Longitudinal Shrinkage of Wood — Part II:

The Relation between Longitudinal Shrinkage and Structure

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Summary

Models put forward by PRESTON and KELSEY to represent the longitudinal shrinkage of wood have been extended to take into account shearing stresses between microfibrils and between fibres. Mathematical relationships have been developed and previous models shown to be approximations to that developed here.

The suitability of the model from various points of view and the variations in the model parameters with changing moisture content are discussed.

The effect of the cross-cutting of the fibres occurring in thin microtomed sections, the effect of delignification and the incidence of an anomalous hysteresis are also discussed.

Curves are given for the parameters of the models developed and these are discussed in the light of the results reported in Part I of this paper.

It is concluded that the non-linearity observed in the longitudinal shrinkage moisture content relationship is due to the development of restraint against slipping of the chain molecules along one another and that this restraint is caused by increasing inter-chain molecular bonding with decreasing moisture content. It is also suggested that the irreversible interfibrillar shearing strain is a cause of the hysteresis.

Introduction

The first part of this study [SADOI and CHRISTENSEN 1965] was concerned with a technique using thin sections for the experimental measurement of the longitudinal shrinkage of wood and the use of this technique for examining factors which influence this shrinkage. In the second part, a model is developed to account for the experimental results found in the first part.
It is a well-known fact that the shrinkage behaviour of wood is related, not only to its gross anatomical structure, but also to the submicroscopic structure of the cell wall. Both aspects have recently been reviewed [KELSEY 1963]. This review included a discussion of the various models which have been proposed to account for the anisotropy in the shrinkage of wood. The present paper is concerned primarily with the relationship between cell wall structure and longitudinal shrinkage, and a model is proposed to take into account the effects of possible stresses or restraints opposing shrinkage. The evidence will be found in the first part.

Basically, the shrinkage of wood is caused mainly by the shrinkage of the microfibrils of cellulose, and some other hygrophilic materials such as hemicelluloses, in the cell walls as adsorbed water is removed from them. The microfibrils shrink much more in breadth than in length on drying. The hemicelluloses, which tend to be oriented parallel to the microfibrils of cellulose [PRESTON 1964], on drying behave perhaps similarly to the microfibrils of cellulose. In the absence of restraint, the longitudinal shrinkage of wood could be considered as the sum of the components parallel to the cell axis of the longitudinal and transverse shrinkages of the microfibrils. It is also considered that stresses developing in the cell wall itself during drying may affect the longitudinal shrinkage.

In normal wood, the microfibrils of the thick middle layer of the secondary wall are arranged in a steep helix around the cell axis. In this case the shrinkage component of the cell wall in the longitudinal direction is small in comparison with that in the transverse direction, typically 0.4% of green dimension in the longitudinal and 6...12% in the transverse direction. In accordance with this fact, the effect of fibrillar angle on the longitudinal shrinkage of wood must firstly be considered as the property is discussed. Although BOUTELJE [1962] recently suggested that the arrangement of the hydroxyl groups of cellulose in concentric lamellae parallel to the axis of the cell, could be the dominant reason for the smallness of the longitudinal shrinkage, this may not be acceptable. If his idea was accepted, variation in the fibrillar angle would not affect the longitudinal shrinkage of wood. Also shrinkage would tend to occur mainly in the radial direction in the fibril wall. In fact, the tangential shrinkage of the outer part of the cell must be a function of the shrinkage in the fibre diameter which is in turn related to the radial shrinkage of the cell wall. Thus the shrinkage of the cell wall does not occur only in the radial direction of the cell but also occurs in the plane of the lamellae. In this plane the microfibrils are aligned at a certain angle to the axis of the fibre and it might therefore be expected that the fibrillar angle would be one of the factors affecting both the longitudinal and the tangential shrinkage of the cell wall.

Apart from the probable effect on longitudinal shrinkage of the fibrillar angle, and the geometry of the cell wall, other factors, particularly stresses arising as the wood starts to shrink, may play a part. These stresses may have various causes such as the occurrence of moisture gradients, and restraints arising from interfibre adhesion. Also, there may be variations in the shrinkage through the thickness of the cell wall, which could be a cause of stress. Moisture content gradients which occur during drying can be eliminated by making the specimen thin enough. The