Preliminary

Shrinkage Stresses Occurring in the Drying Process of Wood using Superheated Steam*[1]

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(Received May 31, 2002)

Keywords : superheated steam, drying, shrinkage stress, high temperature

Introduction

In the process of drying, wood is subjected to non-uniform shrinkage that causes various damages such as cracks or collapse. Although the occurrence and extent of such damage depends largely upon the drying methods or schedules, such problems have a close connection with the viscoelastic properties of wood under non-steady state conditions of moisture and temperature. Recently, we have observed that a drastic stress relaxation occurred above 100°C using saturated steam[1,2]. For example, below 100°C the stress decay in the relaxation experiment for radially compressed wet wood leveled off after a short time, while above 100°C it continued for a longer time compared to that below 100°C. In particular, the stress tended toward zero above 160°C. On the basis of these findings, it seems possible to dry wood without any serious damage above 100°C. In the present paper, an attempt was made to clarify characteristic features of the shrinkage stress appearing in the drying process using superheated steam above 100°C.

Experimental

Sugi (*Cryptomeria japonica* D. Don) wood specimens with an average density of 0.30 g/cm^3 saturated with water (moisture content: 120% or 220%) were used. The size of the specimens for measurement in the tangential direction was 5 cm in the tangential direction (T) by 6.5 cm in the radial direction (R) by 1 cm in the longitudinal direction (L), and for the measurement in the radial direction was 6.5 cm (T) by 5 cm (R) by 1 cm (L).

Drying of the specimens was carried out within a constant humidity-temperature chamber below 100°C, and within an autoclave using humidity- and temperature-controlled superheated steam above 100°C. The shrinkage stress during drying was measured by restraining the shrinkage of the specimens with newly developed equipment.

Results and discussion

The shrinkage stresses appearing in the wood drying process differed significantly below and above 100°C, and such differences are clearly visible in the shrinkage stress-moisture content diagram in the radial direction. Fig. 1 shows the relationship between the radial shrinkage stress and moisture content during drying at 80°C at various relative humidity levels from 0 to 80%. Though the drying rates were greatly different at different relative humidity levels, the overall impression of the curves was that they were similar in shape regardless of the relative humidity used: the stresses were almost zero in the moisture content range of 120 to 50%, while increasing rapidly with decreasing moisture content below 50%. A result similar to this was observed for the tangential shrinkage stress. Furthermore, we observed that the maximum shrinkage stress in each curve, which was reached when visible cracks appeared, were ca. 0.8 MPa

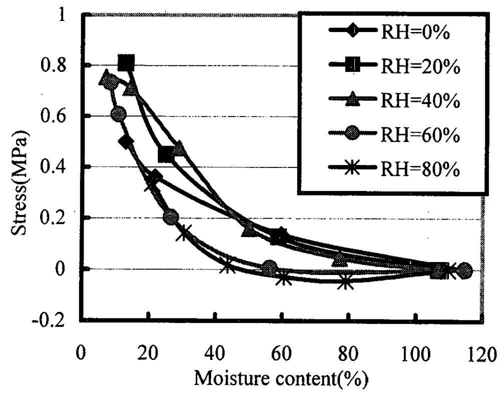

Fig. 1. The shrinkage stress - moisture content curve at 80°C.

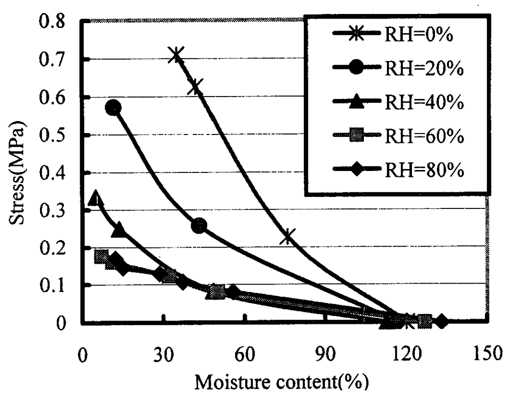

Fig. 2. The shrinkage stress - moisture content curve at 180°C.

*[1] A part of this work was presented at the 51th Annual Meeting of the Japan Wood Research Society in Tokyo, 2001.

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irrespective of the relative humidity. In sharp contrast to this is the result above 100°C. Fig. 2 shows the relationship between the radial shrinkage stress and moisture content during drying at 180°C with relative humidity levels ranging from of 0 to 80%. Unlike the result at 80°C, the stresses remained suppressed until the moisture content reached ca. 10% in the range of 40 to 80% relative humidity, although they increased with decreasing moisture content at 0 and 20% relative humidity. As a result, maximum radial shrinkage stress remained below 0.2 MPa at the level of 60% relative humidity and above. Such suppression of the shrinkage stress was also observed during drying at temperatures between 120 and 170°C. Also, similar results were obtained in the tangential direction. It should be noted, however, that above 160°C the shrinkage stress unrelated to drying appeared under the saturated steam condition, i.e., 100% relative humidity. This stress is thought to stem from shrinkage due to the structural change in the cell wall polymer which is markedly observed above 160°C. This stress could be removed by pre-steaming above 160°C. After its removal the specimen was dried at 180°C at 80% relative humidity under restraint from shrinkage and showed no cracking until the specimen nearly reached an oven dried state. Additionally, we examined the tensile properties of wood in the transverse (T and R) directions which seems closely related to cracking due to drying. In the range of 20 to 180°C at 100% relative humidity, with increasing temperature, tensile stress decreased gradually, while the breaking strain remained constant below 100°C and then increased rapidly above 100°C. We also found that the maximum shrinkage stress observed at a specified relative humidity was comparable to the stress measured in the relaxation experiment at the same time period and same relative humidity as those for the maximum shrinkage stress, although the specimen was in the moisture non-equilibrium state for the former while in the equilibrium state for the latter.

References

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