Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 92, 2015: 74-79
(Ann. WULS - SGGW, For. and Wood Technol. 92, 2015)

Variation in the tracheids length and macrostructural parameters of Douglas fir wood with developed reaction tissue

MAGDALENA CZAJKA [1], EWA FABISIAK [2]
[1] Wood Technology Institute, Poznan
[2] Department of Wood Science, Poznan University of Life Sciences

Abstract: The subject of research was comparison of macrostructural parameters and the length of tracheids in Douglas fir wood with developed reaction tissue and opposite tissue. Macroscopic tests facilitated determination of the width of annual rings and the share of latewood in both tissues. Reaction wood was characterised by wider annual rings and the share of latewood which in the majority of annual rings occupied from 1/2 to 2/3 of their width. Radial variability of the tracheids length along the south radius, in whose area reaction tissue was created, was somewhat different than on the opposite side of the core. In this case, the measured parameter demonstrated large fluctuations; while in the case of opposite wood the tracheids length visibly increased in the first a dozen or so annual rings and them stabilised to some extent and all the way to the circumference. The lengths of tracheids, measured in annual rings of compression wood, were approx. 25% shorter than in the case of tracheids created in the same vegetative periods, but located on the opposite side of the core.

Keywords: reaction wood, opposite wood, Douglas fir, macrostructural parameters, tracheid length

INTRODUCTION

The issue of the structure and properties of reaction wood is investigated at many scientific centres. Presumably, this stems from the fact, that the presence of reaction wood is the reason for changes in the majority of anatomical, physical, and mechanical properties of wood. Diversification of these properties has an adverse effect on the quality of products made from such raw material, and this concerns not only solid wood products, but also paper or wood-based panels. Different values of the properties of reaction wood, compared to normal wood, are the reaction of newly created wood tissue to bending down of the trees. The size of the area, where reaction wood is present, depends on the duration of the external factors' influence on a tree, causing its bending away from vertical direction (Timell 1986). If reaction wood is created during a dozen or so or a few dozen of years of the tree growth, then the cross-section of the tree takes the elliptical shape. If the influence of these factors is a short-term one, then only several or a dozen or so reaction tracheids are created and there are no external symptoms of their presence (such as the tree bending away from rectilinearity or the elliptical trunk cross-section) (Warensjö, Rune 2004). Reaction tissue is created on the side of the core, where annual rings are wider and, in the case of coniferous species, it is called pressure wood or compression wood. The wood created on the opposite side of the core is called opposite wood (Timell 1986, Gorisek, Torelli 1999). The fact that trees lose their vertical direction, even over a very short period of time, is connected with the variability of the level of hormones in cambium within the period of reaction wood creation (Larson 1994).

In principle, in the case of coniferous species, annual rings of reaction wood are wider and characterised by a greater latewood share, compared to normal wood. This is a result of thicker cell walls in the tracheids of reaction wood. Thereby, reaction wood is characterised by higher density, which, however, does not entail better mechanical properties, but just the opposite – it is the reason why this wood tissue is characterised by inter alia lower rigidity or tenacity parallel to grain (Watanabe, Norimoto 1996). Furthermore, moisture-caused deformations of reaction wood determined along the grain may be even several times greater than in the case of normal wood (Harris 1977). Different properties of compared tissues are caused by the differences in the tracheid length and the ultrastructure of cell walls, as well as in their chemical composition (Singh, Donaldson 1999; Burgert et al. 2004; Brémaud et al. 2013). Compared to normal wood, compression wood is characterised by: tracheids which are approx. 30% shorter; a steeper gradient of microfibrils to the longitudinal axis of cells; and tracheid walls containing more lignin and less cellulose (Moliński et al. 2007; Tarmian, Azadfallah 2009). Therefore, the presence of reaction wood in ready products is the reason for many issues connected with their use (Donaldson et al. 2004). The aim of this study was to compare macrostructural parameters and the tracheid length in Douglas fir wood (*Pseudotsuga douglasie* Carr.) with developed reaction tissue and opposite tissue.

MATERIALS

Material for tests was obtained from a 65-year old Doulas fir tree (*Pseudotsuga douglasie* Carr.) located in the forest division of Łopuchówko, commune of Murowana Goślina. The tree was cut from a fresh beech-hornbeam-oak forest. The test material were two 5 cm thick discs cut at the diameter breast high. Next, test slats were cut out from the discs along the bigger diameter of the tree. The longer radius was located near to the south direction (S) determined on the trunk cross-section, and the shorter along the north direction (N).

The width of annual rings and the latewood zones was measured on a slat from the first disc. The measurements were taken using an electronic tree-ring measuring device BIOTRONIK-1A coupled with a computer, which allowed automatic registration of the measurement results with an accuracy of 0.01 mm.

The slat cut out from the second disc was used to determine the length of tracheids. In order to do so, the following annual rings were broken off: the 3rd, 6th, 9th, 12th, 15th, 20th, 25th, 30th and further every 10th ring all the way to the circumference. In these rings the earlywood zone and the latewood zone were separated. Next, the wood was subjected to maceration using a mixture of acetic acid and peroxide with a concentration of 30%, in a proportion of 1:1. The process of maceration was conducted in an incubator for 24 hours at a temperature of 60^{o}C. After rinsing the macerated tissue with distilled water, microscopic sections were prepared from this material. Thirty tracheids of earlywood and latewood from each studied annual ring were measured. These measurements were taken using a computer picture analyser MICROSCAN (Imager 512").

RESULTS

The macroscopic identifier of reaction wood is the width of annual rings and percentage of late wood. The results for these parameters, measured along the bigger diameter of the cross-section, are given in fig. 1 and fig. 2. According to expectations, annual rings with reaction tissue were found along the longer radius. The issue was identified in the 11th, 12th and 15th, further in 20-26th, 30th, 36th, 48th, 49th, 55th, 60th and 63rd annual ring. The average width of annual rings in this part of the trunk cross-section was 2.54 mm, and on the opposite side of the core it was almost 1 mm smaller. The widths of annual rings with developed reaction tissue ranged from 3 to 4 mm. In the case of opposite wood, more than 60% of annual rings was within the bracket up to 1.3 mm, and in the case of reaction wood only 12% of annual rings was within this bracket. In most annual rings with reaction wood, the width of the latewood zone ranged from $^{1}/_{2}$ to $^{2}/_{3}$ of an annual ring. In the case of opposite wood, the width of this zone of a ring reached 1 mm only in 6 annual rings, while in the other rings this zone was much narrower.

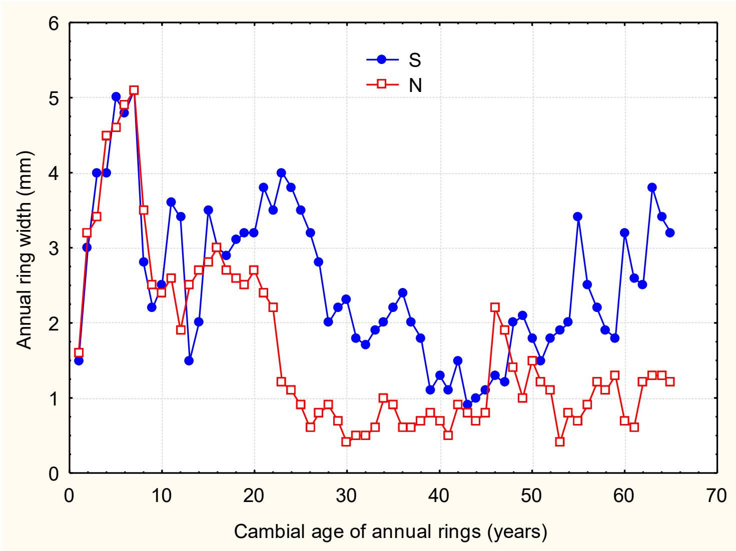

Fig. 1. Radial variability of the width of annual rings along the longer radius (south radius – S) and the shorter radius (north radius – N) in Douglas fir wood

Analysing the average share of latewood present on the opposite sides of the core, it may be observed that this share was similar and equalled 40% (along radius S) and 35% (along radius N) (fig. 2). However, detailed analysis of this parameter suggested, that within the reaction wood zone most of annual rings (60%) was characterised by a latewood share exceeding 40%, and in the case of 10% of annual rings the latewood share even exceeded 60%. In the case of opposite wood, the studied parameter was more even and for most annual rings was in range to 40% of the latewood share. Such arrangement of macrostructural parameters for annual rings located on the opposite sides of the core is characteristic of the trees, which have reaction wood on one side.

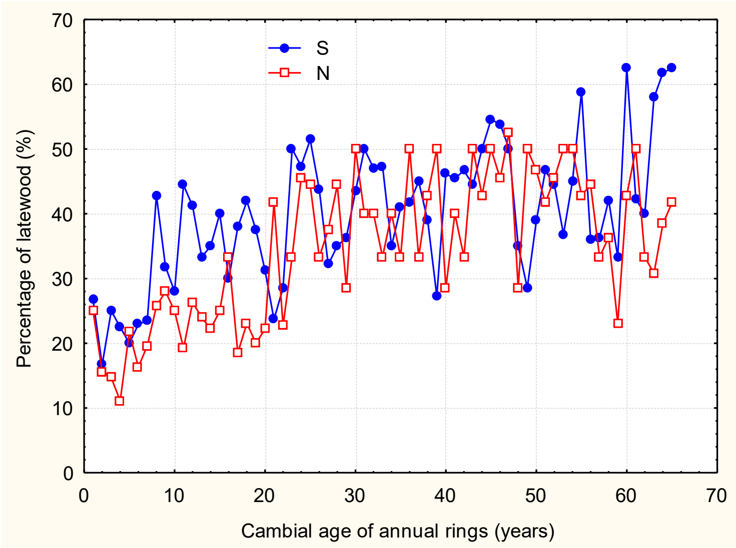

Fig.2. Radial variability of the latewood share within annual rings along the longer radius (south radius – S) and the shorter radius (north radius – N) in Douglas fir wood

The differences in the structure of reaction wood and opposite wood in coniferous species also concern anatomical properties. The length of tracheids was a property which demonstrated values different than in the case of normal wood, and thus worsened mechanical properties. Radial variability of the tracheids length along the south radius, in whose area reaction tissue was created, was somewhat different than on the opposite side of the core. In this case, the measured parameter demonstrated large fluctuations (fig. 3); while in the case of opposite wood the tracheids length visibly increased in the first a dozen or so annual rings (increase of approx. 50%). Starting from the 20th or so annual ring, this parameter stabilised to some extent and all the way to the circumference it changed insignificantly, with average length of 3.6 mm (fig. 4). The lengths of these cells were approx. 25% greater compared to the tracheids of annual rings containing reaction tracheids (in both the earlywood zone and the latewood zone), created in the same years of the tree growth, but located on opposite sides of the core. In close-to-core annual rings, where this specific wood tissue had not been created, the length of tracheids in annual rings, created at the same cambium age, but located on the opposite side of the core, were practically the same.

On the other hand, based on the analysis of diversification of the tracheid length within a single annual ring, it was observed that this diversification depends on the stage of reaction tissue development. In the case where tracheids of compression wood were created all along the annual ring width, their lengths were similar, irrespective of whether they were created in spring or summer. For instance, in the 26th annual ring, tracheids created in the first part of vegetative period were 2850 µm long, and the length of tracheids created in the second part was 2880 µm; while in the case of the 60th ring the lengths were 2700 µm and 2680 µm, respectively. However, in opposite wood the differences in the lengths of earlywood and latewood tracheids within a single annual ring were even all along the tree radius and equalled approx. 10% (fig. 4).

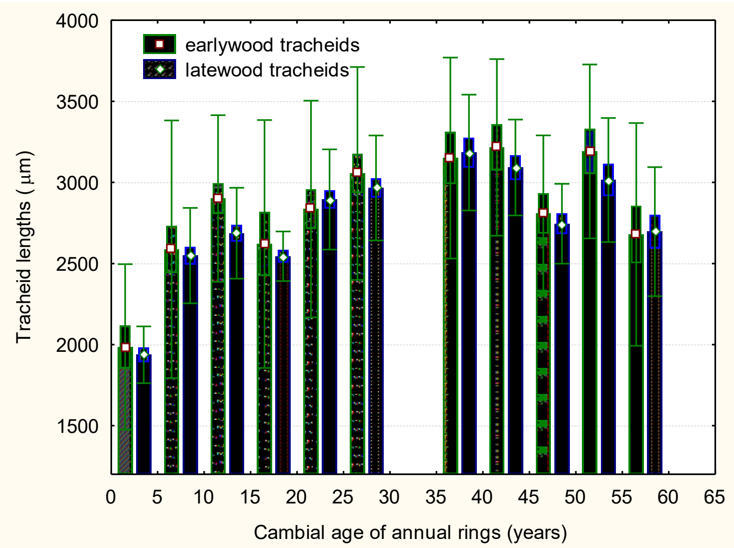

Fig. 3. Radial variability of the tracheids length of earlywood and latewood along the longer radius (south radius – S) in Douglas fir wood

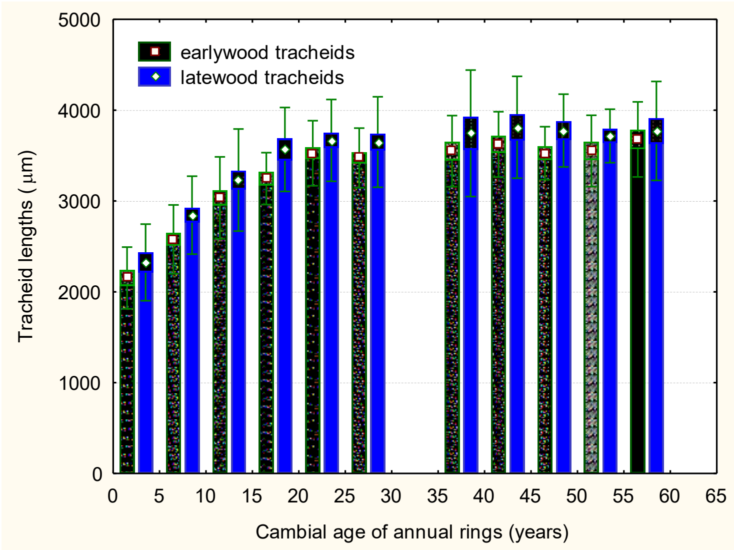

Fig. 4. Radial variability of the tracheids length of earlywood and latewood along the shorter radius (north radius – N) in Douglas fir wood

An unfavourable phenomenon, having a bearing on the huge heterogeneity of the analysed parameter within the trunk cross-section, was the fact that in annual rings neighbouring the reaction wood annual rings the length of tracheids was growing to the size of normal wood tracheids during several vegetative periods. Hence, the tracheids were shorter not only in annual rings, where compression wood was identified by macroscopic technology, but also in the neighbouring annual rings. As a result, undesirable wood properties connected with the tracheid length are also found in products made from these parts of the trunk cross-section.

CONCLUSIONS

1. The width of annual rings, where reaction wood was identified, ranged from 3 to 4 mm, and the share of latewood within an annual ring, depending on the development of reaction tissue, ranged from 40% to 65%. In the case of opposite wood, the width of the latewood zone reached 1 mm only in 6 annual rings, while in the other annual rings this zone was much narrower. Hence, average share of latewood within the tree radius length did not exceed 35%.
2. In opposite wood the length of tracheids visibly increased in the first a dozen or so annual rings (increase of approx. 50%). Starting from the 20th or so annual ring, this parameter stabilised to some extent and all the way to the circumference it changed insignificantly, with average length of 3.6 mm. Within single annual rings, tracheids of earlywood were approx. 10 % shorter than latewood tracheids.
3. Tracheids of reaction wood were approx. 25% shorter than tracheids created in the same vegetative periods, but located on the opposite side of the core. Shorter tracheids were also found in annual rings neighbouring the annual rings of reaction wood. The length of these cells was growing to the size of normal tracheids during several vegetative periods, therefore in this part of the cross-section there were large fluctuations of the analysed parameter.

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Streszczenie: *Zmienność długości cewek i parametrów makrostrukturalnych w drewnie daglezji z rozwiniętą tkanką reakcyjną.* Przedmiotem badań było określenie parametrów makrostrukturalnych i długości cewek w drewnie daglezji z rozwiniętą tkanką reakcyjną. Wielkości te porównano z cechami przyrostów wytworzonych w tych samych okresach wegetacyjnych, ale położonych po przeciwnej stronie rdzenia. Drewno reakcyjne cechowało się szerszymi przyrostami rocznymi i większym udziałem drewna późnego (dochodzącym w niektórych przyrostach do $^{2}/_{3}$ ich szerokości) w porównaniu do drewna opozycyjnego. Promieniowa zmienność długości cewek wzdłuż promienia, w obszarze którego wytworzyła się tkanka reakcyjna, kształtowała się inaczej niż w drewnie opozycyjnym. Cewki pochodzące z przyrostów rocznych w których wytworzyło się drewno reakcyjne były o około 25% krótsze od cewek powstałych w tych samych latach wzrostu drzewa, ale położonych po przeciwnej stronie rdzenia.

Corresponding authors:

1) Wood Technology Institute
Winiarska 1, 60-654 Poznań
e-mail: m_czajka@itd.poznan.pl
2) Department of Wood Science
Poznań University of Life Sciences
60-627 Poznań, Poland
e-mail: efabis@up.poznan.pl