

Influence of Veneers' Lathe Checks on Strain Distribution at Wood-adhesive Interphase Measured by Electronic Speckle Pattern Interferometry (ESPI)

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Abstract

When lathe checks exist in veneers, adhesive will penetrate excessively along them into wood substrate causing strain alteration at bonding interphase under loads, which affects the overall bonding strength of board. We plan to apply ESPI (Electronic Speckle Pattern Interferometry) to study the effect of lathe checks on the strain distribution at wood-adhesive interphase and to find a solution against the lathe checks. A sealing treatment is supposed to be figured out to improve the low bonding strength of board due to over-penetration of adhesive without adding more adhesive to veneers.

Keywords: veneers' lathe checks, sealing treatment, bonding interphase, ESPI, strain distributio

Introduction

With growing attention on global ecological changes and environmental problems, more rational and effective use of forest resources has been emphasized. From this point, wood adhesives and adhesion will be the significantly important factor. For peeling veneers, adhesive will penetrate along lathe checks into deep part of wood substrates and affect the geometry of interphase, which would ultimately have a significant impact on the performance of the bond (Kamke 2007). Thus, it is critical to investigate the influence of checks on the geometry and bond performance of wood components.

Fluorescence microscopy was found superior to other optical techniques for observing adhesive distribution among interphase where there is poor color contrast (Kamke 2007). Electronic speckle pattern interferometry (ESPI) is an optical 3D gauging technique which has been demonstrated by a few authors that this new technique is applicable to wood surfaces and allows analysis of multiaxial sample deformation (Dumail 2000 and Jernkvist 2001). For example, the strain distribution along wood bond lines of lap joint specimen was studied (Muller et al. 2005), the measurements showed that a very small volume of material close to the ends of the overlapping area was highly strained.

In the present work, we characterized the influences of lathe checks on the geometry of interphase by fluorescence microscopy, as well as the strain distribution at the interphase of phenol formaldehyde resin (PF) glued components using ESPI to understand the effect of lathe checks on wood-adhesive interphase.

Materials and Methods

Materials. Peeling and planing veneers of poplar (*Populus Euramevicana Cv.*) with dimensions of 400mm×400mm×3mm and 180mm×70mm×5mm respectively were both from South Wood Technology Ltd. (Lian Yungang, China). The process of self-made phenol formaldehyde resin was as follows: phenol, water and sodium hydroxide were added to reactor and stirred at a temperature range of 40-45°C. The first part of formaldehyde (80% of total amount) was added and the liquid in the reactor was heated up to 80-85°C. After reaction for 45min, the water was warmed up to boiling for 10min. Then the liquid was cooled to 40-45°C to accept the left formaldehyde. The total solution was reacted at 85-90°C for 80min. Finally, the reaction mixture was cooled down to room temperature and poured out. The formula and property of adhesive can be found on Table 1. The process of self-made soy adhesive was as follows: defatted soy flour was added to water slowly and stirred for 15min until no massive substance was observed. Then sodium hydroxide (concentration of 30%) was put in the suspension and stirred until it became sticky. The mass ratio of components was soy flour: sodium hydroxide: water=100:15:400.

Table1 Formula and property of PF adhesive

Resin	F: P Ratio	NaOH (%)	Solid content (%)	Viscosity (mPa.s)
PF adhesive	1.5	8.8	46.3	36

Sealing treatment on interface between wood and adhesive. Ordinary soybean adhesive was chosen as sealant and spread on the surface of veneers having checks prior and laid aside for 30min. Then PF adhesive covered the sealed the surfaces of veneers which were laid up parallel to longitude with the checks on both sides facing each other. The assembly was pre-loaded for 30min before hot-press. Double-side glue application of soy adhesive was 150 g/m², single-side glue application of PF adhesive was 150 g/m². The parameters of hot-press were 140°C1min/mm, 2.6MPa.

Characterization of adhesive penetration into wood. Slices of 20µm were achieved with microtome (YAMATO TU-213). The slices were stained for 30min with toluidine blue water solution with a concentration of 0.5%. Finally, sections were observed under microscopy (Olympus BX51). The optical filter set used consisted of a 450-480nm excitation filter, 575nm dichromatic mirror and a 500nm emission filter. Specific process can be obtained via reference (Kamke 1992).

Strain distribution measurement along wood bondline. The basic principle of the ESPI technique can be explained by the example of a Michelson interferometer (Gerthsen et al. 1986 and Muller et al. 2005). The specimens were sawed according to the dimension in Figure 1. Tensile tests were performed on lap shear samples as shown in Figure 2 using a manually loading device combined with a TS-SI-1XP ESPI (Suzhou, China). Since the available device here can only detect the displacement of one dimension, in order to achieve the shear strain, measurements parallel and vertical to bondline were conducted respectively. The size of the field of view observed with ESPI was 45 mm by 36 mm. A pre-tension of 15 N were imposed on specimens and 8 steps of strain with an increment of 2 N. Thus, total load of 31N were applied to specimens, which ensured only elastic deformation of the samples. A speckle image of the field of view was taken at each displacement step. The displacement maps were calculated by summing up information from all 8 displacement steps. The stack of speckle images obtained was stored on computer and used for deformation calculation after the mechanical experiments. Post-processing of the speckle images was performed with Matlab software. The strain components, i.e., axial strain ϵ_x , ϵ_y , γ_{xy} can be calculated from the 2D deformation field according to equations (Eqs.(1), (2) and (3)).

$$\epsilon_x = \frac{\partial u}{\partial x}, \quad (1)$$

$$\epsilon_y = \frac{\partial v}{\partial y}, \quad (2)$$

$$\gamma_{xy} = \frac{1}{2} \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right), \quad (3)$$

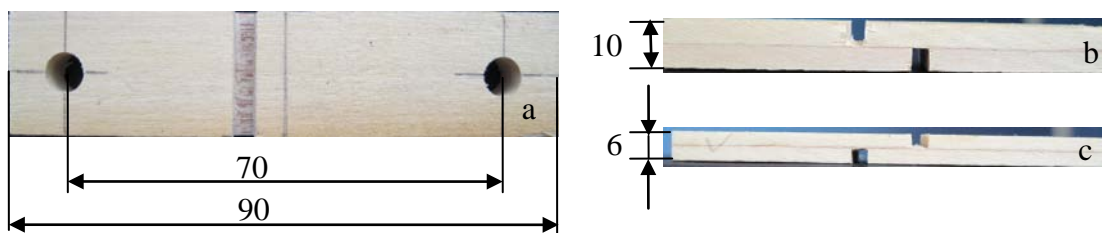


Fig. 1 Dimensions (mm) of shear samples from planing veneers (a, b) and peeling veneers (c).

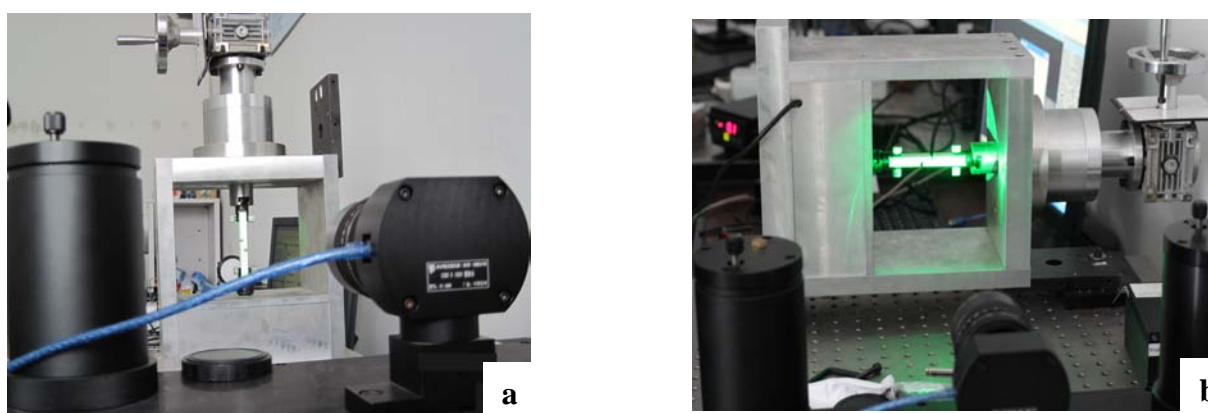


Fig. 2 Tensile shear experiments on samples by ESPI vertical (a) and parallel (b) to bondline.

Results and Analysis

Influence of sealing treatment of veneer surface on PF penetration into poplar. The images of sections were processed by ImageJ image analysis software (<http://rsb.info.nih.gov/ij/>) and performance index of penetration were shown on Table 2. The EP is the total area of adhesive detected in the interphase region of the bondline divided by the width of the bondline. The MP is the average distance of penetration of the five most distant adhesive objects detected within the field of view. Specific process of measurements can be achieved via reference (Sernek 1999).

Table 2 Performance index of PF penetration into wood

Material type	Soy adhesive consumption g/m ²	MP μm	EP μm	Adhesive penetration area (%)
Planing veneer	0	596	44	3.5
Peeling veneer	0	921	113	7.1
	75	756	98	5.8

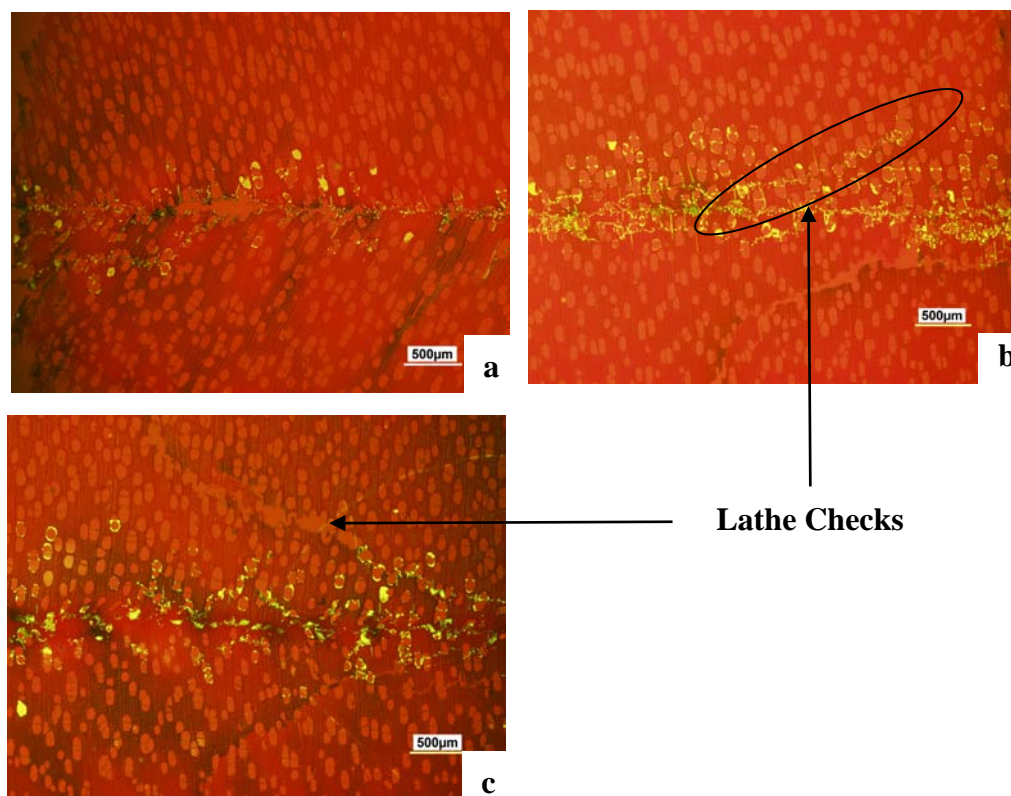


Fig. 3 Fluorescent graphs of planing-veneer based sample (a) and peeling-veneer based sample without (b) and with (c) sealing treatment.

It can be informed from Figure 3 and Table 2 that due to the lathe checks, the EP and MP of PF into peeling veneer were much more than those of planing veneer, because checks provide accessible paths for adhesive into deep part of wood. Then, spreading soy adhesive on veneer surfaces before applying PF adhesive could efficiently prevent adhesive from over-penetration into wood. The MP descended by 18%, EP decreased by 13%. The reason might be that soy adhesive fills the macro gaps such as checks and cell lumen, thus channels for adhesive into wood substrates are reduced. Moreover, soy with modified protein and existence of soluble carbohydrates can absorb moisture (Hunt et al. 2010) from PF adhesive, increasing the viscosity of adhesive.

Strain distribution at wood-adhesive interphase. Figure 4 showed that compared to planing-veneer based sample, peeling-veneer based sample had higher strain as a whole. Besides, the former owned higher strain at interphase than at wood substrate, while the latter's strain tended to be homogeneous. Because PF penetrated into deep part of wood substrates, which could dissipate the shear stress from bulk adhesive into softer substrates, creating greater strain at these areas.

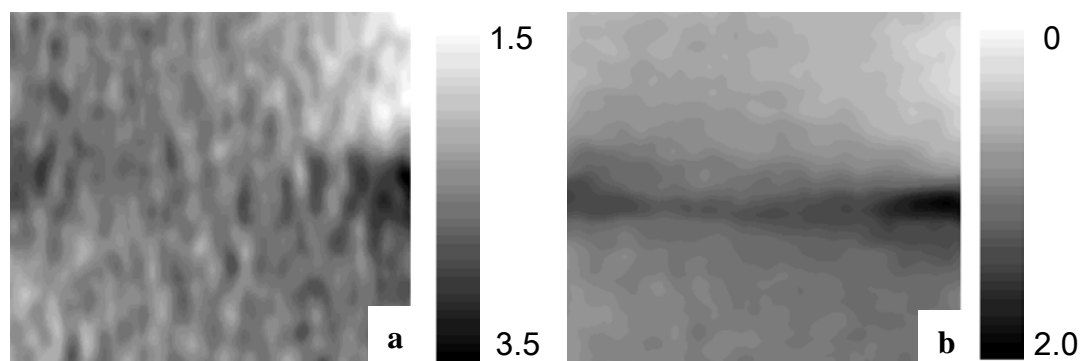


Fig. 4 Shear strain of peeling-veneer based sample (a) and planing-veneer based sample (b). Scale bars indicate strains multiplied by 10^{-3} .

As indicated in Figure 5, these two kinds of samples had high strain concentration at both ends of the overlapping area along the bondline. However, peeling-veneer based sample had higher strain (2.8×10^{-3}) than planing-veneer based sample (1.2×10^{-3}) did. Due to the over-penetration of PF into veneer, the bulk adhesive does not have enough adhesive left in the bondline to form a strong bridge between the substrate (Frihart 2005), leading to generate higher strain under load.

Ground on the results of Figure 6, sample with sealing treatment owned less strain (1.8×10^{-3}) compared to that (2.8×10^{-3}) without treatment did, owing to effective blocking of PF over-penetration, as a result, stress from bulk adhesive couldnot be transferred to deep substrate. Meanwhile, the bulk adhesive strain of the former (2.0×10^{-3}) was less than that of the latter (2.9×10^{-3}) as a result of enhancement on mechanical strength of bulk adhesive with sealing treatment withstanding over-penetration. It should be mention that the strain of sample with treatment still tended to be homogeneous. Maybe two-lay peeling-veneer LVL has thin thickness and low mechanical strength, reulting in deformatng easily under load.

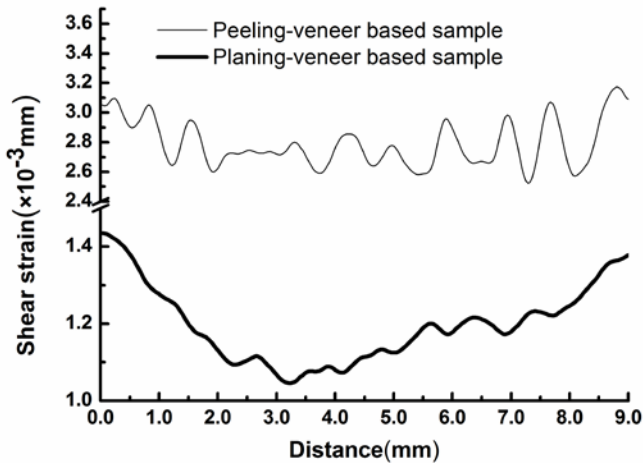


Fig. 5 Shear strain distribution along the bondline of peeling-veneer based sample and planing-veneer based sample.

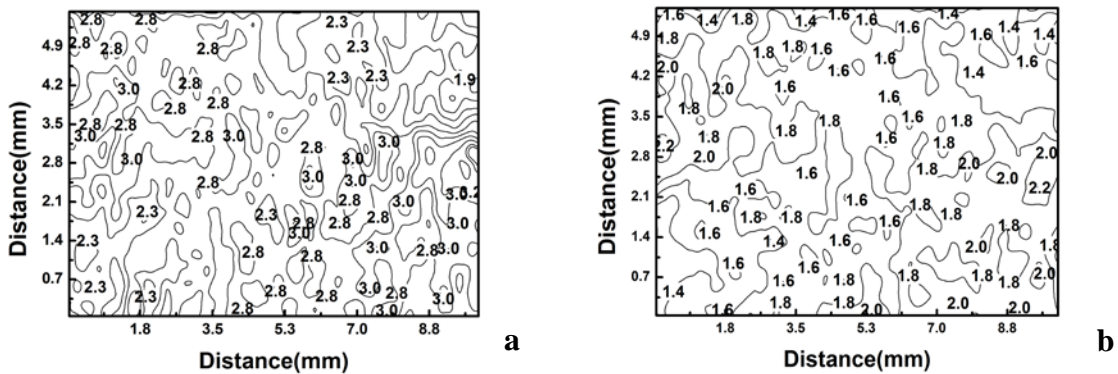


Fig. 6 Shear strain distribution on the observed field of peeling-veneer based samples without (a) and with (b) sealing treatment.

Conclusions

Fluorescence microscopy analysis showed that spreading soy adhesive on peeling veneer surfaces before applying PF adhesive can efficiently prevent adhesive from over-penetration into wood. As indicated in the ESPI test, as a whole, planing-veneer LVLs owned less strain than peeling-veneer LVLs did. Peeling-veneer LVLs with sealing treatment had lower strain than that without treatment did. Thus, sealing treatment can decrease the interphase strain of peeling-veneer based LVL. .

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References

- Dumail, J.-F., Kenneth, O., Salmen, L. 2000. An analysis of rolling shear of spruce wood by the Iosipescu method. *Holzforschung*. 54: 420-426.
- Frihart, C.R. 2005. Utility of Horioka's and Marra's models for adhesive failure. In: *Wood Adhesives 2005*; 2005 November; San Diego, CA. Forest Products Society, Madison, WI, pp. 233-238.
- Gerthsen, C., Kneser, H.O., Vogel, H. 1986. *Physik*. Springer-Verlag, Berlin, Heidelberg, New York, Tokyo. 504–508 pp.
- Hunt, C., Wescott, J., Lorenz, L. 2010. Soy Adhesive-Moisture Interactions. In: *Wood Adhesives 2009*. South Lake Tahoe, CA, Forest Products Society, Madison, WI, pp. 280-284.
- Jernkvist, L.O., Thuvander, F. 2001. Experimental determination of stiffness variation across growth rings in *Picea abies*. *Holzforschung*. 55: 309-317.
- Kamke, F.A., Johnson, S.E. 1992. Quantitative analysis of gross adhesive penetration in wood using fluorescence microscopy. *J. Adhesive*, 40:47-61.
- Kamke, F.A., Jong, N.L. 2007. Adhesive penetration in wood-A review. *Wood and Fiber Science*. 39(2): 205-220.
- Muller, U., Sretenovic, A., Vincenti, A., Gindl, W. 2005. Direct measurement of strain distribution along a wood bond line–Part I: shear strain concentration in a lap joint specimen by means of electronic speckle pattern interferometry. *Holzforschung*. 59: 300-306.
- Sernek, M.J., Resnik, Kamke, F.A. 1999. Penetration of liquid urea formaldehyde adhesive into beech wood. *Wood Fiber Sci*. 31(1):41–48.