

## PRODUCING PROCESS FOR VENEER DECORATIVE STRAW PARTICLEBOARDS

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### ABSTRACT

Technical parameters in different steps of birch (*Betula alnoides* Buch.-Ham. ex D. Don) veneered decorative straw particleboards producing process including moisture content adjustment, sanding, hot-pressing and conversation to improve the surface warp was discussed in this study. The results showed that it took at least 24 h to adjust the stable moisture content between 8 and 10 % in environment of 30°C and 40 % relative humidity (RH). Surface warp decreased with the increase of sand thickness till 0.8 mm which indicated the complete remove of hardening layer. Modified “PVAc+GB-3+flour” bonded boards had better surface bonding strength than PVAc with a best hot-pressing parameter: unit pressure 0.7 MPa, temperature 90°C and hot pressing time 180 s. In addition, surface warp of hot-pressed veneer decorative straw particleboards stabled when conserved for 24 h sealed with plastic films. Enterprise large scale production according to this technical process proved to decrease the surface warp from 1.05±0.3 % (normal process with sanding thickness of 0.3 mm) to 0.84±0.2 %.

KEYWORDS: Veneer decorative straw particleboard, surface warp, surface bonding strength.

### INTRODUCTION

In 2008, forest area in China was 195 million hm<sup>2</sup> with reserves of 13.721 billion m<sup>3</sup> ranking the 5<sup>th</sup> and 6<sup>th</sup> around the world (China Forest Resources Management Office, 2010). However, forest resources are still in shortage because of huge population and market demand. Every year large amount of forest resources are being consumed especially with the increasing of population and economics. China accounts for 35 per cent of world's farms (FAO, 2014) offering around 31

million tons of agri-residues (Hu 2002). In traditional Chinese farming culture, farmers burned the agri-residues as fertilizer for future farming which caused serious air pollution.

Development of agri-residues composites offered a possibility to utilize the agri-residues without burning. Agri-residues composites are attempted to be substitute for wood materials for the advantage of good mechanical properties, built-in insulation, low cost (Parker 1997) and environmental contributions in 21<sup>st</sup> century. To improve the properties, adhesives such as the most commonly used urea formaldehyde (UF), phenol formaldehyde (PF) and methylene diphenyl diisocyanate (MDI) were applied as well as soybean protein isolate and soybean flour (Mo et al. 2003), EPU (Zhang et al. 2011) and polyalcoholic polymers-based adhesive (Basta et al. 2013) and other adhesives. On the other hand, various of agri-residues were used to make kinds of composites (Hiziroglu et al. 2008, Tabarsa et al. 2011). Now, agri-residues composites, especially straw composites (mainly straw fiberboard and particle board) can be utilized as furniture, flooring, acoustic panel, cabinet, packaging and interior decoration materials (Alyssa et al. 2005).

In practical application, monotonous color of straw composites causes such products have to be decorated by veneers or painted as furniture materials. Cold or hot pressing was the most common method based on traditional wood substrate overlaying technology, in process of overlaying surface veneers in factories. Though various of products were developed, we often neglect the guidance to practical use which might cause our development more or less meaningless. In our investigation to factories in China, because of lacking of guidance and references, the faultiness of overlaying technology and improper control of bonding performance about straw particleboard and veneer, straw particleboard with veneer decoration often have the defects about shrinkage, bending, deformation and cracking, especially surface warp. Most methods were proposed to solve such problems in process of wood based composites. Tree species, types of adhesives, front and back of veneer, curing condition and assembling time were considered as important cause for surface crack (Cassens 2003). So far, no technical process was proposed especially focusing on processing straw particleboards for furniture use.

Several factors causing the surface warp could be concluded: 1) moisture content of substrate boards and veneers were not properly adjust to equilibrium moisture content; 2) the substrate boards were usually sanded by 3 mm from the surface to keep enough roughness while remaining the hardening layer which caused uneven internal stress distribution and surface warp; 3) hot-pressing parameters were not controlled strictly causing low surface bonding stress and surface warp; 4) conversation time was not enough for adhesive to cure after hot-pressing (Wu 2002; Shen and Lu 2006).

Based on this, this work attempts to investigate a proper technical process for practical production in factories which can reduce surface warp while ensuring high mechanical properties, through moisture content adjustment of straw particleboard substrate and veneer, controlling sanding thickness from the substrate surface, controlling hot-pressing parameters (pressure, temperature and time) and proper conversation time. In addition, the practical verification was carried out in the factory according to our technical process gained from experiment.

## MATERIAL AND METHODS

1) Straw particleboards were obtained from Jiangsu Dingyuan Science and Technology Development Co, Ltd., size of particleboards was 1220×2440×18 mm, average density was 0.75 g.cm<sup>-3</sup>, moisture content was around 11.9 %, the surface roughness was around 108 μm, Ra was 8.65 μm, Sm was 0.16 mm.

2) Decorating material. Birch (*Betula alnoides* Buch.-Ham. ex D. Don) veneers were used. Average thickness was 0.6 mm and initial moisture content was 15 %;

3) Adhesives. Polyvinyl acetate emulsion (PVAc, from Zhejiang Dehua Bunny New Decorative Material Co., Ltd., the surface appears milky, solid content is  $48 \pm 2$  %, the viscosity is 50000 pa.s, PH is 5-7) and modified "PVAc+GB-3+flour" (GB-3, non-formaldehyde adhesives, from Nanjing Gaobao Rubber Co.,Ltd, the viscosity is 15000 pa.s, solid content is 50 %, the surface appears milky, PH is 6.8-7; Modified blend glue mixed with 60 % PVAc and 40 % GB-3 and some flour, solid content controlled in 49.7 %, the viscosity is 36000 pa.s were used to bond veneers and straw particleboards.

4) Main equipment. Moisture analyzer (KT-10, Italy KLORTNER), surface roughness tester (Type 2222 portable multi-parameter surface roughness tester, Harbin Measuring Tool Factory), electronic universal mechanical testing machine and ancillary equipment (CMT6104, Shenzhen Sansi Material Testing Co., Ltd.), hot press (XLB, Qingdao Third Rubber Machinery Factory), precision push table saw (MJ6132, Fujian Markov Woodworking Machinery), hot and cold cycle test machine (DHG-9143BS-III, Shanghai Xinmiao Medical Devices Co., Ltd.), customized square iron (20×20×20 mm), fixture, and wide belt sanding machine (100#), etc.

5) Conservation materials. Plastic film.

6) Enterprise large-scale experiment. Enterprise large-scale experiment was carried out in Guangdong Yihua Timber Industry Co., Ltd. (the biggest wood products manufacturing company in China, mainly produces wooden veneer material, furniture, wooden doors).

## Determine of pre-processing parameter

### *Moisture adjustment before hot-pressing*

Final equilibrium moisture content of 8-10 % in both surface and substrate particleboards was proved to be best to reduce surface warp (Rao 2001). To determine the best storage condition, straw particleboards were kept in environment of 30°C and 40 % RH. Moisture content of 5 % randomly selected straw particleboards was measured for every 2 hours moisture analyzer. Five positions were measured randomly on each board. Birch veneers were kept for air drying then adjusted to stable moisture content to 8-10 %.

### *Sanding*

Substrate straw particleboards were divided onto four groups (5 boards in each group), sanded by 0.3 mm (as same as sanding in factories), 0.5, 0.8 mm (accuracy:  $\pm 0.1$  mm) from the surface and one group without sanding. Surface roughness was measured. According to the proper storage condition from former experiment, final of particleboards kept in the condition of 30°C and 40 % RH together with veneers for 24 hours. PVAc painted on surface of substrate straw particleboards with amount of  $120 \text{ g.m}^{-2}$ , then birch veneers were overlaid. Hot-processing was conducted in condition of 25-30°C and 55~65 % relative humidity with unit pressure of 0.6 MPa and temperature of 90°C for 120 s according to normal parameter in factories. After veneer decorative straw particleboards were conserved for 48 h after hot-pressing, surface warp degree of was measured. Average and standard deviation were calculated in the same group.

## Determine of hot-pressing parameter

### *Hot pressing process*

In this experiment, moisture content of straw particleboards and veneers was controlled to 7-8 % in condition of 30°C and 40 % RH for 12 and 2 hours respectively. According to the former experiment, sanding thickness of  $0.8 \pm 0.1$  mm which could reduce the warp degree most

effectively was chosen. PVAc and "PVAc +GB-3+ flour" were painted on surface of particleboards with amount of  $120 \text{ g}\cdot\text{m}^{-2}$  respectively, then veneered. Before hot-pressing, the veneered boards were aged for 5 minutes. Orthogonal test was designed in hot pressing with factors shown in Tab. 1. Three particleboards were hot pressed in each group.

Tab.1: Orthogonal test factors.

Level	(A)Unit pressure/ (Mpa)	(B)Hot pressing temperature (°C)	(C)Hot pressing time (s)
1	0.6	90	120
2	0.7	100	180
3	0.8	110	240

#### Surface bonding strength test

The veneer decorative straw particleboards were cut into size of  $50\times 50 \text{ mm}$  after hot-pressing. Room temperature rapid curing adhesive SK63 was used to connect the fixture which was held by universal mechanical testing machine and veneer decorative straw particleboards surface (Fig. 1).



Fig. 1: Method to test surface bonding strength.

Stretch orientation was vertical to the bonding interface. Then the samples were stretched in a constant speed (less than  $6000 \text{ N}\cdot\text{min}^{-1}$ ) till destruction. Maximum load was measured as surface bonding strength. Average and standard deviation were calculated in the same group. Difference analysis and ANOVA was used to analyze the effect of three hot-pressing parameters on SBS.

#### Enterprise large-scale experiment

Enterprise large-scale experiment was conducted in Guangdong Yihua Timber Industry Co., Ltd. The best experiment condition from former experiments was selected. Total 1000 straws particleboards were produced. To ensure a better dimensional stability, stretch film or plastic film was usually used to seal the semi-finished veneer decorative panels. 20 veneer decorative panels were chosen randomly, sealed by plastic film and kept in environment of  $25\sim 30^\circ\text{C}$  and  $40\sim 70\%$  RH. The surface warp degree was measured after 6, 12, 24, 48 and 72 h. Average and standard deviation were calculated. After conversation for 72 h, these panels were cut to test the surface bonding strength. At the same time, 20 veneer decorative panels produced in normal process (sanding thickness:  $0.3\pm 0.1 \text{ mm}$ , adhesive: PVAc, hot-pressing pressure:  $0.6 \text{ MPa}$ , pressing temperature:  $110^\circ\text{C}$ , pressing time: 2 min, conversation time: 24 h) were used to test the warp degree and surface bonding strength as control group.

## RESULTS AND DISCUSSION

### Change of moisture content

Fig. 2 showed moisture content continued decreasing sharply in the first 12 h after kept in the environment of 30°C and 40 % RH. Then there was a slight drop from 12 to 24 h. After that, moisture content was stable around 8.851 %. This indicated that the straw particleboards need at least 24 h for moisture content adjustment to 8-10 % in environment of 30°C and 40 % RH.

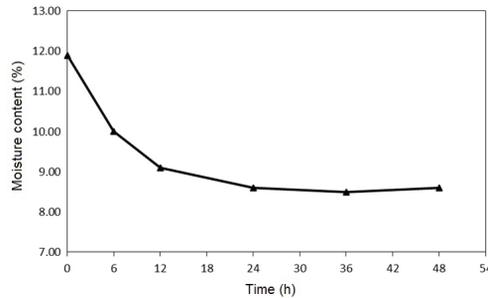


Fig. 2: Moisture content change in environment of 30°C and 40 % RH.

### Sanding effect on warp

Most uses for particleboard require a uniform thickness from edge to edge and a smooth flat surface can be attained through sanding. Sanding ensure a proper roughness which is a function of both raw material properties and production processes (Nemli et al. 2007). There was no obvious relation among different sanding thickness which all met the requirement for veneering (Yu 2002, Wu 2012). Average surface roughness (Ra) of substrate straw particleboards in all groups was 5.81  $\mu\text{m}$ .

In addition, sanding can remove the hardened layer more or less and reduce the internal stress after hot pressing. The surface warp degree of five different sanding thickness veneer decorative straw particleboards were shown in Fig. 3.

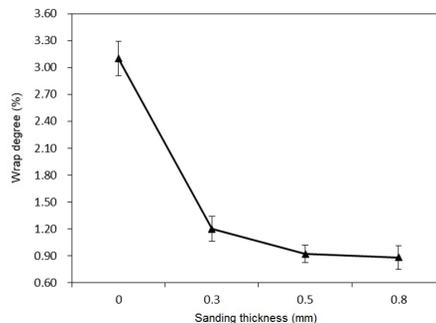


Fig. 3: Surface warp degree in different sanding thickness.

Boards which the substrate straw particleboards were not sanded before hot-pressing had the highest warp degree of  $3.11 \pm 0.19$  %, then warp degree decreased sharply to  $0.92 \pm 0.17$  % with the increase of sanding thickness till 0.5 mm. Surface warp degree was similar when the substrate

straw particleboards was sanded by 0.5 and 0.8 mm which indicated that hardened layer of substrate particleboards was around 0.5 - 0.8 mm. Internal stress which caused the warp degree was eliminated when hardened layer was totally removed from the particleboards. To ensure the hardening layer will be removed totally, sanding thickness of 0.8 mm was selected as the best sanding thickness.

**Effect of hot-pressing on surface bonding strength**

Quality of decorative veneered straw particleboard was mainly controlled by hot-pressing factors (pressure, time, temperature). Surface bonding strength is one of the most important indicators that evaluate the bonding quality of veneer coated panels. Surface bonding strength of PVAc and “PVAc+GB-3+flour” bonded veneer decorative straw particleboards using different hot-pressing parameter were better than 0.40 MPa which is the Chinese national standard for decorative veneered wood based panel (SAC 2006). It was clear from the Figs. 4 and 5 that unit pressure of 0.8 MPa, hot pressing temperature of 90°C and hot pressing time of 240 s while unit pressure of 0.7 MPa, hot pressing temperature of 90°C and hot pressing time of 180 s was the best scheme for the surface bonding strength of veneer decorative straw particleboards using “PVAc+GB-3+flour” as adhesive with a higher surface bonding strength.

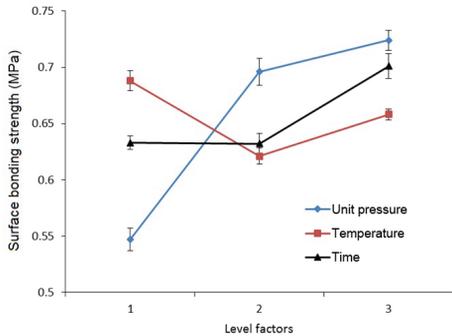


Fig. 4: Intuitive analysis diagram surface bonding strength using PVAc.

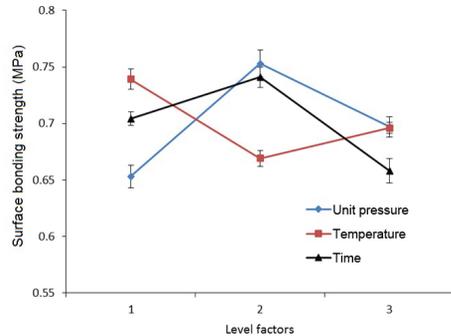


Fig. 5: Intuitive analysis diagram surface bonding strength using “PVAc+GB-3+flour”.

ANOVA of veneer decorative straw particleboards using PVAc showed that impact of factor (unit pressure) was significant for surface bonding strength, and the impact of factor B (hot pressing temperature) and factor C (hot pressing time) was not significant. In difference analysis, RA> RC>RB indicated that factor A (unit pressure) was the most effective factor on the surface bonding strength, following by factor C (hot pressing time), and factor B (hot pressing temperature). ANOVA and difference analysis of veneer decorative straw particleboards using “PVAc+GB-3+flour” showed the similar result though all three factors was not significant (Tabs. 2 and 3).

In consideration of the higher surface bonding strength, “PVAc+GB-3+flour” should be used as adhesive with unit pressure of 0.7 MPa, hot pressing temperature of 90°C and hot pressing time of 180 s.

Tab. 2: ANOVA and difference analysis of SBS of veneer decorative straw particleboards using PVAc

Source of variation	bias squares	Degree of freedom	Mean sum of square	f-value	Critical value	Differential R
	S <sub>j</sub>	f <sub>j</sub>	S <sub>j</sub> /f <sub>j</sub>		F(f <sub>j</sub> ,f <sub>e</sub> ) (a=0.05)	
A	0.164	2	0.082	3.68*	3.49	0.177
B	0.020	2	0.010	0.45	3.49	0.067
C	0.028	2	0.014	0.63	3.49	0.069
Error e	0.446	20	0.022			
Total	0.658	26				

Tab. 3: ANOVA and difference analysis of SBS of veneer decorative straw particleboards using "PVAc+GB-3+flour".

Source of variation	bias squares	Degree of freedom	Mean sum of square	f-value	Critical value	Differential R
	S <sub>j</sub>	f <sub>j</sub>	S <sub>j</sub> /f <sub>j</sub>		F(f <sub>j</sub> ,f <sub>e</sub> ) (a=0.05)	
A	0.045	2	0.023	1.748	3.49	0.100
B	0.023	2	0.011	0.868	3.49	0.070
C	0.031	2	0.016	1.213	3.49	0.083
Error e	0.259	20	0.013			
Total	0.358	26				

## Enterprise large-scale experiment

### Surface warp degree in different conversation time

Surface warp degree becomes worse without enough conversation time which enables the adhesive complete curing and stress balance in the particleboard after hot-pressing. In Fig. 6, surface warp degree was highest when the boards were conserved for 6 h after hot-pressing then decreased till 24 h which indicated that adhesive continued curing within 24 h after hot-pressing. In consideration of product efficiency, conversation of hot-pressed boards should be kept for at least 24 h.

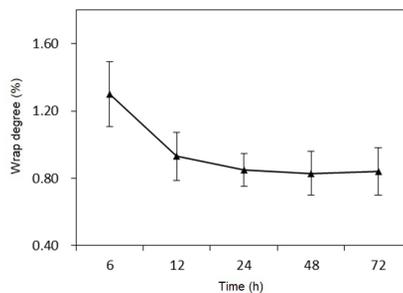


Fig. 6: Surface warp degree in different conversation time.

### Comparison of surface warp degree and surface bonding strength

72 h after conversation, average warp degree of 20 selected particleboards produced by the best scheme from the experiment was  $0.84 \pm 0.2$  % while warp degree of boards produced by normal process was  $1.05 \pm 0.3$  %. The improvement of warp degree mainly contributed to

our thick-sanding which removed the hardening layer. In factories, usually the boards were sanded by 0.3 mm to reach the suitable surface roughness. However, internal stress could not be eliminated by sanding 0.3 mm from the surface of substrate straw particleboards. Fig. 7 showed the distribution of surface warp degree in two different processed veneer decorative straw particleboards. Most of the surface warp degree was between 0.7-0.8 % in our process while 0.9-1.0 % in normal process.

**Processing process**

The processing process was concluded:

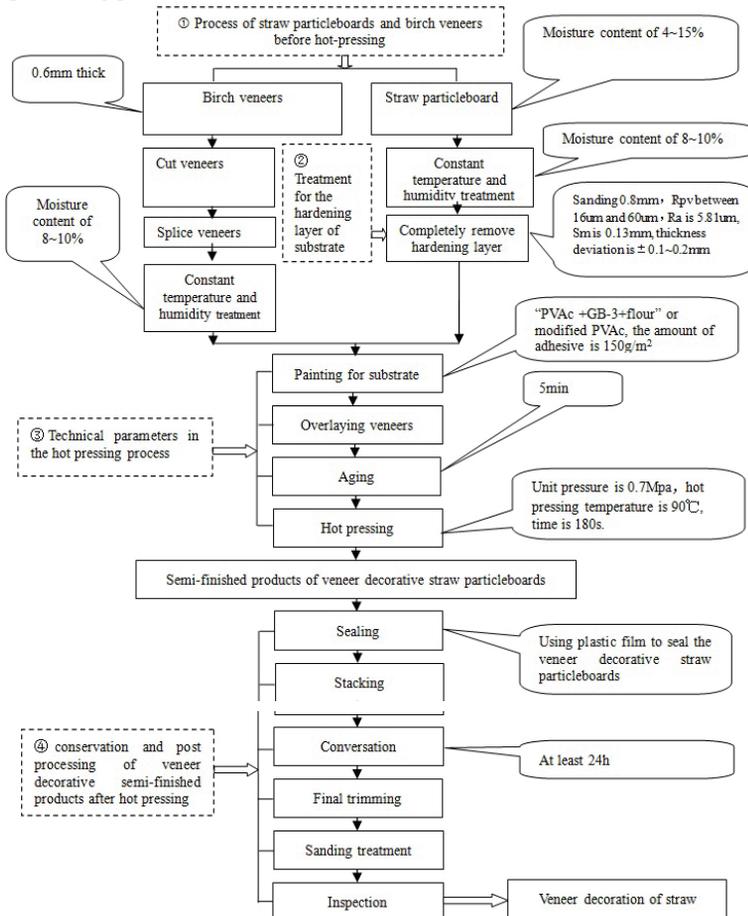


Fig. 7: Technology process of veneer decoration of straw particleboard.

Surface bonding strength of 20 particleboards was  $0.743 \pm 0.14$  MPa which was higher than control group with  $0.702 \pm 0.21$  MPa. This was mainly caused by different adhesive and hot-pressing parameter.

Enterprise large-scale experiment proved our improvement of producing process was practical and could improve warp degree significantly while maintaining a relatively high surface bonding strength.

## CONCLUSIONS

There are many factors that influence the veneer overlaying quality. However, too much warp often occur after process of veneer decorative straw particleboards. It could be solved by thick sanding and conserved with plastic films while remaining enough surface bonding strength.

1) Moisture adjustment before hot-pressing

Adjustment of moisture content should be kept in environment of 30°C and 40 % RH for at least 24 h to gain a stable moisture content between 8-10 %.

2) Sanding

Straw particleboards should be sanded by 0.8 mm from the surface which could remove the hardening layer to eliminate the internal stress and improve the surface warp. The surface roughness.

3) Hot pressing

In hot-pressing process, modified adhesive such as "PVAc+GB-3+flour" should be chosen and veneer particleboards should be aged for 5 minutes to maintain enough time for adhesive to penetrate into boards. Proper hot-pressing parameter (unit pressure of 0.7 MPa, temperature of 90°C and hot pressing time of 180 s) should be set up. This step will mainly affect the surface bonding strength.

4) Conservation

Conservation is another important process to reduce warp of particleboards. The hot-pressed veneer decorative particleboards need to be conserved with plastic films for at least 24 h.

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