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Microfibril Angle in Juvenile, Adult and Compression Wood of Spruce and Silver Fir

By

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Summary

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Using modified iodine crystal technique variation of the microfibril angle (MFA) in radial and tangential walls in early and latewood of successive growth rings from the pith towards the periphery of a tree of spruce (*Picea abies* Karst.) and silver fir (*Abies alba* Mill.) was measured. In both tree species MFA decreases from pith towards the periphery. In the age of 15 to 35 years the stabilisation of MFA between 2° and 8°, as a characterisation of adult wood, was established. Higher MFA in adult wood was observed only in compression wood. Microfibril angle in radial walls is higher compared to tangential one. In the same time high variability of microfibril angle was observed in radial walls.

Introduction

During cell wall development and growth, a typical array of laminate microfibril structure develops, which is characteristic of individual forms, types and age of cells. Laminar structure consists of more or less spiral and physically aggregated cellulose chains (microfibrils) surrounded by partly linked short-chain polyoses joined together in an amorphous matrix of disordered and ramified polymers (BOYD & FOSTER 1975).

In the primary wall, microfibrils are loosened and more or less randomly interwoven. In the outer layer of the secondary wall, one encounters several

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lamellae with alternating S and Z helix at the angle of 50° to 70° with respect to fibre axis. In the predominant middle layer of the secondary wall (S2), microfibrils mainly wind in the form of Z helix, with the pitch depending on the time of occurrence and functionality of the cell; in early wood the angle is greater (approx. 30°), in late wood it is much smaller (only up to 10°), and a somewhat greater angle occurs in compression wood (even more than 40°). In the inner layer of the secondary wall, fibrils run at a gentle slope (angle between 60° and 90°) (PANSHIN & ZEEUW 1980).

The orientation of microfibrils in the predominant S2 has a characteristic impact also on physical and mechanical properties of wood. Fibres with steeper arrangement of fibrils have superior strength, smaller longitudinal and greater tangential shrinkage. Due to microfibril angle (MFA) which falls in the direction from the pith to the periphery at all heights of the tree, physical and mechanical properties of juvenile wood behave accordingly.

Presumably, a rather close correlation also exists between MFA and the length of fibres: short fibres tend to have larger MFA and vice versa (MEGRAW 1985). Great MFA are encountered in compression wood (c.f. DONALDSON 1992). In early juvenile period, the deviation of microfibrils from vertical axis is greatest, and it is even a bit greater in early wood than in late wood (MEYLAND & PROBIN 1969, MCMILLIN 1973).

Materials and Methods

MFA was studied at the breast height of spruce (*Picea abies* Karst.) and fir (*Abies alba* Mill.). Sampling proceeded in the direction from the pith to cambium in strictly oriented main anatomical directions, with possible to measuring MFA in radial and tangential walls of tracheids. The samples were carried out for every second annual ring, separately for early and late wood.

For measuring MFA the method proposed by SENFT & BRENDTSEN 1985 was improved and adapted. On microtome, from fresh specimens a slice which comprised two parallel sets of split neighbouring tracheids was cut. Thus, slice thickness was identical with average cross diameter of tracheids, most often it was 25 μm. Slices were macerated by Jeffrey's solution, to separate the split sets of cells, and at the same time in the cell wall microcracks running parallel to fibrils were injected and coloured by iodide crystals. Angles were measured on a digital table and the data were captured and evaluated by picture analysis software (MELES). In each annual (growth) ring, 30 to 50 angles were measured.

Results and Discussion

Measurements confirmed the quite distinct decrease in MFA as a function of the age or the distance from pith in spruce and fir wood, although no significant differences between these species were identified. The values rapidly decrease (from 35°), and in 15 to 35 years they already reach their lowest and most stable values (between 2° and 8°), with characteristic of adult period (Fig. 1 and Fig. 2). Trends are characteristic for MFA of early and late wood, and also of radial and tangential walls. Greater stability and lesser variability of MFA are more typical of tracheids of late wood, which should be ascribed to the already confirmed correlation between MFA and cell wall thickness, the size of cell lumens and the length of tracheids (MEGRAW 1985).

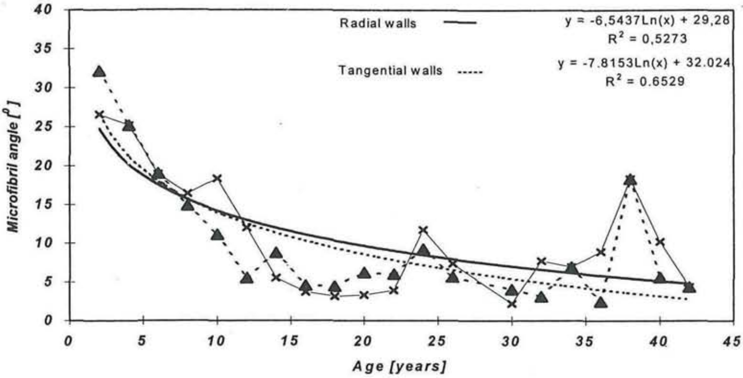

Fig. 1. Microfibril angle related to number of rings from pith in radial and tangential walls of early wood.

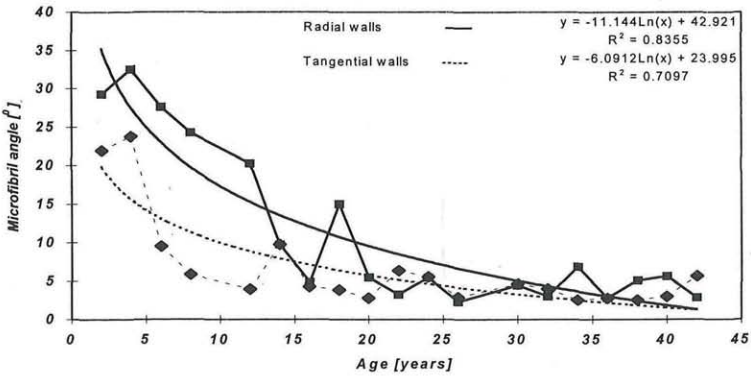

Fig. 2. Microfibril angle related to number of rings from pith in radial and tangential walls of late wood.

Great disorder, variability and lower regressive dependence of MFA in radial walls are due to great number of pits, what are extremely evident in permeable early wood. Differences in the orientation of MFA between walls also explain transverse shrinkage anisotropy in coniferous trees.

The decreasing of MFA with age also coincides with the elongation of tracheids and in general also with the shift of spiral grain from left to right-hand (TORELLI & al. 1998). The stabilisation of MFA and tracheid length, and change of spiral grain are an indication of the ending of the juvenile period and of substantial improvement of wood properties from technological point of view. The share of »undesirable« juvenile wood with inferior and unstable properties depends on the rate of growth of a tree in the early period.

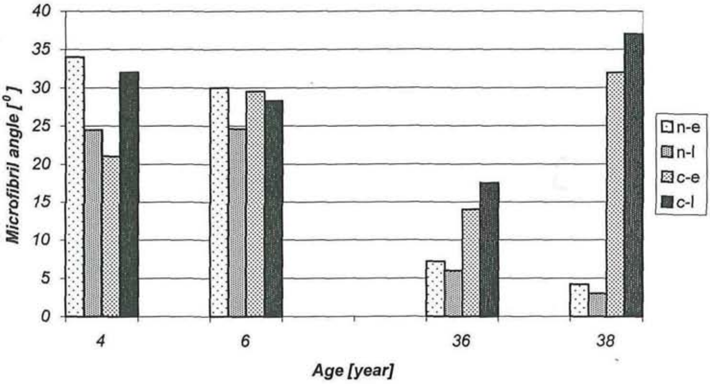

Fig. 3. Microfibril angle in normal early (n-e), normal late (n-l), compression early (c-e) and compression late (c-l) wood from juvenile and adult period.

MFA of compression wood of the juvenile period is not typically different from that of normal wood of the same period (Fig. 3). In adult wood the extraordinarily high values of MFA are characteristic of compression wood in which the values exceed also those of juvenile tracheids. The phenomenon is extremely pronounced in tangential walls of late wood, which confirms the reports that compression wood appears in the later period of the development of the growth ring.

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