Moisture evaporation rates from sapwood and heartwood samples of Douglas fir (Pseudotsuga menziesii Franco) green wood

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Samples made of Douglas fir (Pseudotsuga menziesii Franco) green wood were dried in order to establish moisture evaporation rates from their end faces. Experiments were carried out separately for heartwood and sapwood because of high differences in their initial moisture contents. Drying tests were conducted at the constant set value of equilibrium moisture content of 12% and two different temperatures of 30 °C and 60 °C. The moisture evaporation rate was expressed by the flux density of evaporated water. The maximum values and the run of the rate in the whole range of moisture contents were compared for heartwood and sapwood as well as for both drying temperatures. The constant drying rate period was not identified even for green sapwood. The obtained data can be used to establish the initial and boundary conditions for wood drying modelling.

1 Introduction
It is well known that wood of freshly cut trees, especially of conifers, is characterised by remarkably different moisture contents of heartwood and sapwood parts of the transverse cross-section of a trunk. In many cases moisture content of sapwood is several times higher than the one of heartwood (e.g. Peck 1953; Nikolov and Enchev 1967). The knowledge of moisture content differentiation of freshly cut trees is important for many technologies in the wood processing industry, due to its direct influence on wood weight, net caloric value and especially on drying processes of wood. The moisture content gradient transverse in the cross-section of wood blocks is the essential factor inducing desorption stresses responsible for checks in wood which may cause wood degradation during drying (Pang 1996). Changes of moisture content distribution in wood being dried are also influenced by its initial moisture content (Samad and Wallin 1966; Simpson 1992). It mainly refers to round softwood or to structural square-sawn timber which simultaneously contain sapwood and heartwood in the same cross-section. Presently in practice of drying, green timber is more often sorted into groups, according to the initial moisture content before drying, which brings measurable economical profits (Taylor and So 1990; Warren and Johnson 1997).

However, moisture content distribution in the transverse cross-section of freshly cut timber is relatively well known, moisture evaporation rates from the end faces of sapwood and heartwood, as it is supposed, are not studied sufficiently (Guzenda et al. 1998). The lack of empirical data in this area makes it difficult to improve models predicting changes of moisture content distribution during wood drying (Chen et al. 1996; Pang and Wiberg 1998).

In order to reduce, at least partially, the lack of data in the described area, it was decided to conduct experiments aiming at obtaining values of moisture evaporation rates from the end faces of freshly cut Douglas fir wood separately for heartwood and sapwood parts of a trunk.

2 Material and methods

2.1 Samples preparation
Experiments were carried out for green Douglas fir (Pseudotsuga menziesii Franco) wood obtained from a
45-year old tree (breast height diameter with bark 31 cm, height 22.3 m), freshly cut in February 1998. The test tree was selected from a forest stand located in West Poland in the Murowana Goslinia Experimental Forest Station of Agricultural University of Poznan. For experiments 25 mm thick discs were obtained coming from the height of 1.3 m and 5.5 m (1/4 of the tree height) from the root collar.

Immediately after cutting the discs were protected against drying by tight warping with several layers of aluminium and polyurethane foil and placed in a refrigerator. The discs coming from 1/4 of the tree height were used to study moisture evaporation rates. The diameter of experimental discs without bark was 21 cm. The pith was located somewhat eccentrically (R_{max}/R_{min} = 1.3). The mean width of sapwood was ca. 4 cm. The discs from the height of 1.3 m were used to determine the wood macrostructure and diametral distribution of moisture content in the green state. Figure 1 presents the scheme of discs cut into 25 mm wide segments and their further division into samples for moisture evaporation rate determination. Samples of heartwood were cut from mature wood only (the near pith zone of juvenile wood was omitted).

The thickness of samples was compatible with the longitudinal direction and its value was selected taking into account the length of tracheids. Assuming that the mean length of tracheids of Douglas fir mature wood is equal to ca. 4 mm (Wagenführer 1989; Zimmer et al. 1998), the thickness of samples perpendicular to the grain equal 5 mm was selected. Therefore, during double-sided drying of the samples, the way length of moisture transport to the surface was limited to 2.5 mm only, that is to the value lower than the length of tracheids. The proposed assumption should reduce the resistance of moisture transport to the surface from inner layers of wood (the thin layer). Therefore, evaporation rates should obtain their maximum values typical for the thin layer of the transverse cross-section. The values of the rate should depend on drying air parameters, actual moisture content and structure of the surface layer.

The initial moisture content of green wood samples depends significantly on the position in the cross-section (heartwood or sapwood). Figure 2 presents an example of the diametral profile of moisture content in the cross-section of the experimental Douglas fir trunk. The mean moisture content of green heartwood was 32% while the one of sapwood was 102%. The mean density (dry weight per green volume basis) of heartwood was 480 kg/m³ while that of sapwood was 520 kg/m³. Width of growth rings for heartwood was 2.65 (1.38–3.15) mm, while for sapwood it was 2.64 (1.46–3.81) mm.

2.2 Drying experiments

Measurements of flux densities of evaporated moisture were performed on an experimental stand (Fig. 3) which enabled to record continuously the mass of dried samples as well as parameters of air (Guzenda et al. 1998).

Drying experiments were characterised by the constant set value of equilibrium moisture content of 12%. Experiments were performed in two drying temperatures, namely 30 °C and 60 °C. The following values of air relative humidity corresponded to the above described

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**Fig. 1.** Scheme of samples’ cutting of heartwood and sapwood from the cross-section

**Bild 1.** Schema des Probeneinschnitts von Kern- und Splintholzauf dem Stammquerschnitt

**Fig. 2.** Diametral profile of green moisture content in the cross-section of the Douglas fir trunk at height of 1.3 m. HW: Heartwood; SW: Sapwood

**Bild 2.** Feuchtigkeitsprofil über den Querschnitt eines Douglastienstammes in 1,3 m Höhe. HW: Kernholz; SW: Splintholz