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STUDY ON CONTINUOUS COLD-PRESSING TECHNOLOGY OF ENGINEERED WOOD FLOORING WITH EPI ADHESIVE

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ABSTRACT

The effects of process parameters (adhesive spread, press time, and applied pressure) on the gluing performance of engineered wood flooring bonded with emulsion-polymer-isocyanate (EPI) adhesive were studied. The results showed (shear strength and aging test) that the major factors were adhesive spread and press time. The optimized parameters for best gluing performance of engineered wood flooring were 160 $g \cdot m^{-2}$, 14 s, and 60 s for adhesive spread, heat time, and press time, respectively, within certain ranges.

KEYWORDS: EPI, engineered wood flooring, shear strength, aging test.

INTRODUCTION

The use of the engineered wood flooring (EWF) has increased in daily life because of its natural grain, fine comfort level and good stability (Chen et al. 2015). The engineered wood flooring has become the leading product of flooring (Irland 1990, Lamy 1997). Nowadays, most of the engineered wood flooring manufacture adopt the hot-pressing technology. This technology has the advantages of simple process and machine, there are following shortcomings though. For example, melamine-urea-formaldehyde adhesive (MUF) and urea-formaldehyde adhesive (UF) were used for hot-pressing, these adhesives contained free formaldehyde which was not in accordance with the requirements of the green home; the technology was difficult to achieve continuous automatic operation, the efficiency of production was low. What's more, hot-pressing not only consumed a large amount of energy but also led to the movement of water when the engineered wood floorings were heated which may cause the deformation of engineered wood floorings. Deformation is one of the most important indexes of engineered wood flooring, many scholars have studied (Gaff and Gasparik 2015, Gaff et al. 2015, Gaff et al. 2016). These studies start from the impact of material properties and this paper focuses on the adhesive and the continuous cold-pressing technology.

In order to overcome the shortage of hot-pressing, most enterprises employ cold-pressing which is periodical with polyvinyl acetate adhesive (PVAc) and emulsion-polymer-isocyanate adhesive (EPI). In 2002, an Italian company proposed a new type of cold-pressing technology which can achieve continuous production of engineered wood flooring using One-component polyurethane adhesive (PUR). This continuous cold-pressing technology not only overcome the limitations of traditional hot-pressing, but also leads to continuous production of engineered wood flooring. However, the high price of PUR adhesive increased the cost of floorings which cannot be afforded for enterprises. This technology was not promoted extensively.

At present, common cold-pressing adhesive like PUR, PVAc and EPI can all used in production of engineered wood flooring (Zheng 2005). PVAc adhesive is poor water resistance and PUR adhesive is too much expensive, overall, applying the EPI adhesive to the production of engineered wood flooring has a spacious prospect. Although this type of adhesive has been intensively studied (Wang et al. 2016, Grostad and Pedersen 2010, Blanchet 2008, Xu and Gao 2007), there have been no reports on continuous cold-pressing technology of engineered wood flooring with EPI adhesive. So the main objective of this study is to investigate the effects on continuous cold-pressing technology of engineered wood flooring bonded with EPI adhesive, and find out an optimum technological parameters to support the practical application.

MATERIAL AND METHODS

Materials

The core board and surface layer of engineered wood were all provided by Dare (Jiangsu) Parquet Co., Ltd. Tab. 1 gave an overview of the core board and surface layer used in this study.

Tab. 1: Properties of the core board and surface layer.

Materials	Wood species	Length (mm)	Width (mm)	Thickness (mm)	Moisture content (%)
Surface layer	Birch	800	95	2	6-10
Core board	Birch	840	340	10	8-12

The bonding processes were performed using EPI adhesive (Dynea, Shanghai). The properties of this adhesive was shown in Tab 2.

Tab. 2: Properties of EPI adhesive used in this study.

Adhesive	Color	White
	Viscosity	7000~9000cps (25°C)
	Solid content	57~59%
	PH	7~8
	Density	1.25±0.05
Hardener	Color	Dark brown
	Viscosity	<0.2Pa.s (25°C)
Adhesive: Hardener ratio	100:15	

The type of continuous cold-pressing equipment was continuous flat press (model number K450, Jinshan Corporation, Hangzhou, China). IR wood heating equipment adopted the infrared dry technology.

The shear strength tests were conducted on a microcomputer control electronic universal testing machine (model number CMT6104, MTS, Shenzhen, China).

Methods

The parameters studied during the continuous cold-pressing of engineered wood flooring with EPI adhesive included adhesive spread, heating time, and pressing time. The EPI adhesive was used to bond the surface layers and core boards, and adopted IR wood heating technology to improve the permeability of adhesive which can shorten the press time and achieve the continuous production of engineered wood flooring. The continuous cold-pressing technology was shown in Fig. 1 and the specific process parameters and levels were shown in Tab. 3.

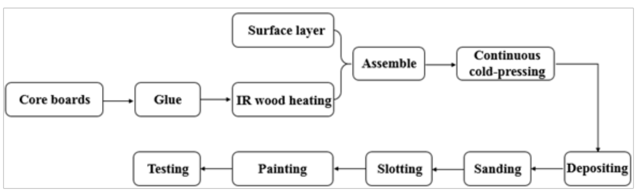


Fig. 1: Process of continuous cold-pressing technology.

At first, substrates were treated in order to improve the precision and ensure high surface finish. Short active period of EPI adhesive (about 25 min) determined to glue rapidly. Then, carry on the IR wood heating systems to evaporate water from adhesive which can improve the permeability of adhesive and curing speed. Next, assemble with machine. Gluing and assembly should be completed within 15 min to prevent pre-curing of adhesive. In total, 27 samples were produced, i.e., 3 samples for each combination of the process parameters. After the bonding process, all samples were stored in a conditioned room at 23°C and 50% relative moisture content to reach the required moisture content.

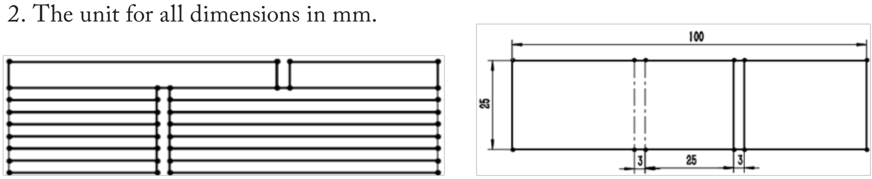
Tab. 3: Process parameters.

Process parameters	Levels		
Adhesive spread ($g \cdot m^{-2}$)	120	140	160
Heating time (s)	8	14	20
Pressing time (s)	40	60	80

Measurement of properties

The properties measured included modulus of rupture (MOR), modulus of elasticity (MOE), shear strength and aging test.

The shear strength of engineered wood flooring were tested according to Chinese National Standard GB9846.7 (1998). The dimensions of testing samples for shear strength were shown in Fig. 2. The unit for all dimensions in mm.



(a) (b)

Fig.2: Standard samples for the test of shear strength.

The remaining tests were conducted depending on the GB/T 18103 (2013). The MOR and MOE were measured through a three-point bending test and the specimen dimensions for MOR and MOE testing were 250×50×12 mm. The dimensions of testing samples for aging test were 75×75×12 mm. In total, 54 samples were produced, i.e. 6 samples for each combination of process parameters. All samples were placed in hot water (70±3°C) for 2 hours, then put in drying chest (60±3°C) for 3 hours. Engineered wood floorings were considered to have failed in this test when the cumulative length of each side of glue delamination was over one third of the whole glue length.

RESULT AND DISCUSSION

Shear strength

As shown in Fig. 3, the shear strength increased with increasing adhesive spread and pressing time. The wood has an ability of permeability, when the adhesive spread is 120 $g \cdot m^{-2}$, most of the adhesive penetrates into wood which can't form a complete glue line (Li 2015). With an increase of adhesive spread, enough adhesive can form a uniform glue line in the press processing. It is the reason to get a better gluing performance and higher shear strength. But the shear strength will decrease when the adhesive spread is at a higher level, because too much adhesive forms a thick glue line which has a negative effect on shear strength (Hu 2013, Follrich et al. 2010 Kurt 2006).

For the parameter of pressing time, a relatively long pressing time is necessary to get a good gluing performance. With longer pressing time the wood can be penetrated more adhesive which can improve the shear strength.

For the parameter of heating time, the shear strength increased gradually with the increase of heating time at first, when the heating time is up to 14 s the shear strength is the highest, but the shear strength decreases when the heating time continues to increase. It is may be that longer heating time leads to higher surface temperature of engineered wood flooring which may make adhesive pre-cure and decrease the shear strength.

An analysis of variance and range are conducted and the analysis of variance is for a level of significance of 5%. As shown in Tab. 4, the heating time and the pressing time show statistically significant contributions to the shear strength according to the F-value greater than F0.05. However, there is no significant indication that the adhesive spread has any influence on the shear strength.

Tab. 5 indicates that the most important factor which influences shear strength is pressing time, heating time comes second and the last one is adhesive spread. This is in agreement with the conclusions the analysis of variance comes to. Based on the better parameters listed in Tab. 5, the optimized parameters for highest shear strength are 160 g·m^{-2}, 14 s and 80 s for adhesive spread, heating time and pressing time, respectively.

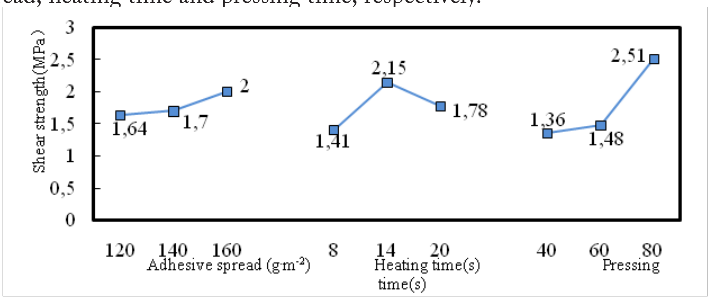


Fig. 3: Relevance graph for shear strength.

Tab. 4: Analysis of variance of the shear strength.

Source	df	Mean Square	F value	P.
Corrected model	6	0.573	46.204	0.021
Intercept	1	28.551	2300.456	0.000
Adhesive spread	2	0.111	8.928	0.101
Heating time	2	0.403	32.499	0.030
Pressing time	2	1.206	97.185	0.010
Error	2	0.012		
a. R Square=0.993 (Adjusted R Square=0.971)				

Tab. 5: Analysis of range of the shear strength.

Source	Adhesive spread	Heating time	Pressing time
Mean value 1	1.640	1.413	1.357
Mean value 2	1.703	2.147	1.477
Mean value 3	2.000	1.783	2.510
Ranges	0.360	0.734	1.153
Sequence factors	3	2	1
Better parameters	A3	B2	C3

Aging test

The conclusions from Fig. 4 are generally in agreement with the conclusions stated above except the 60 s for pressing time. When the parameters are 160g·m^{-2}, 14 s and 60 s for adhesive spread, heating time and pressing time, the performance for aging test is the best.

An analysis of variance and range are conducted and the analysis of variance is for a level of significance of 5%. As shown in Tab. 6, for the aging test, the adhesive spread, heating time and pressing time show statistically significant contributions to the aging test according to the F-value being greater than the F 0.05. From Tab. 7 it can be seen that parameters for pressing time and adhesive spread are more priority than heating time. Based on the better parameters listed in Tab. 7, the optimized parameters for better glue performance are 160 g·m^{-2}, 14 s and 60 s for adhesive spread, heating time and pressing time.

When the press time is 80s, the result of the aging test is not up the standard. In summary, the optimized parameters for best gluing performance of engineered wood flooring for adhesive spread, heating time, and press time are 160 g·m^{-2}, 14 s, and 60 s, respectively.

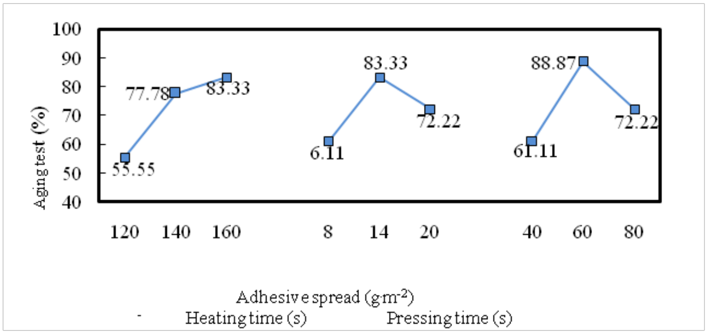


Fig. 4: Relevance graph for aging test.

Tab. 6: Analysis of variance of the aging test.

Source	df	Mean Square	F value	Sig.
Corrected model	6	555.535	49998334.00	.000
Intercept	1	46943.000	4.225e9	.000
Adhesive spread	2	648.241	58341667.00	.000
Heating time	2	370.296	33326668.00	.000
Pressing time	2	648.074	58326667.00	.000
Error	2	1.111e-5		
a. R Square=1.000 (Adjusted R Square=1.000)				

Tab. 7: Analysis of range of the aging test.

Source	Adhesive spread	Heating time	Pressing time
Mean value 1	55.55	61.11	61.11
Mean value 2	77.79	83.33	88.89
Mean value 3	83.33	72.22	66.67
Ranges	27.78	22.22	27.78
Sequence factors	1	2	1
Better parameters	A3	B2	C2

CONCLUSIONS

1. The shear strength of engineered wood flooring bonded with EPI adhesive increased with increasing adhesive spread and press time.
2. The gluing performance of engineered wood flooring bonded with EPI adhesive was affected by adhesive spread and pressing time, heating time had insignificant effects on gluing performance.
3. The optimized parameters for best gluing performance of engineered wood flooring for adhesive spread, heating time, and press time are 160g/m2, 14s, and 60s, respectively.

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