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The influence of microfibril angle on the wood stiffness parameters

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Abstract

The cellulose microfibrile angles /MFA/ in tracheids of spruce wood were observed using the polarization microscope treatment. For the wood samples tested, the modulus of elasticity in compression strain was performed. The close dependency of the MFA values on to the parameters of modulus of elasticity was established. The portion of early wood and late wood of each of the annual growth rings was determined using the stereomicroscope, even the content of the cell wall thicknesses was determined using the optical microscope. The dependency of the late wood ratio in the cross section including only the content of the cell wall in the annual growth ring of spruce on to the stiffness parameters was established.

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1. Introduction

Studies have shown that a wood cell consists of several layers. These layers form a fibre-reinforced composite with rigid cellulosic fibrils embedded in a soft matrix of hemicellulose and lignin [1]. One of these layers – the middle layer of the secondary cell wall (S2 layer) occupies more than 80 % of the total cell wall thickness [2]. Furthermore, in this layer cellulose microfibrils are not randomly oriented, but parallel-oriented, forming a microfibril angle (MFA) due to the long axis of the cell wall. These parameters show that the S2 layer plays a crucial

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role in the mechanical properties of wood cell walls. Certain correlations had been found between the MFA and the stiffness [3], [4] and also between the MFA and the shrinkage [5] of the wood. A major part of the studies has been focused on looking for correlations between the mechanical properties and the MFA on single fibres [6], [7], or on the microtome sections of wood [8]. Studies show that the MFA varies within each growth ring, being highest in the first earlywood cell and decreases to the last latewood cell [4], also that microfibril angle is larger in the earlywood cells than in the latewood cells [9]. This study therefore combines the influence of the earlywood and latewood cells on the wood stiffness parameters.

1.1. Methods of measuring the MFA

There are a lot of techniques used for measuring the microfibril angle in a wood cell wall. Polarised light microscopy is a method which relies on the optical properties of crystalline cellulose [10], [11], [12], [13]. There is the possibility to impregnate lumina with mercury, which acts as a mirror for the polarised light [10]. The reason for doing so is that the polarised light must go through the single cell wall. Otherwise the measurement would be effected by the opposite cell wall, because the microfibrils in that wall would be oriented in the opposite direction. The most common way to measure the MFA is by looking for the extinction position and then measuring the angle between the extinction position and the longitudinal cell axis [11]. Also, it is possible to cut a very thin longitudinal section of the wood cell, which provides only one cell wall for the polarised light [12]. These methods have been improved and simplified over the years. Donaldson's method [13] is based on looking through the bordered pits in the opposite single cell wall. There are also other methods for microfibril measuring such as X-ray diffraction [14], [15], infrared spectroscopy [16] and some direct methods using physical or chemical treatment [17], [18].

2. Experiment

2.1. Materials and methods

Experiments were carried out on the spruce wood (*Picea abies*), to establish the maximum variation among measured values of the MFA, samples being gathered from different wood pieces. The test samples for determining stiffness were prepared in a size of 30×30×180 mm. The modulus of elasticity (MOE) in compression was assessed in parallel to the wood grain according to ČSN EN 408, the deformation parameters were measured by two devices placed on opposite surfaces in the middle part of the test sample at a length of 120 mm.

For each of the tested wood samples, the microfibril measurements were carried out at five different places on the cross section. The MFA measurements were carried out on early and late parts of the growth rings. The MFA measurements were recorded in accordance with the method described by Donaldson [13] using the microscope Leica MD 4000 M. The values of the MFA have been determined by using the polarised light microscopy method by looking through the bordered pits in the cell wall to the other side of the cell wall.

From five different places on the cross section, the wood pieces were taken from the annual growth rings and longitudinal slices were prepared by a rotary microtome. These slices were then macerated in the solution of hydrogen peroxide and acetic acid in the ratio 1:1. The solution was then heated for 24 hours at 60 °C to remove the pit membrane and to delignify the samples. After rinsing in distilled water, a single wood cell (tracheids) was placed on the glass microscope slide for polarized microscopy observation. The angle between the fibre axis and the maximum extinction position (MEP) was recorded. This value is the average MFA of the cell wall, which is approximately the MFA of the S2, because S1 and S3 layers are relatively thin compared to the S2 layer.