 seconds, until veneers were oven dry. In this way, 30 veneers were tested. The measured MC was calculated from mean values of 9 points in veneer, and real MC was got from weighted. Regression analysis was made between measured values and true values.

#### *MC measurement during hot-press drying*

Based on the previous reports (Hua 2005; Gu et al. 2000) and the commonly used process in plywood mills, 10 veneers (a group) were placed between two platens with a temperature of 120°C, a pressure of 0.2 MPa, a press time duration of 30 min. Three replicates were applied. The veneer sheets were numbered No. 1 to No. 10 from the bottom to the top of the press.

Six drying runs, 10 veneer sheets each, were completed 5, 10, 15, 20, 25 and 30 min were used for Run 1, Run 2... Run 5, respectively. After drying, each veneer was weighed and the 9 points MC (Fig. 1) were measured immediately. The MC value at point 5 was taken as a center MC,  $\omega_c$ ; the average of other 8 points MC was considered as the edge MC,  $\omega_e$ . Veneers in Run 6 were placed on shelves (Fig. 2) for 30 min after the hot-press drying. After that, veneers in Run

6 were weighted again,  $W_2$ . At the end of the drying process, each veneer was oven-dried, and weighted,  $W_3$ . Therefore, instantaneous MC value was  $(W_1 - W_3) / W_3 \times 100\%$ , and final MC was  $(W_2 - W_3) / W_3 \times 100\%$ . Data analyses were performed using SAS software.

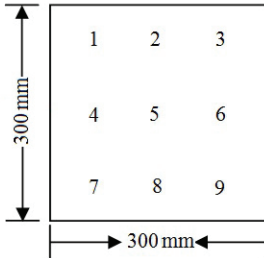


Fig. 1: Veneer MC tested.

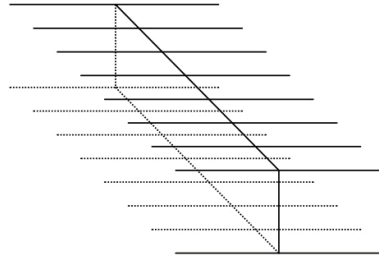


Fig. 2: Shelves for placing veneers.

## RESULTS AND DISCUSSION

### MC tester

There was a good linearity relationship between measured MC and real MC (Fig. 3). The equation was  $y = 1.2444x - 4.628$  ( $R^2 = 0.9193$ ). In the regression equation,  $y$  was real MC (%), and  $x$  was measured MC (%).

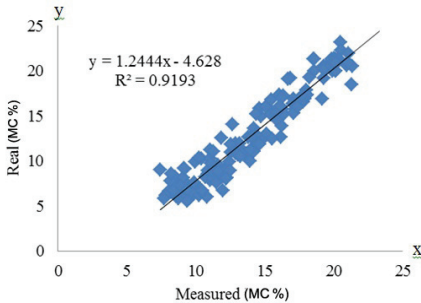


Fig. 3: Linear relationship between measured MC and real MC.

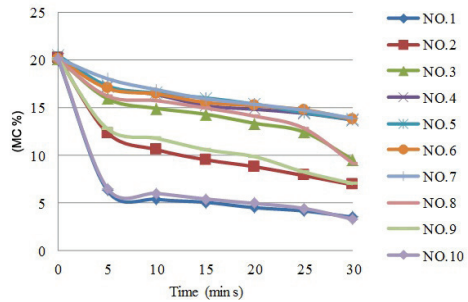


Fig. 4: The MC varieties of 10 veneers.

### MC variety of veneers

After the process of hot-press drying, the MC variation of air-dried veneers with low MC is showed in Fig. 4. The MC variation of veneers depended on the location that between platen. As Fig. 4 illustrated, MC of veneers next to platen (NO. 1, NO. 10) and near platen (NO. 2, NO. 9) decreased sharply in first 5 minutes, and the rate of MC decrease slowed down in the following 25 minute. MC of other six veneers in the middle decreased slowly during the hot-press drying. The MC profiles were obviously divided into 3 groups from 5 to 25 minute: The first group was NO. 1 and NO. 10 veneers, which had the lowest MC. The second group was NO. 2 and NO. 9 veneers, which had MC values distinctly higher than the first group, and lower than the other six veneers. The third group was six veneers in the middle, which MC decreased extremely slowly. At 30 minutes, MC of NO. 3 and NO. 8 veneers had a sharp decline. At this moment, 10 veneers

were divided into 4 groups according to MC.

During the drying process, veneer MC was determined every 5 min and to use MC of the veneers at 7 time intervals to represent MC variety of the veneers during the hot-press drying.

**MC field at horizontal and vertical direction of veneers**

The center and edge moisture content of each veneer at 0 min (Fig. 5A), 5 min (Fig. 5B), 10 min (Fig. 5C), 15 min (Fig. 5D), 20 min (Fig. 5E), 25 min (Fig. 5F), and 30 min (Fig. 5G) during hot-press drying is shown in Fig. 5. This figure shows the center MC was little higher than edge MC in the horizontal direction at each veneer. This is probably because moisture evaporation in the edge was easier than in the center. In the vertical direction, MC of NO. 1 and NO. 10 veneers had a sharp decline, while there were slower fall in MC at the NO. 4, NO. 5, NO. 6, and NO. 7 veneers. Therefore, MC had a great difference in the vertical direction. The course was similar to MC variety in lumber and thick veneer during hot-press drying (Tang et al. 1994; Tschernitz 1985). The process of lumber hot-press drying was from the board surface to the core.

**Variance analysis of MC field at horizontal and vertical direction**

T-test was used to analyze the center and edge MC of the 10 veneers at the 7 time intervals during hot-press drying (Tab. 1). Tab. 1 shows that the P value of each veneer at the 7 time intervals was greater than 0.05, indicating that no significant difference in MC between the center and the edge of each veneer during hot-press drying was discovered.

Tab. 1: T-test for center MC and edge MC of 10 veneers.

NO.	Hot-press drying moments (min)													
	0		5		10		15		20		25		30	
	t	P	t	P	t	P	t	P	t	P	t	P	t	P
1	0.76	0.4900	0.16	0.8801	0.31	0.7699	0.09	0.9337	0.53	0.6273	1.10	0.3317	0.40	0.7063
2	0.05	0.9656	0.06	0.9532	0.47	0.6658	0.56	0.6047	0.38	0.7220	0.01	0.9933	1.73	0.1591
3	0.69	0.5288	0.25	0.8147	0.76	0.4881	0.88	0.4280	1.44	0.2226	0.10	0.9258	0.63	0.5633
4	0.34	0.7476	0.22	0.8352	0.47	0.6819	0.71	0.5194	1.56	0.1931	1.03	0.3605	0.14	0.8918
5	0.13	0.9036	0.40	0.7120	0.08	0.9435	0.30	0.7807	0.64	0.5588	1.10	0.3331	1.62	0.1808
6	0.43	0.6896	1.34	0.2502	0.57	0.5993	1.91	0.1293	0.74	0.4984	0.92	0.4087	0.67	0.5379
7	0.27	0.8026	0.25	0.8176	0.20	0.8496	0.44	0.6838	0.52	0.6308	0.30	0.7825	0.33	0.7570
8	0.80	0.4684	0.65	0.5526	1.39	0.2366	1.29	0.2663	0.37	0.7286	1.80	0.1458	0.44	0.6850
9	0.62	0.5662	0.73	0.5078	0.28	0.7932	0.43	0.6875	0.07	0.9459	0.12	0.9109	1.12	0.3253
10	0.16	0.8816	0.21	0.8457	0.13	0.9011	0.40	0.7094	0.65	0.5540	1.07	0.3456	1.08	0.3393

Tab. 2 shows there was no difference (P>0.05) among the 10 veneers before hot-press drying in vertical direction (0 min). However, a significant difference (P<0.01) was existed in the 10 veneers after the drying began, as well as during the whole process (5-30 min).

Tab. 2: F-test for MC at vertical direction.

Item	Hot-press drying moments (min)						
	0	5	10	15	20	25	30
F	0.26	143.53	221.66	329.83	232.83	224.23	209.72
P	0.9795	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

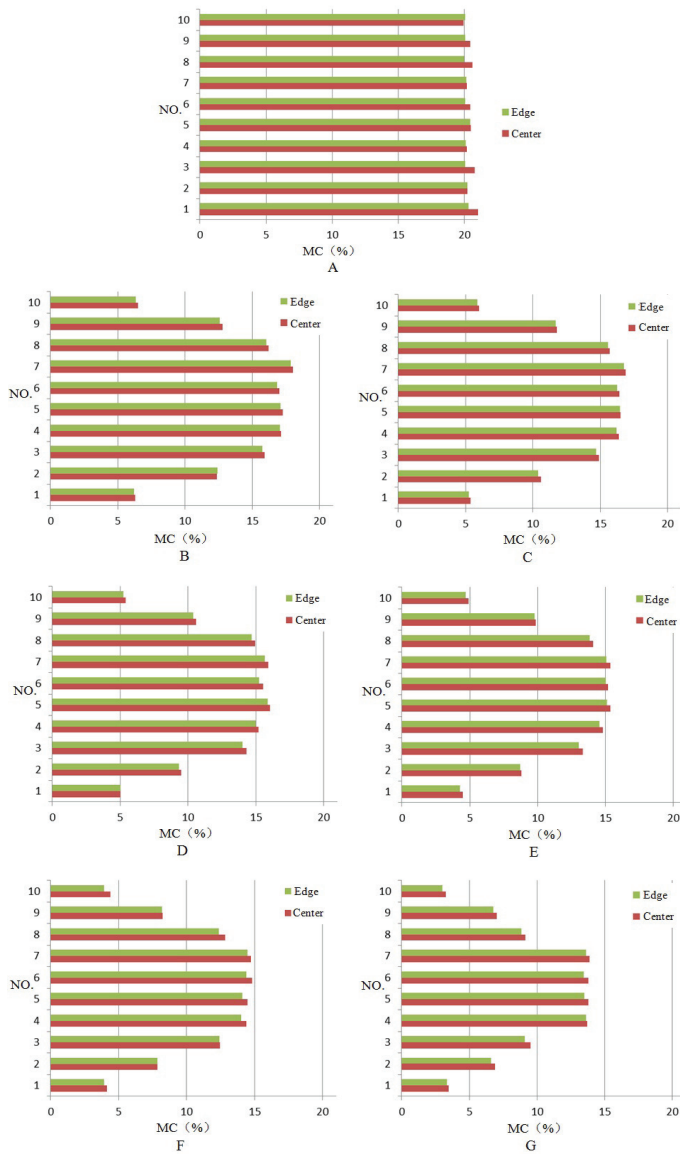


Fig. 5: Edge and center MC of each veneer at 7 moments.

Furthermore, Duncan-test (Tab. 3) showed that MC of the 10 veneers taking the NO. 4, NO. 5, NO. 6, NO. 7 veneers as the center were almost symmetrical. The MC of the 4 veneers in the middle had no significant difference except for the NO. 4 and NO. 5 veneers at 15 min. Fig. 4 illustrates that the 10 veneers divided into 3 groups from 5 to 25 min, and into 4 groups at 30 min. The differences of them can also carry out similar grouping. The NO. 1 and NO. 10

veneers were the first group with a significantly lower MC than the other veneers in the whole process. The NO. 2 and NO. 9 veneers were the second group with a significant higher MC than the first group and lower than the rest veneers. The NO. 3 and NO. 8 veneers were the third group with a significantly higher was than the first and second group, but lower than the 4 veneers in the middle. There was no significant difference in MC within the group except for the second group at 10, 15, and 20 min.

Tab. 3: Duncan-test for MC of each veneer at vertical direction.

NO.	Hot-press drying moments (min)					
	5	10	15	20	25	30
1	6.27e	5.36f	5.04g	4.48f	4.14d	3.48d
2	12.36d	10.58e	9.52f	8.79e	7.86c	6.89c
3	15.94c	14.92c	14.31d	13.35c	12.45b	9.53b
4	17.16ab	16.37ab	15.20bc	14.83ab	14.41a	13.71a
5	17.28ab	16.53ab	16.03a	15.37a	14.47a	13.77a
6	17.02abc	16.44ab	15.54abc	15.20a	14.80a	13.80a
7	18.03a	16.88a	15.93ab	15.35a	14.73a	13.89a
8	16.21bc	15.73bc	14.96cd	14.10bc	12.84b	9.14b
9	12.79d	11.77d	10.58e	9.84d	8.24c	7.01c
10	6.50e	5.99f	5.40g	4.92f	4.41d	3.27d

Same character means no significant difference at 0.05 levels.

**Final MC**

The 10 veneers were placed on the shelves after the hot-press drying. Final MC of individual veneer is shown in Fig. 6. Although there was still significant difference in final MC of the 10 veneers (Tab. 4, Fig. 6), the range was reduced from an initial MC of 10.62 % ( 3.27-13.89 %) to a final MC of 3.56 % (7.58-11.14 %), which was within the limits of veneer drying requirements (Walker 2006). The reason may be that the 10 veneers were laid overlap and water in the middle veneers was not easily evaporated. Large amount of vapor and vaporization heat were gathered in the middle of the veneers. When the veneers were moved from the hot platen and placed on shelves, vapor in the veneers vaporized rapidly and many checks on veneer surface created. Thus, MC of the middle veneers was reduced. However, MC in the veneers near platen was lower respect to the environment humidity. Because the veneers would absorb moisture, MC of the veneers near platen increased.

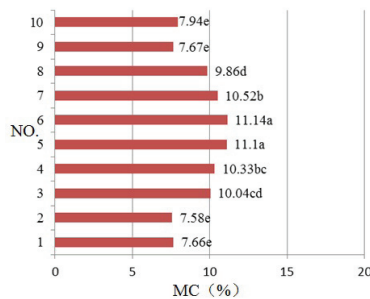


Fig. 6: Final MC distribution of 10 veneers.

Tab. 4: *F*-test for final MC of 10 veneers.

<i>df</i>	SS	<i>s</i> <sup>2</sup>	F	P
9	66.49	7.39	215.92	<0.0001

## CONCLUSIONS

In the horizontal direction, MC of veneer center was slightly higher than the edge MC during the drying process. However, there was no significant difference between them.

In the vertical direction, the MC field taking the NO. 4, NO. 5, NO. 6, NO. 7 veneers as the center were symmetrical. MC of the veneers near the platen was low, while the middle veneers' MC was high. The 10 veneers were divided into 4 groups by symmetric positions. There was a significant difference in veneers' MC among the different groups, while the difference of veneers' MC in same group was not significant.

Final MC of the 10 veneers still had significant difference, while the range had reduced from 10.62 to 3.56 %, which meets the veneer drying requirements.

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