EFFECT OF RE-WETTING TREATMENT ON THE DIMENSIONAL CHANGES OF SUGAR MAPLE WOOD

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ABSTRACT

Air-dry wood samples are often simply re-wetted by direct immersion in order to raise the moisture content above the fiber saturation point. It is assumed that this treatment has no effect on the properties of wood and is equivalent to the green condition. A preliminary study was undertaken here to evaluate the influence of water re-saturation processes on the dimensional changes in sugar maple wood. Matched samples were subjected to three different full-water saturation treatments, from a four-step mild procedure to a one-step drastic procedure. Results showed that the re-wetting process had a significant effect on swelling and shrinkage of sugar maple wood.

Keywords: Swelling, shrinkage, re-wetting, sugar maple.

INTRODUCTION

Changes in the equilibrium moisture content (EMC) and subsequent changes in dimensions are important aspects of the physical and mechanical properties of wood. The relationship between these properties has been comprehensively described by Skaar (1988). The swelling and shrinkage of wood are the result of moisture (gain or loss, respectively) interactions within and between the cell walls. Dimensional changes occur as a result of the internal deformation of the wood tissue. The magnitude of these deformations is influenced by the drying rate (shrinkage) or by the adsorption rate (swelling). For example, Stevens (1963) has reported variable shrinkage for beech wood dried at two different drying rates. Given the complexity of these wood properties, carefully controlled experimental conditions are required.

Specimens for evaluation of the physical and mechanical properties of wood must often have a moisture content above the fiber saturation point (FSP), commonly referred to as the green condition. Strength properties are normally evaluated at this condition. The green state is also the starting point for determining many other wood properties (shrinkage for example). When only air-dry material is available, specimens are simply re-wetted until the moisture content is raised above the FSP. Much research dealing with the EMC and wood properties does not take into account the type and process of re-wetting or the adsorption period, or the method of re-wetting is not described adequately, with the assumption that this process has no effect on the wood properties. However, Covington (1965) found that there was a significant reduction in mechanical strength for re-wetted samples compared to

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never-dried green samples. Hernández and Bizoň (1994) suggested that re-wetting samples by immersing the 14% initial MC wood directly in distilled water could have produced permanent creep and caused the observed relatively high tangential shrinkage in sugar maple wood.

The aim of this work was to evaluate the effect of previous moisture saturation treatment on the dimensional changes in sugar maple wood. Three types of saturation treatments, varying from mild to severe, were used. The partial swelling up to the saturated state and the partial and total shrinkage over subsequent desorption were evaluated. We examined both end-coated, and uncoated samples. We presumed that the desorption rate could influence the wood shrinkage.

MATERIAL AND METHODS

Experiments were carried out using sugar maple (*Acer saccharum* Marsh.) sapwood samples (20 mm (L) × 20 mm (R) × 60 mm (T)). Tangential and radial faces were finished using the fixed-knife pressure-bar planing method (Stewart 1989). Samples were equilibrated in a conditioning room at 20°C and 70% RH, and the initial MC of the samples was 13.3%. Initial dimensions in all principal directions were measured with a micrometer to the nearest 0.001 mm. A total of 120 samples were divided into three longitudinally matched groups of 40 each. Three re-wetting treatments were applied to the three groups at room temperature.

The first group (group I) was fully saturated in four steps as follows: 1) 9 days over a KCl saturated salt solution (about 86% RH), 2) 10 days over a K_2SO_4 saturated salt solution (about 96% RH), and 3) 22 days over distilled water (nearly 100% RH). Gains in MC of the samples at this point were 2.4%, 3.5%, and 4%, for the three steps, respectively. The samples were then immersed in distilled water to achieve full saturation. The second group (group II) was fully saturated in two steps: 1) 20 days over distilled water (nearly 100% RH). The gain in MC at that point was 9.5%. Then samples were immersed in distilled water as above to full saturation. Finally, the third group (group III) was directly immersed in distilled water without any intermediate steps.

The step of final immersion was the same for all of the treatments, and samples remained immersed in distilled water for 3 days. During this period, vacuum (up to 72 cmHg) and atmospheric pressure cycles were applied to ensure full saturation. All samples were reweighed to the nearest 0.001 g, and dimensions in all principal directions were again taken using a micrometer for partial swelling values. Each group was divided into two subgroups. Transverse faces of samples of one subgroup were sealed; these were designated "coated samples." Samples of the other subgroup were not sealed and are designated "uncoated samples." This was done in order to check the movement of free water in the longitudinal direction and to evaluate its influence on shrinkage of sugar maple during desorption.

After saturation, all samples were placed in a conditioning room at 20±1°C and 70±2% RH. Weight and dimensions were monitored until equilibrium was reached. Samples were weighed and measured at this time, after approximately 4 months for percent partial shrinkage. The samples were gradually oven-dried after equilibrating as follows: for 2 days at room temperature; then the temperature was gradually increased starting at 35°C to 102°C over 7 days. Final measurements were then made on the oven-dried wood. The partial percent swelling between the initial state (about 13.3% MC) and the fully saturated state, and the partial and total percent shrinkage between the saturated state and the final desorption were calculated based on saturated dimensions. Changes in volume were estimated from the radial and tangential dimensional changes. Significance was tested using analyses of variance with significance reported at the 1% probability level.

TABLE 1. *Initial and final moisture content of the three saturation treatments, and mean and standard error of the mean (SE) for partial swelling from initial moisture content to full saturation.*

Type of saturation	Moisture content		Radial		Tangential		Volumetric	
	Initial	Final	Mean[a]	SE	Mean	SE	Mean	SE
	%		%		%		%	
I	13.4	105.1	2.36^{A}	0.04	6.58^{A}	0.04	8.78^{A}	0.03
II	13.2	105.2	2.36^{A}	0.04	6.70^{B}	0.03	8.90^{B}	0.04
III	13.3	106.2	2.55^{B}	0.04	6.74^{B}	0.04	9.11^{C}	0.03

[a] Means with the same letter within a column are not statistically different at the 1% probability level.

RESULTS AND DISCUSSION

Effect of saturation treatment on the initial partial swelling

The moisture content and the percent swelling of the samples after the saturation treatments are presented in Table 1. The average initial moisture content of the samples was 13.3%, and the average saturated moisture content was 105%. There were no statistically significant differences between groups.

The saturation treatment had a significant effect on partial radial and tangential swelling. The mild and intermediate treatments (groups I and II) had similar partial radial swelling values. However, the radial swelling for samples that had been drastically saturated (group III) was significantly (8%) higher than that of the other groups. Tangential swelling was significantly higher for groups II and III compared to group I (1.8% and 2.4%, respectively). The mean values for groups II and III were not statistically different. This means that when the partial volumetric swelling was considered, all treatments produced significantly different patterns of swelling. The volumetric swelling was 1.4% greater for group II and 3.9% greater for group III, compared with group I.

This demonstrates that the saturation process does influence the swelling behavior of wood. The greater swelling associated with faster saturation processes may be due to higher internal stresses compared with those induced during a slower saturation regime. Under some conditions, this local internal stress could exceed the strength of the material. The stressed tissue then "dislocates" or moves from its dehydrated position. Swelling pressures may also produce micro-checks or permanent separation of tissues induced by a nonhomogeneous distribution of hygro-stresses (Rice and Peacock 1992), which lead to a greater external deformation. Poliszko et al. (1992) proposed a similar explanation for acoustic emission (AE) generated by beech wood during swelling in water.

Covington (1965) compared several mechanical properties, in the green state, of never-dried samples and re-wetted samples. As in this study, there was a significant difference between the groups; the re-wetting treatment reduced most of the mechanical properties studied.

Effect of saturation treatment on the shrinkage

The effect of the saturation process on shrinkage during the subsequent desorption was similar to results for initial swelling. Partial and total shrinkage obtained for the three saturation treatments are presented in Table 2 for uncoated samples. The results for coated samples were similar to those obtained with uncoated samples.

The saturation treatment significantly affects the partial and total shrinkage of sugar maple. The mild and intermediate treatments (groups I and II) produced similar values for shrinkage, in both the radial and tangential directions. However, the drastic saturation treatment (group III) produced a significant effect with greater partial and total shrinkage. The samples of group III shrank approximately 7.7% and 4.5% more in the radial and tangen-

TABLE 2. *Partial (from green state to 14.9% EMC) and total shrinkage for uncoated samples for three types of water saturation treatments.*

Shrinkage	Type of saturation	Partial Mean[a] %	Partial SE	Total Mean %	Total SE
Radial	I	2.07^A	0.05	5.10^A	0.07
	II	2.12^A	0.06	5.16^A	0.07
	III	2.23^B	0.06	5.26^B	0.07
Tangential	I	5.15^A	0.10	9.62^A	0.18
	II	5.15^A	0.11	9.60^A	0.18
	III	5.38^B	0.08	9.81^B	0.16
Volumetric	I	7.11^A	0.13	14.22^A	0.22
	II	7.17^A	0.13	14.27^A	0.22
	III	7.49^B	0.10	14.56^B	0.19

[a] Means with the same letter within a column are not statistically different at the 1% probability level.

tial directions, respectively, from simulated green state to 14.9% MC than those in the group I. In the case of total shrinkage, the difference between these two types of saturation was reduced to 3.1% and 2% for the radial and tangential directions, respectively. It was noticed during the experiment that the difference between these groups was at a maximum at the early stages of desorption (not shown). As desorption progressed, the difference between groups III and I was reduced to the values shown. These differences were significant at the 1% probability level.

The ratio of tangential and radial shrinkage (T/R) was slightly greater for group I than for groups II and III, due to the greater effect on shrinkage in the radial direction with the more rapid saturation treatment. Since the tangential direction has the lowest mechanical strength, the saturation treatment probably could not affect the shrinkage in this direction much more. Consequently, the radial direction showed greater sensitivity (response) to the saturation treatment. During the desorption period, it was noticed that radial shrinkage began later in group I than in samples for group III and progressed at a slower rate. Tangential shrinkage progressed at the same rate in both groups (data not shown). It is important to note that values for percent shrinkage are based on the saturated dimensions; these values were previously affected by the re-wetting process to different degrees. This means that the basis of the above calculations is not constant or independent.

The initial hygrothermal condition before the partial swelling measurements was the same as that for partial shrinkage measurements, that is 20°C and 70% RH. The partial swelling and partial shrinkage should have been similar since both are considered to be based on green dimensions. Tables 1 and 2 show that partial swelling values are greater than the partial shrinkage values. Regular weighing during the desorption conditioning period over 4 months indicated that the samples had reached the equilibrium before partial shrinkage measurements were made. However, the radial and tangential dimensions of samples were on average 0.3% and 1.5% greater than the initial dimensions of samples before saturation treatment. MC was also 1.6% higher than initially noted (14.9% compared to 13.3%). If it is assumed that samples at the start were in an adsorptive state, the difference between partial swelling and partial shrinkage could be explained by the sorption hysteresis and by the second order effect of MC on swelling (Hernández 1993). This latter concept implies that for a given EMC, tangential and radial dimensions, and hence the volume of wood, are greater after desorption than after adsorption.

These results must be considered limited, as only one type of wood with one specific orientation and dimension was used. The magnitude of the effect of previous saturation history on dimensional changes in wood may vary with wood species, size, and orientation of the samples used. However, these results do show the potential influence of internal stress during drying and re-wetting processes on the physical and mechanical properties of wood.

CONCLUSIONS

Three different re-wetting treatments were applied on air-dried longitudinally matched samples of sugar maple. It was found that rapid re-wetting leads to greater swelling and shrinkage. For a given hygrothermal condition, shrinkage started sooner in the most drastically saturated samples. The radial direction was more affected than the tangential direction, despite the fact that shrinkage in this direction started later than in the tangential direction.

These results support the earlier hypotheses that during direct soaking of air-dried wood, internal defects such as micro-checks can be activated and develop further at low tensile stresses. This study demonstrates that the method of re-wetting dry samples prior to measuring wood properties merits further attention.

Intermediate saturation processes produced results similar to those observed with the slowest treatment. However, the species, size, and orientation of the samples used for the measurement of wood properties may all be affected by the intensity of the saturation process, and a conservative approach must be adopted.

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