CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762024

Effect of Chemical Treatment on the Stress Relaxation of Wood

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In order to analyze the mechanical relaxation phenomenon of copper plated poplar veneer multilayer composite, the multilayer composite materials with different structures are taken as the experimental object, the effect of temperature, structure and moisture content on the stress relaxation of poplar treated with chemical treatment is studied. The study on stress relaxation provides basic theory and technical parameters for the research and application of geothermal floor materials in wood material industry. The results show that the relative stress relaxation of the three structures of A, B and C tends to slowly change with the increase of joint size. Under the same temperature condition, the change rate of relative stress is A structure>B structure>C structure. The reason is that the stress relaxation of the material is aggravated after the veneer in the A structure is swollen by moisture. Because the copper ions in the surface copper layer blocks the moisture, the C structure retards the stress relaxation. The B structure has two factors of A and C, and the stress relaxation changes in the center.

1. Introduction

In order to utilize wood resource with low quality and high yield plantation reasonably and effectively, it is necessary to use various new technologies to improve the physical and mechanical properties of artificial forest timber, thus overcoming the shortcomings of plantation wood itself. Electroless copper plating on plantation wood can impart electrical conductivity and electromagnetic shielding to wood (Oguz and Pawan, 2017). Moreover, the wood can be endowed with new decorative and functional properties after the electroless copper sheet is compounded.

In the process of wood stress relaxation, the movement of wood molecules is affected by several factors. In addition to the own structure, moisture and temperature will directly affect the stress release of the growth inside the wood (Anshari et al., 2017). Therefore, it can be seen that temperature and moisture content inside the wood have a great effect on stress relaxation. The effect of temperature on the mechanical properties of wood is complex. At room temperature, the effect of temperature on the mechanical properties of the material is relatively small (Xu et al., 2017). However, under high and low temperature conditions, the effect of temperature is relatively large. In most cases, the mechanical strength of wood decreases with the increase of temperature (Ninoslav and Kypros, 2015). When using the dry wood to test, the effect of temperature on the stress relaxation of wood is very small under normal temperature (Anshari et al., 2012). Under high humidity, when the temperature reaches a certain height, the stress relaxation rate of wood will increase sharply, which is caused by the thermal decomposition of the cell wall of wood (Zia et al., 2017). Moisture is an important factor which affects the mechanical properties of the material. It can affect some structural properties of lignin, cellulose and hemicellulose (Zhou et al., 2017), thus affecting the binding energy of molecular chains inside the wood and the size of stress relaxation (Pavlina et al., 2017). The joint size of the material has a great effect on the stress relaxation.

In order to investigate the interfacial properties of composite wood after electroless copper plating, the stress relaxation characteristics of three kinds of structural materials under different conditions such as joint size, temperature and moisture content are compared and analyzed, which provides basic information for the preparation and application of high performance composite material.

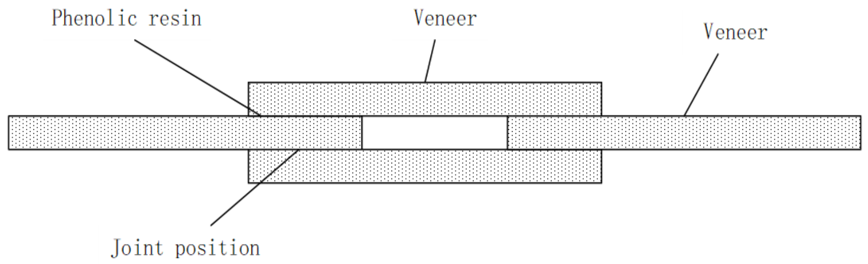
Please cite this article as: Liangsong Cheng, Mingbin Liu, 2017, Effect of chemical treatment on the stress relaxation of wood, Chemical Engineering Transactions, 62, 139-144 DOI:10.3303/CET1762024

2. Method

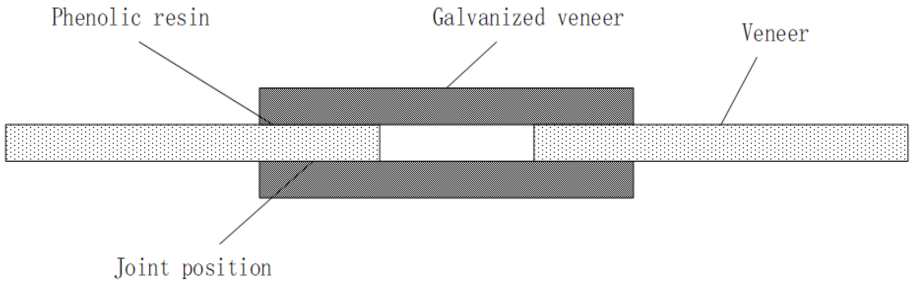
2.1 Raw materials and equipment

Experiment materials: Hebei's Chinese white poplar veneer; copper plated poplar veneer with plating time of 25min; copper plated poplar veneer with a copper loading of 5.164μm. The size is 200 (L) x 200 (T) x 1 (R) mm.

Assuming that B and C are two kinds of substrate structure of copper plated solid wood clad plate, and pure poplar veneer composite A structure is the reference group. The composite structure with 25mm joint size is shown in Figure 1. The hot-pressing parameters are shown in Table 1.



A



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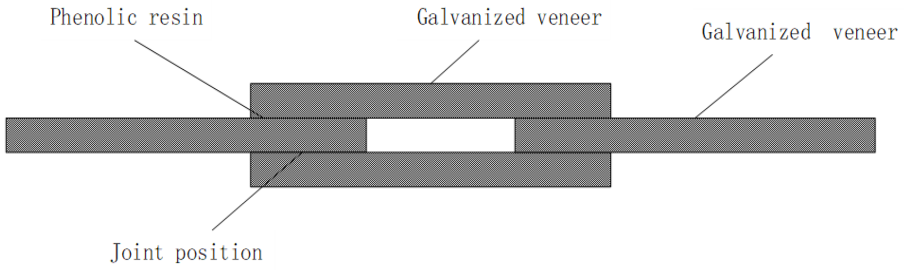

C

Figure 1: The glued structures diagram of stress relaxation

Table 1: The craft of hot press

Time (min)	Temperature (℃)	Pressure (MPa)	Resin content (g/m^2)
5	150	1.3	Phenolic resin/138g/m^2

The stress relaxation tester is a self-made stress relaxation tester from Beijing Forestry University.

2.2 Experimental procedure

After fixing the specimen with the upper and lower clamping heads, the specimens are pre-stabilized for 10 minutes, and then the stress relaxation is measured. The tensile ratio of the specimen is 1%. The measurement time of each specimen is 100min (Ou et al., 2014), and the data of stress relaxation are automatically recorded every 10s by computer.
All the specimens are put into the drying chamber before the measurement. During the measurement, all specimens are sealed with plastic film to avoid water exchange between the specimen and the external environment.
Different humidity conditions (32%Rh, 50%Rh, 75%Rh): The axial tensile stress relaxation of the composites with 25mm joint size under three structural conditions is measured at ambient temperature of 30℃ (Frank et al., 2013).
Different temperature conditions (50℃, 60℃, 70℃): The axial tensile stress relaxation of the composites with 25mm joint size under three structural conditions is measured at different temperatures (Pedreño-Rojas, et al., 2017).

3. Result and discussion

3.1 Stress relaxation under different temperature conditions

Figure 2 is the stress relaxation curve of B composite under different temperatures. Because the curve difference of the three structures is not large, the stress relaxation curves of the B structural composites are only listed here. As shown in the figure, the relative stress of the composite decreases with the increase of temperature. When the temperature is 50℃ and 60℃, the relative stress of composite material has little difference.
However, when the temperature increases to 70℃, the relative stress of the composite changes obviously, and the initial relative stress is nearly 10% less than that of low humidity. When the temperature increases to 80℃, the difference is more obvious, and the initial relative stress is nearly 20% less than that of low temperature.

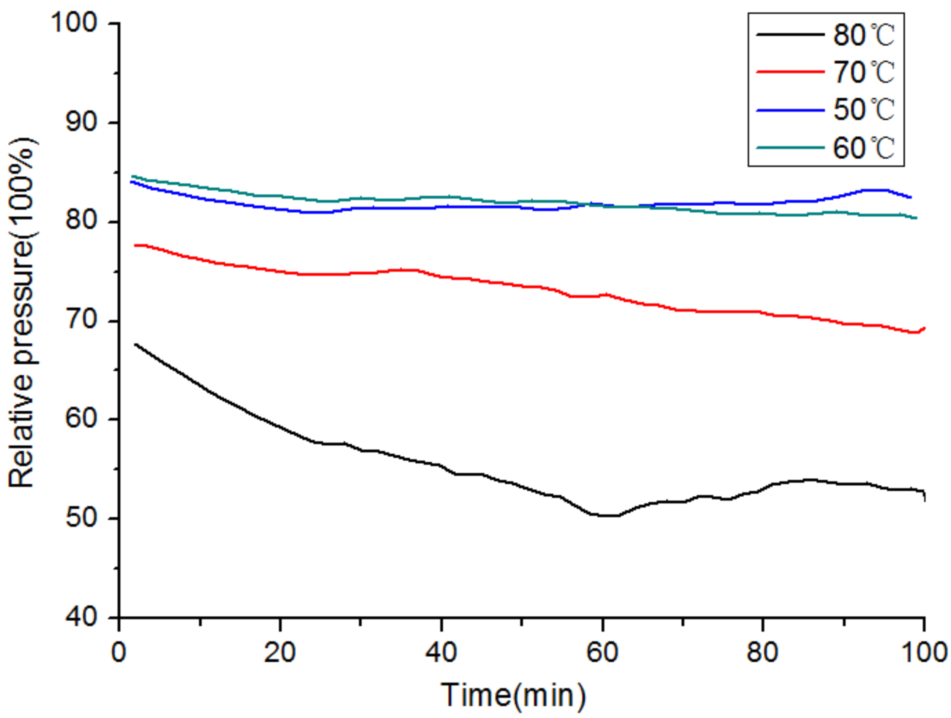

Figure 2: The different temperature of stress relaxation curve of composites

The stress relaxation rate of the composites at different temperatures is shown in Table 2. With the increase of temperature, the stress relaxation rate of poplar multilayer composite increases.

In addition, the effect of temperature on the C structure composite is more obvious. However, the composites of A structure and B structure increase with temperature rise, and stress relaxation rate only increases a little. When the temperature rising from 50℃ to 80℃, the stress relaxation rate of C structure composite increases from 0.0980 to 0.1456, showing a very severe stress relaxation phenomenon. It shows that the bonding strength of C structure composite decreases sharply with the temperature rise. Therefore, the rate of stress relaxation accelerates. This is because the B structure is a plain plated structure, and the surface is a bonding layer of wood and coating. The wood heat conduction is slower and the copper layer heat conduction is faster. Therefore, the temperature change has great effect on the B structure composites due to uneven heating (Gustaf, et al., 2016).

However, the A structure composite is a plain plated structure. On the one hand, wood is a poor conductor of heat, and the thermal conductivity of poplar veneer composite is only 0.116W/M • K (Kyziol, et al., 2016). On the other hand, the temperature has a certain effect on the stress relaxation property of wood, but the temperature does not destroy the internal structure of wood (Fang, et al., 2017). Therefore, the temperature change has little effect on the A structure composite, and the relative stress does not change obviously when the temperature rises. However, the surface of C structure composite is covered with copper layer, and the thermal conductivity of composite is up to 0.334 W/M·K (Simon, et al., 2016). The heat conduction rate is faster. Therefore, the temperature has a great effect on the C structure composite, but the temperature change has little effect on the C structure composite.

Table 2: Rates of stress relaxation of composites with different temperatures

Temperature (℃)	Stress relaxation rate (×10^{-2})		
	Structure A	Structure B	Structure C
50	2.65	3.43	9.80
60	2.80	4.63	9.43
70	2.76	4.66	11.01
80	2.92	5.31	14.56

3.2 Effect of different structures on stress relaxation at constant temperature

Table 3 is the relative stress of composites with different structures after 100min tension when the temperature range is between 50℃ and 80℃. When the temperature is 50□, the initial stress of the A structure composite is about 87%. After 100min stretching, the relative value drops to about 80%, and the difference is about 7%. The initial stress of the B structure composite is about 78%. After 100min stretching, the relative stress drops to about 70%, and the difference is about 5%. The initial stress of the C structure composite is about 73%. After 100min stretching, the relative stress drops to about 60%, and the difference is about 12%. When the temperature is 80℃, the initial stress of the A structure composite is about 82%. After 100min stretching, the relative value drops to about 60%, and the difference is about 20%. The initial stress of the B structure composite is about 63%. After 100min stretching, the relative stress drops to about 30%, and the difference is about 30%. The initial stress of the C structure composite is about 60%. After 100min stretching, the relative stress drops to about 25%, and the difference is about 35%. Therefore, the effect of temperature change on relative stress of C structure composite is the largest. The relative stress of B structure composite at low temperature has no obvious change with time, but the relative stress changes gradually with the temperature rise (Urve et al., 2017). The effect of temperature change on relative stress of A structure composite is the smallest.

Table 3: The relative stress of different structure wood curve after 100min stretch

Structure	0mim f(t)/f(0) %		100mim f(t)/f(0) %	
	50℃	80℃	50℃	80℃
A	87.35	82.73	81.12	61.26
B	78.24	63.90	70.39	39.64
C	73.82	60.86	61.42	26.33

3.3 Effect of moisture content on stress relaxation of three kinds of structural composites

The stress relaxation rate of composites with different moisture rate is shown in Table 4. Changing from dry to 70% moisture content, the relaxation rate of A structure and C structure composites is obviously affected by moisture content, while the relaxation rate of B structure composites remains almost unchanged. The stress relaxation rate of A structure composite increases with the moisture content. This shows that the plain veneer cellulose is easy to be swelled by water under the action of water, which causes the movement of molecular chain to be aggravated, and the relaxation of composite material is accelerated (Hristov, et al., 2017). The stress relaxation rate of C structure composite shows the opposite trend and decreases with the increase of water content. Because the veneer surface of C structure composite has a copper plating layer, the layer blocks the penetration of water molecules with the increase of water content (Michael, et al., 2017). Therefore, the cellulose in wood does not swell by water, and the movement between molecular chains is reduced, thus decreasing the stress relaxation rate. However, the B structure composite is a composite structure of plain veneers and copper plated veneers (Wang, et al., 2017). Due to the superposition of the two factors, the change of the stress relaxation rate is not obvious with the change of water content (Seung, et al., 2017).

Table 4: Rates of stress relaxation of composites with different moisture contents

Moisture contents	Stress relaxation rate ($\times 10^{-2}$)		
	Structure A	Structure B	Structure C
Absolutely dry	2.69	2.7	6.90
Rh32	5.47	2.38	7.39
Rh50	5.9	2.30	5.50
Rh70	8.5	2.54	4.35

4. Conclusion

In order to study the stress relaxation of multilayer composites material after wood composite, the mechanical properties of the composite are analyzed in detail, and the stress relaxation characteristics of the composite are studied. The research results are as follows: Because the surface of C structure composite is covered with copper layer, its heat conduction speed is faster, and the temperature is the most important influence.

A structure composite is the plain structure, and the wood is a poor conductor of heat, the temperature change has a little effect on it. At the same temperature, the relative stress of C structure composite is greatly affected by the temperature change. The relative stress of B structure composite at low temperature has no obvious change with time. However, the relative stress changes gradually with the temperature rise. Under the action of water, the plain veneer cellulose is easily swelled by water. Therefore, the movement of the molecular chain and the stress relaxation of the composite are aggravated.

At the same time, the stress relaxation rate of A structure composite increases with the increase of water content. The surface of C structure composite veneer is covered with copper layer, and the surface of the forged copper layer blocks the infiltration of water molecules with the increase of moisture content. Therefore, the movement of the molecular chain is not reduced after the cellulose of wood is swelled by water, while the stress relaxation rate shows a downward trend.

Reference

Aicher S., Hirsch M., Christian Z., 2016, Hybrid cross-laminated timber plates with beech wood cross-layers, Construction and Building Materials, 124, 1007-1018, DOI: 10.1016/j.conbuildmat.2016.08.051

Anshari B., Guan Z.W., Kitamori A., Jung K., Komatsu K., 2012, Structural behaviour of glued laminated timber beams pre-stressed by compressed wood, Construction and Building Materials, 29, 24-32, DOI: 10.1016/j.conbuildmat.2011.10.002

Anshari B., Guan Z.W., Wang Q.Y., 2017, Modelling of Glulam beams pre-stressed by compressed wood, Composite Structures, 165, 160-170, DOI: 10.1016/j.compstruct.2017.01.028

Fang Y.M., Lin L.J., Feng H.L., Lu Z.X., Emms G.W., 2017, Review of the use of air-coupled ultrasonic technologies for nondestructive testing of wood and wood products, Computers & Electronics in Agriculture, 137, 79-87, DOI: 10.1016/j.compag.2017.03.015

Holcapkova P., Stloukal P., Kucharczyk P., Omastova M., Kovalcol A., 2017, Anti-hydrolysis effect of aromatic carbodiimide in poly (lactic acid)/wood flour composites, Composites Part A: Applied Science and Manufacturing, 103, 283-291, DOI: 10.1016/j.compositesa.2017.10.003

Hristov P.O., Diaz F.A., Saavedra E.I., Guzmán C.F., Farooq U., 2017, Probabilistic sensitivity analysis to understand the influence of micromechanical properties of wood on its macroscopic response, Composite Structures, 181, 229-239, DOI: 10.1016/j.compstruct.2017.08.105

Kyziol L., 2016, Reinforcing wood by surface modification, Composite Structures, 158, 64-71, DOI: 10.1016/j.compstruct.2016.06.055

Larsson G., Gustafsson P.J., Serrano E., Crocetti R., 2016, Bond line models of glued wood-to-steel plate joints, Engineering Structures, 121, 160-169, DOI: 10.1016/j.engstruct.2016.04.053

Ninoslav P., Kypros P., 2015, Tensile stress-strain relaxation as a failure precursor for FRP-strengthened RC beams, Composite Structures, 125, 530-541, DOI: 10.1016/j.compstruct.2015.01.052

Oguz K.O., Pawan S.T., 2017, Stress relaxation behavior of oat flakes, Journal of Cereal Science, 77, 84-89, DOI: 10.1016/j.jcs.2017.08.005

Ou R.X., Xie Y.J., Wolcott M.P., 2014, Effect of wood cell wall composition on the rheological properties of wood particle/high density polyethylene composites, Composites Science and Technology, 93, 68-75, DOI: 10.1016/j.compscitech.2014.01.001

Pedreño-Rojas M.A., Morales-Conde M.J., Pérez-Gálvez F., Rodríguez-Liñán C., 2017, Eco-efficient acoustic and thermal conditioning using false ceiling plates made from plaster and wood waste, Journal of Cleaner Production, 166, 690-705, DOI: 10.1016/j.jclepro.2017.08.077

Ramage M.H., Burridge H., Busse-Wicher M., Fereday G., Reynolds T., Shah D.U., Wu G.L., Yu L., Fleming P., Densely-Tingley D., Allwood J., Depree P., Linden P.F., Scherman O., 2017, The wood from the trees: The use of timber in construction, 68, 333-359, DOI: 10.1016/j.rser.2016.09.107

Seung H.E., Sagar K., Sang Y.L., Chung G.L., Lahoon J., Yun S.C., 2017, Establishment and validation of tar fouling mechanism in wood pellet boiler using kinetic models, Applied Thermal Engineering, 127, 165-175, DOI: 10.1016/j.applthermaleng.2017.07.212

Stoeckel F., Konnerth J., Gindl-Altmutter W., 2013, Mechanical properties of adhesives for bonding wood—A review, International Journal of Adhesion and Adhesives, 45, 32-41, DOI: 10.1016/j.ijadhadh.2013.03.013

Urve K., Hele J., Targo K., Lembit K., 2017, Assessment of durability of environmentally friendly wood-based panels, Energy Procedia, 132, 207-212, DOI: 10.1016/j.egypro.2017.09.756

Wang Y.J., Xiong H., Wang Z.J., 2017, Effects of different durations of acid hydrolysis on the properties of starch-based wood adhesive, International Journal of Biological Macromolecules, 103, 819-828, DOI: 10.1016/j.ijbiomac.2017.05.102

Xu G.J., Wang H., Zhu H.Z., 2017, Rheological properties and anti-aging performance of asphalt binder modified with wood lignin, Construction and Building Materials, 151, 801-808, DOI: 10.1016/j.conbuildmat.2017.06.151

Zhou Y.H., Fan M.Z., Lin L.Y., 2017, Investigation of bulk and in situ mechanical properties of coupling agents treated wood plastic composites, Polymer Testing, 58, 292-299, DOI: 10.1016/j.polymertesting.2016.12.026

Zia U.D., Xiong H., Wang Z.J., Fei P., Ullah I., 2017, Effects of sucrose fatty acid esters on the stability and bonding performance of high amylose starch-based wood adhesive, International Journal of Biological Macromolecules, 104A, 846-853, DOI: 10.1016/j.ijbiomac.2017.06.090