Distortion of Norway spruce timber

Part 2. Modelling twist

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This paper deals with the development of models for twist in structural timber. Twist was measured on 240 studs of Norway spruce (Picea abies). Several material parameters were also measured, such as spiral grain angle, shrinkage in all three directions, annual ring width and density. Twist in the studs was measured at four different times at different moisture contents. The amount of twist correlated well with the moisture content and was reversible throughout several moisture changes. When the moisture content decreased, the twist increased and vice versa. About 50% of the variation in twist could be explained by a single parameter, i.e. the average growth ring curvature. All studs with severe twist were cut with its centroid within a radius of 75 mm from the pith. A statistical analysis of the data shows that growth ring curvature and spiral grain angle together explained about 70% of the variation in twist. Other parameters, such as shrinkage strains, density and ring width, did not increase predictability. When using a model developed by Stevens and Johnston (1960), about 66% of the variation in twist could be explained. The model also explained twist quantitatively well. The model included curvature of the growth ring, spiral grain angle and the tangential shrinkage strain.

Verwerfung von Fichtenschnittholz.
Teil 2. Simulation der Verdrehung


1
Introduction

1.1 Background

Twist is one of the main reasons for studs being rejected at the building site. It is widely known that the problems associated with distortion in timber (especially twist) are the main obstacle to the extended use of timber in the building industry, Sinclair (1992), Johansson et al. (1994), among others. It is therefore crucial to develop models, which would improve the understanding of how distortion varies. Modelling moisture-related distortion (twist, spring and bow) in full-size timber has been a challenge for many years. Twist of studs has been a subject for research during the last 40 years. Scientists have tried to find out which parameters influence twist in studs. The most common way to predict twist is based on statistical evaluation of measured data. A few trials have been made to predict twist analytically and numerically.

The statistical method is the methodology that has been applied by the majority of scientists. Trials have been made to correlate the measured twist of the studs with measured material parameters, such as log diameter or distance from the stud to the pith, grain angle, knots and compression wood. (Kloot and Page 1959, Brazier 1965, Balodis 1972, Mishiro and Booker 1988, Woxblom 1993, Beard et al. 1993, Cown et al. 1996).

In the mid-fifties Stevens and Johnston (1960) proposed an analytical model of how a thin cylindrical shell of wood will twist. The experimental results showed that this model produced results that correlated rather well with twist of
shells. Balodis (1972) confirmed that this method was applicable to studs.

In recent years a finite element approach has been used to model twist (see Ormarsson 1995, for example). In his model elastic properties, mechanosorptive creep coefficients, spiral grain angle and shrinkage were used as parameters to predict twist of drying studs. A parametric study to investigate the influence on twist using the finite element method showed that spiral grain angle and the distance from the stud to the pith had the largest influence on twist (Ormarsson 1995).

All these methods contribute to the understanding of twist in dried studs. However, some problems have been reported too. For example, to correlate the measured parameters to the measured values of twist may sometimes present a problem. All studs have often been dried and conditioned with external loads, to a smaller or larger extent. This external load is caused by studs stored at a higher position in the stack. As a result the external load has not been the same on all the measured studs. External load, large enough, can lower the twist of some studs substantially (Arganbright et al. 1978).

1.2 Objective
The objective of the entire project was to measure and model moisture-related distortion in full-size timber. The results are presented in a series of three papers. In the first paper in this series (Perstorpher et al. 2001), a description of the experimental set-up is presented, together with the results for important material properties which have some impact on distortion. This paper is the second in the series and deals with the formulation of a physical (analytical) explanation of moisture-related changes in twist. The third paper by the authors (Klicer et al. 2001) focuses on modelling bow and spring.

The main aim of this paper is to clarify the influence of material parameters on twist and to evaluate different modelling approaches.

2 Summary of the experimental set-up
In the earlier paper in this series (Perstorpher et al. 2001), an overall description of the research plan is presented; a short description of these issues is presented here. Trees from two large-diameter stands of Norway spruce, one fast-grown and one slow-grown were harvested in southern Sweden for this project. For an additional description of the stands, see Perstorpher et al. (1995) and Klicer et al. (1995). The upper butt logs of 40 trees were sawn into 2.9 m long battens, 70 × 290 (in mm) before kiln drying, to approximately 12% moisture content. The members were then ripped and planed to the final stud dimensions 45 × 70 × 2900 (in mm). Six studs were cut from each batten, in all 240 studs representing three stud groups with respect to radial location, outer, intermediate and core (Fig. 1).

Each piece of timber was hung vertically in a conditioning room. Twist in all the studs was measured four times during moisture changes between approximately 85% relative humidity (RH) and 30% RH. Measurements of growth characteristics are described in detail in Perstorpher et al. (2001). Spiral grain angle, shrinkage, ring width and density were measured on a 200 mm long more or less knot-free section taken at the top end of each stud. These properties were thus not measured on the actual stud. Stand characteristics like density and ring width for the two stands can be seen in Table 1.

This 200 mm section was then cut in three slices, each 13 mm thick. Spiral grain angle was measured on the tangential face on all three 200 × 70 × 13 (in mm) slices (A, B, C), see Fig. 1. The slices were then cut to a total of...