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Variation in the microfibril angle in annual rings of pine wood with developed reaction tissue

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Abstract: *Variation in the microfibril angle in annual rings of pine wood with developed reaction tissue.* The paper presents results of measurements of microfibril angle in pine wood, in which reaction tissue was formed over a considerable cross-section area. Annual increments were selected from the mature wood zone, in which tracheids of compression wood were found over their entire width. Arrangement of cellulose fibrils was determined in tangential walls of tracheids in relation to the longitudinal axis of these cells. Slight fluctuations were found in the microfibril angle in tracheids of compression wood within the width of individual annual increments. It was found that the mean microfibril angle for the tested annual increments is around 19°.

INTRODUCTION

Reaction wood may be formed in every tree. This is produced under the influence of external factors, resulting in the inclination of the tree stem from the vertical direction. The area covered by this tissue depends on the duration of these factors. In the case of reaction wood formation in around a dozen up to several dozen years of growth the tree cross-section takes an elliptical shape. Reaction tissue is formed on this side of the pith, where increments are wider and in coniferous species it is called compression wood. Wood formed on the opposite side of the pith is called opposition wood. Identification of reaction wood is essential, since its properties differ completely from those of normal wood (Timell 1986, Gorišek and Torelli 1999). Although tracheid cell walls in reaction wood are thicker and the density of this wood is greater than that of normal wood, it is characterised by lower stiffness and tensile strength in the longitudinal direction (Brémaud et al. 2013). Moreover, longitudinal moisture deformations may be even several times greater than in normal wood (Harris 1977, Watanabe and Norimoto 1996, Hannrup et al. 2001, Xu et. al. 2009). The different properties of compared tissues are caused by differences in tracheid length, tracheid wall ultrastructure and chemical composition (Burget et al. 2004, Yeh et al. 2005, Nanayakkara et al. 2009). In compression wood tracheids are by approx. 30% shorter, microfibrils in relation to the longitudinal cell axes are arranged at a greater angle, while tracheid walls contain more lignin and less cellulose than in normal wood (Donaldson et al. 2004, Tarmian and Azadfallah 2009).). The presence of reaction wood in finished products causes many problems during their service life (Donaldson and Turner 2001).

In view of the above data and observations it was decided at the Department of Wood Science, the Poznan University of Life Sciences to conduct studies in order to determine cellulose microfibril angle in tangential tracheid walls in increments with the developed reaction tissue, found within a single tree.

METHODS

Analyses were conducted on wood collected from a 103-year old Scots pine (*Pinus sylvestris* L.). A dominant tree with a markedly elliptical cross-section, indicating the presence of developed reaction tissue, was selected for analyses. The experimental disc of 3 cm in thickness was collected from a height of 1.3 m from the butt end. A strip was cut from this disc along the longest radius, i.e. the area in which compression wood was found in most

annual increments. Four annual increments were selected for analyses (54, 73, 84 and 102), characterised by the most developed reaction tissue. Sample preparation for measurements consisted in the procedure to reveal microfibril arrangement in cell walls according to the method proposed by Wang et al. (2001), as modified by Fabisiak et al. (2006b). From such prepared material using a sliding microtome tangentially oriented specimens of approx. 20 μm were cut, from which microscope slides were next prepared. Microfibril angles were measured using a light microscope and a computer image analyser. Twenty angles were measured in each specimen, with no more than 2 in one tracheid.

RESULTS

Results of microfibril angle measurements in tangential tracheid walls along the increment width are presented based on an example of the 45th increment (Fig. 1). Each point

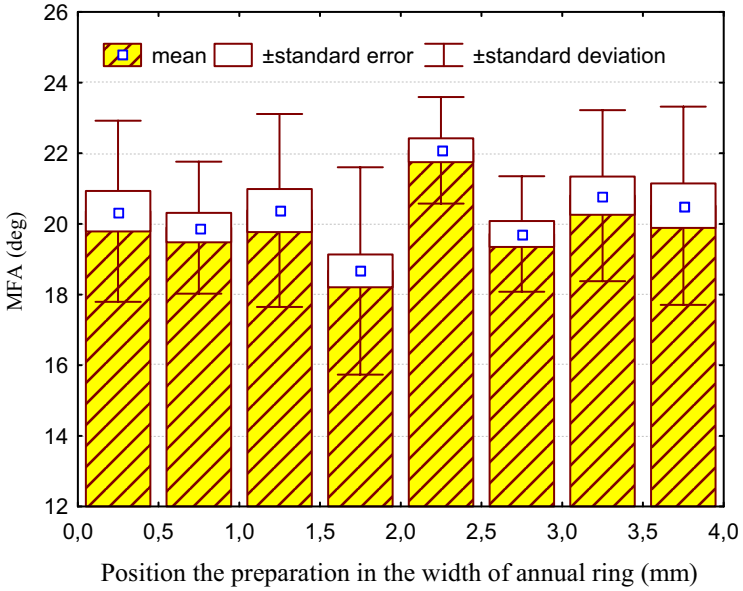

Fig. 1 The variation in MFA along the width of ring 45 in reaction wood of pine

on this graph is a mean from 20 measurements on a given slide. Moreover, the error and standard deviation are also marked on the graph. Results indicate that fluctuations of the measured parameter within an annual increment are very small, since this angle ranges from 17.5° to 22.1°. Cellulose fibril angle in relation to the longitudinal axes of cells in the width of the other experimental increments is similar. In the tested annual increments coefficients of variation range from 13.6% to 18.9% in tracheids formed in the first part of the vegetation period, while it is from 11.5% to 18.6% in tracheids formed in the summer.

When analysing values of microfibril angle for early and late wood zones in the examined annual increments it may be stated that they are similar and range from 17.7° to 20.3°. Statistical characteristics of the measured parameter are presented in Table 1. These results indicate that ultrastructure of compression wood tracheids differs significantly from those in normal wood. In annual rings coming from the mature wood zone, in which tracheids of reaction wood were not formed, the microfibril angle decreases with an increase in the distance of tracheids from the boundary of the annual increment. Fabisiak et al. (2008) determined MFA in tracheids of increments coming from the mature wood zone in dominant pine (*Pinus sylvestris* L.) trees, coming from the same geographical region from which wood

Tab. 1 MFA values in early and latewood tracheids in selected rings of reaction pine wood and basic statistical parameters (±S– standard deviation, V –coefficient of variation)

The tested growth	Zone of wood	Statistical parameters				
		Min.	Average	Max.	±S	V
		deg				%
45	early	12.6	20.0	25.1	2.7	13.6
	late	15.9	20.3	25.1	2.3	11.5
73	early	13.2	19.4	27.3	2.8	14.4
	late	13.1	17.7	23.2	2.9	16.6
84	early	12.4	19.6	25.3	2.8	14.3
	late	10.4	18.4	25.3	3.4	18.6
102	early	14.0	19.2	27.5	3.6	18.9
	late	13.3	19.3	26.1	3.1	16.2

was collected for this study. The cited authors showed that for example in the 54th annual increment in tracheids produced at the beginning of the vegetation period microfibrils ran at an angle of 14.8°, while in tracheids formed towards the end of this period it was 7.7°, i.e. microfibril inclination decreased almost two-fold. Similar results confirming a marked reduction of MFA in the function of annual increment width in the mature wood zone showing no presence of reaction tissue were reported e.g. Anagnost et al. (2005), Sedighi-Gilani et al. (2005).

The MFA value averaged for the examined annual increments is presented in Fig. 2.

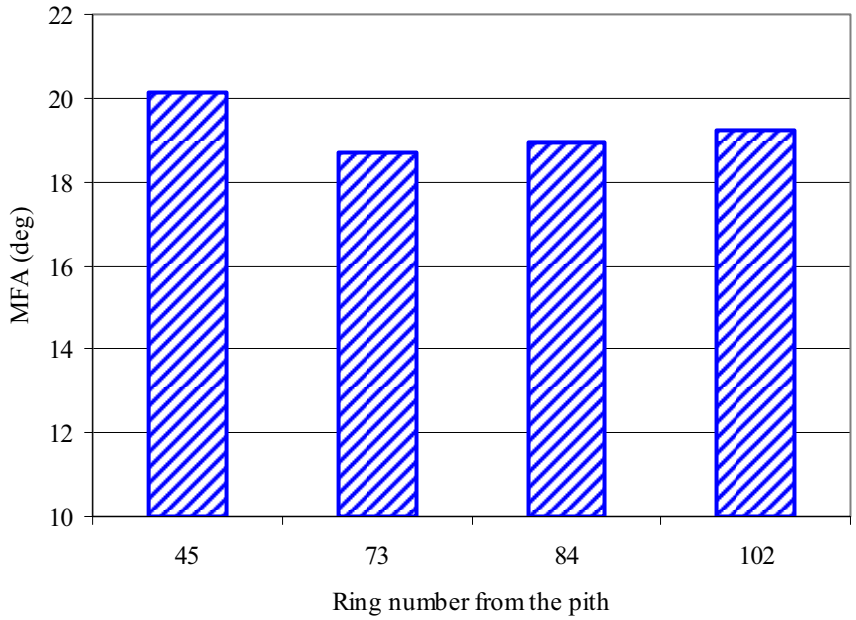

Fig. 2 Mean MFA in selected of annual rings in reaction of pine wood

Although these increments come from the mature wood zone the average value of microfibril angle was similar to the value of this measured parameter in tracheids of early wood, coming from the juvenile zone of normal pine wood (Lichtenegger et al. 1999, Yeh et al. 2005, Fabisiak et al. 2006a, Larson et al. 2009). The specific ultrastructure of compression wood tracheids in combination with the chemical composition and the other anatomical properties in this wood tissue explains different properties of reaction wood.

CONCLUSIONS

1. Microfibril angle in tangential tracheid walls along the width of the annual increment with the developed reaction tissue changes slightly and ranges from approx. 17.5^{o} to 22.1^{o}.
2. Mean values of cellulose microfibril angles in relation to the longitudinal cell axes in tracheids in the early and late wood zones of the same annual increment are very similar. Scatter of this parameter does not exceed 2^{o}.
3. Differences between the microfibril angle average for the entire annual increment in tangential walls of tracheids from the mature wood zone with the developed reaction tissue do not exceed 8%.

REFERENCES

1. ANAGNOST S.E., MARK R.E., HANNA R.B. 2005: S2 orientation of microfibrils in softwood tracheids and hardwood fibers. IAWA Journal, Vol. 26, 3: 325–338.
2. BRÉMAUD I., RUELLE J., THIBAUT A., THIBAUT B. 2013: Changes in viscoelastic vibrational properties between compression and normal wood: roles of microfibril angle and of lignin. Holzforschung vol. 67(1):75-83.
3. BURGERT, I., FRUHMANN, K., KECKES, J., FRATZL, P., TSCHEGG S.S. 2004: Structure-function relationship of four compression wood types: Micromechanical properties at the tissue and fiber level. Trees 18, 480-485.
4. DONALDSON L.A., TURNER J.C.P. 2001: The influence of compression wood and microfibril angle on the occurrence of distortion in window framers made from radiate pine (Pinus radiate). Eur. J. Wood Prod. 59, 3:163-168.
5. DONALDSON L.A., GRACE J., DOWNES G.M. 2004: Within-tree variation in anatomical properties of compression wood in radiate pine. IAWA J. 25(3): 253-271.
6. FABISIAK E., KOCJAN H., MOLIŃSKI W. 2006a: The microfibril angle variation in juvenile zone of larch wood (*Larix decidua* Mill.). Ann. Warsaw Agricult.Univ.-SGGW, For and Wood Technol. 58: 289-293.
7. GORIŠEK Ž., TORELLI N. 1999: Microfibril angle in juvenile, adult and compression wood of spruce and silver fir. Plant Physiology vol**.** 39 (3): FABISIAK E., MOLIŃSKI W., CISOWSKI M. 2006b: Changes in the MFA at the tangential walls of tracheids in larch wood (*Larix decidua* Mill.) versus the cambial age of annual rings. Proc. "Wood Structure and Properties '06" (Eds. S. Kurjatko, J. Kudela & R. Lagana) Zvolen, Arbora Publishers: 39-42.
8. FABISIAK E., MOLIŃSKI W., ZIELIŃSKI Ł. 2008: Variation in the microfibril angle in tangent walls of tracheids in individual annual rings of dominant pine trees (*Pinus sylvestris* L.). Ann. WULS - SGGW, For and Wood Technol., 65: 35-41.
9. 129-132.
10. HANNRUP**,** B.; DANELL, O.; EKBERG, L.; MOELL. M. 2001**:** Relationships between wood density and tracheid dimensions in *Pinus sylvestris* L. Wood and Fiber Science 33(2):173-181.
11. HARRIS J.M. 1977: Shrinkage and density of radiate pine compression wood in relation to its anatomy and mode of formation N.Z.J. Forestry Sci. 7:91-106.
12. LICHTENEGGER H., REITERER A., STANZL-TSCHEGG S.E., FRATZL P. 1999: Variation of cellulose microfibril angles in softwoods and hardwoods - A possible strategy of mechanical optimization. Structural Biology 128 , 257-269.
13. NANAYAKKARA, B., MANLEY-HARRIS, M., SUCKLING, I.D., DONALDSON, L.A. 2009: Quantitative chemical indicators to assess the gradation of compression wood. Holzforschung 63:431 – 439.

14. SEDIGHI-GILANI M., SUNDERLAND H., NAVI P. 2005: Microfibril angle non-uniformities within normal and compression wood tracheids Wood Sci Technol 39: 419-430.
15. TARMIAN A., AZADFALLAH M. 2009: Variation of cell features and chemical composition in spruce consisting of opposite, normal, and compression wood. BioResources 4(1): 194-204.
16. TIMELL T.E. 1986: Compression Wood in Gymnosperms. Springer-Verlag, Heidelberg, Germany.
17. WANG H.H., DRUMMOND J.G., REATH S.M, HUNT K., WATSON P.A. 2001: An improved fibril angle measurement method for wood fibres. Wood Sci. Technol. 23, 493-503.
18. WATANABE U., NORIMOTO M. 1996: Shrinkage and elasticity of normal and compression woods in conifers. Mokuzai Gakkaishi 42, 7:651-658.
19. XU P., LIU H., EVANS R., DONALDSON L.A., 2009: Longitudinal shrinkage behaviour of compression wood in radiata pine. Wood Sci Technol (2009) 43:423–439.
20. YEH T. F., GOLDFARB B., CHANG H.M., PESZLEN I., BRAUN J.L. KADLA J.F. 2005: Comparison of morphological and chemical properties between juvenile wood and compression wood of loblolly pine. Holzforschung 59:669-674.

Streszczenie: *Zmienność kąta nachylenia mikrofibryl w przyrostach rocznych drewna sosny z rozwiniętą tkanką reakcyjną.* W pracy przedstawiono wyniki pomiarów kąta nachylenia mikrofibryl w warstwie S2 stycznych ścian cewek, pochodzących ze strefy drewna dojrzałego. Do badań wybrano przyrosty roczne, w których w całej ich szerokości występowały cewki drewna naciskowego. Wykazano, że kąt ułożenia mikrofibryl celulozowych w stosunku do podłużnej osi cewek wykazuje nieznaczne fluktuacje w szerokości pojedynczych przyrostów, a jego średnia wartość kształtuje się na poziomie ok. 19^{o}.

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