

# Permanent Fixation of Transversely Compressed Wood by Steaming and its Mechanism<sup>\*1</sup>

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## Introduction

Large transverse deformation of wood is fixed permanently by high temperature steaming<sup>1)</sup>. It is speculated that this fixation is related to the structural changes of the cell wall polymers such as cross-linking, crystallization and the release of stored stresses. To clarify the dominant mechanisms of the fixation, detailed information regarding the viscoelastic properties of wood under high temperature steam is necessary. In this paper, compressive stress relaxation measurements under high temperature steam for sugi wood specimens and immersion tests of the compressed specimens in boiling water and swelling liquids were performed to understand the mechanisms of the fixation.

## Materials and Methods

Sugi (*Cryptomeria japonica*) heartwood specimens of 10 mm (*L*) by 20 mm (*R*) by 20 mm (*T*) were used. Air-dried specimens were steamed at 120°C for 20 min in an autoclave, cooled slowly to room temperature in the autoclave saturated with moisture, and then kept over distilled water in a closed chamber at room temperature for at least 2 weeks. The specimens were conditioned almost to the fiber saturation point. Compressed stress relaxation measurements in transverse direction were carried out under steam. Specimens were compressed to 50% of their original thickness over a temperature range of 120 to 180°C within 60 min. The compressed specimens subjected to stress relaxation measurements were boiled in water and then immersed in pyridine, dimethyl sulfoxide (DMSO) or 4% aqueous solution of sodium hydroxide (4% NaOH) for two weeks. After that, they were immersed in ethanol for a week and then in water for a week to remove swelling liquids. At each stage, the recovery of deformation was measured.

## Results and Discussion

Figure 1 shows stress relaxation curves at indicated temperatures. Plots in the figure show the residual stresses when the measurements were stopped. Figure 2 shows the relationship between the residual stress and

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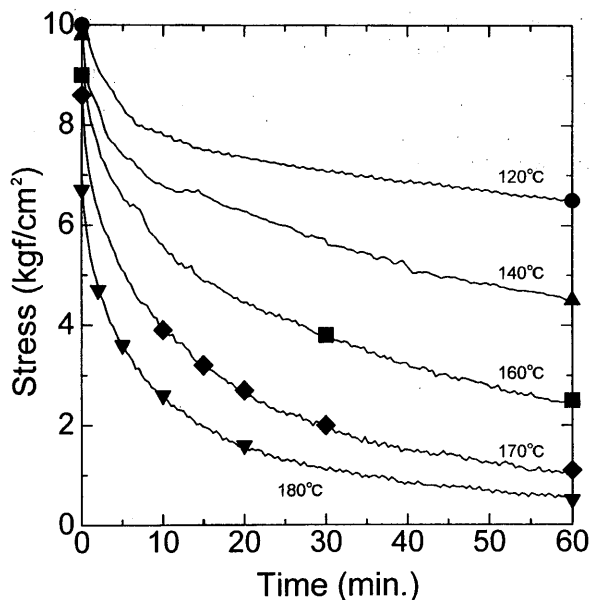


Fig. 1. Compressive stress relaxation curves for wet sugi in transverse direction. Plots show residual stresses measured at respective steaming times (0–60 min.) and indicated temperatures (120–180°C). Legend: ●: steamed at 120°C, ▲: 140°C, ■: 160°C, ◆: 170°C, ▼: 180°C.

strain recovery in boiling water ( $SR_W$ ) and the residual stress. It was worth noting that all the plots laid a single curve regardless of time and temperature. A great reduction in  $SR_W$  between 0.60 and 0.20 accompanied little fall in the residual stress. It was speculated that this result was mainly due to the structural changes of both the increase in width or in regularity of cellulose crystals<sup>1,2)</sup> and some kinds of potential cross-linking in the cell wall polymers.

To confirm these structural changes, immersion tests of compressed specimens in swelling liquids were performed. Figure 3 shows the comparison of the strain recoveries in DMSO ( $SR_D$ ) and in boiling water ( $SR_W$ ). The strain recovery due to DMSO was very large, especially within 0.60 of  $SR_W$ . Even after the specimens were immersed in ethanol ( $SR_{Ed}$ ) and then in water ( $SR_{Wd}$ ) to remove DMSO, the strain recovery was still very large. The recoveries of deformation in 4% NaOH and pyridine were also larger than in boiling water ( $SR_W$ ). These facts suggested that the fixation of deformation in the plateau

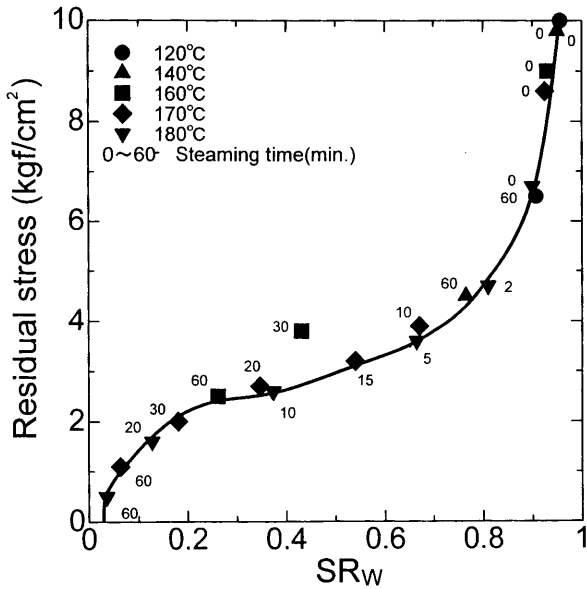


Fig. 2. Relationship between residual stress and strain recovery in boiling water ( $SR_W$ ). Steaming condition: ●: 120°C, ▲: 140°C, ■: 160°C, ◆: 170°C, ▼: 180°C. Numerals (0–60) besides plots indicate steaming time (min.).

region was not due to the formation of potential cross-linking in the cell wall polymers and the crystallization of cellulose, but due to the formation of some cohesive structure, which was not permanent. The residual fixation after the recovery by the immersion in swelling liquids may result from the release of stored stress by the degradation of the cell wall polymers.

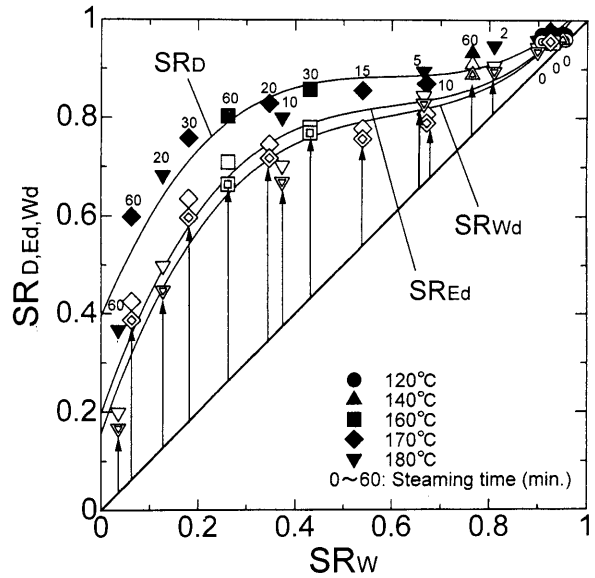


Fig. 3. Comparison of the strain recoveries in DMSO ( $SR_D$ ,  $SR_{Ed}$ ,  $SR_{Wd}$ ) and in boiling water ( $SR_W$ ). Steaming condition: Refer to Fig. 2. Legend: ●: in DMSO ( $SR_D$ ), ○: in ethanol to remove DMSO (in DMSO→ethanol) ( $SR_{Ed}$ ), ◎: in water to remove ethanol (in DMSO→ethanol→water) ( $SR_{Wd}$ ).

### References

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