Brinell Hardness of Silver Birch Wood

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An analysis was undertaken of the Brinell hardness of silver birch wood and its dependence on stand location, tree age, tree thickness and forest habitat type, and the interactions between these factors. Wood was obtained from 12 forest districts throughout Poland, from trees aged approximately 30, 50, and 70 years. A total of 51 study plots was established, from which 306 trees were taken. Hardness was measured on three surfaces (transverse, radial, and tangential sections) for 4777 samples, giving a total of 14,331 measurements. It was shown that the hardness of silver birch wood in Poland is significantly influenced by location, tree age, tree thickness and habitat type, and by interactions between those factors. Habitat type was not shown to affect radial hardness, except in the case of Giżycko forest district. For the whole of the analysed material, the mean hardness on a transverse section was calculated as 66.26 MPa, corresponding to a very hard wood on Mörath's scale, whereas the values for the lengthwise sections (radial 44.06 MPa, tangential 44.02 MPa) correspond to a soft wood.

Keywords: brinell hardness ; tree age ; forest habitat type ; tree thickness ; geographical location ; wood technical quality

1. Introduction

The hardness of wood is an important strength parameter. It is particularly significant for machining processes, and affects the durability of elements subject to abrasive action [1][2]. The first definition of hardness was given by Heinrich R. Hertz [3], who defined it as the force pressing two spheres that would cause their plastic deformation. Later, hardness was defined as the resistance encountered by a foreign body attempting to penetrate the anatomical structure of the wood [4]; as the resistance provided by the wood material on working with tools [5]; as the resistance provided by a material to bodies being pressed into its surface, expressed in $kG{\cdot}cm^{-2}$ or $kG{\cdot}mm^{-2}$ [6]; or as the resistance of a material to permanent deformations under the action of concentrated forces acting on a small surface area of the material [7]. At present, hardness is measured as the resistance provided by a body when an indenter is pressed into it, with regard to plastic deformations [1]. The hardness of a material is not as unambiguous as, for example, its strength or modulus of elasticity. Multiple tests and scales have been developed for the measurement of hardness. Indenters of different shapes are used depending on the hardness of the tested material. The round shape used in the methods of Brinell, Janka, Krippel, and Meyer is significantly better for the testing of wood than, for instance, the conical shape used in Rockwell's method [8]. The measurement of hardness by Brinell's method is a standard test for determining a floor's resistance to indentation [9], and Doyle and Walker [10] report it to be the most frequently applied method in materials science. They note, however, that the precise measurement of the size of a permanent indentation is problematic, particularly when a large ball is used. Given the non-uniform structure of wood, a distinction must be made between hardness on longitudinal and transverse sections. Hardness also depends on the dryness of the wood [1][6][8]. A drop in water content causes an increase in hardness, and when the moisture content is less than 8% the wood becomes so brittle that it is not possible to measure its hardness. For this reason, wood hardness is determined at a moisture content above 8% [11]. Studies have also been conducted of how the hardness of wood is affected by various modifications, including compaction of the wood [12][13], thermal treatment [14][15][16] and chemical treatment [17]. The impact of the felling season, drying method, and distance from the core has also been investigated [18] However, there is little available information on the dependence of hardness on geographical location, forest habitat type, tree age or tree thickness. Klisz et al. [19] report that age has an impact on the hardness of birch wood.

Birch is among the most economically important tree species in Europe [20]. In Poland it is the most important broad-leaved species. It currently covers 7.3% of the total forest area, and accounts for a greater share in privately owned forests. The largest birch stands are located in Warmińsko-mazurskie province, and the smallest in Małopolskie [21]. Birch wood is easily worked, and its physical and mechanical properties make it suitable for use in the cellulose and paper industry, in the production of plywood and veneer, and in furniture and flooring [20]. A pilot study was carried out in forests of fresh broad-leaved type (FBF) in northeast Poland concerning selected structural, physical, and mechanical properties of silver birch wood and their dependence on geographical location, tree age (approximately 50 and 70 years), and tree thickness. This provided a broad foundation for conducting the current research on silver birch wood according to the same methodology. The result of this is a database describing, in the most extensive manner to date, the variation in certain properties of birch wood in Poland, these properties being important determiners of the technical quality of the wood. Of many completed studies, results have recently been published concerning the elementary structure, fuel properties, chemical composition and density of silver birch wood as functions of selected factors; these show that stand location, habitat type, tree age, and tree thickness have a significant impact on most of the studied parameters [22][23][24][25]. No previous studies have been carried out to determine the effect of geographical location, tree age, tree thickness and habitat type on hardness values of silver birch wood from the whole of Poland. The following analyses complement the comprehensive studies of the technical properties of silver birch wood growing in Poland, and may guide the future commercial use of this raw material.

2. Study Site

All tests of the properties of silver birch wood were carried out on material obtained from study plots established in the main commercial growing regions of this species in Poland.

Studies were carried out in stands belonging to the Polish State Forestry Board (PGL LP). Birch trees aged approximately 30, 50 and 70 years were selected in stands of the fresh broad-leaved (FBF) and fresh mixed broad-leaved (FMBF) forest habitat types. These are the two habitat types in Poland where birch stands are most prevalent in terms of area and wood volume [23]. A description of these habitats can be found in previous publications [22][24]. The studies were carried out in 12 forest districts distributed across the country, using trees in three age categories (approximately 30, 50 and 70 years), in the habitat type FBF, and in some districts also FMBF (**Figure 1**). In total, field studies were conducted in 51 study plots.

Figure 1. Geographical distribution of the forest districts where the test plots were located [26].

3. Conclusions

1. There was found to be a significant effect from location, tree age, tree thickness and habitat type, and from the interactions between these factors, on the Brinell hardness of Polish silver birch wood measured both on transverse sections and on longitudinal radial sections. Habitat type was not shown to influence the radial hardness except in the case of Gizycko forest district.

2. For the whole of the analysed material, the mean hardness on a transverse section was 66.26 MPa, which indicates that the birch wood is very hard on Mörath's scale, whereas the values on the longitudinal sections (radial 44.06 MPa, tangential 44.02 MPa) indicate it to be a soft wood.

3. For the whole of the analysed material, the ratio of the wood hardness on a transverse section to the mean hardness on the longitudinal sections was 1.5.

4. The highest mean values of hardness on a transverse section were recorded for wood from the forest districts of Gizycko (FMBF) (70.51 MPa) and Sokołów (FBF) (70.14 MPa), and the highest mean values on a radial section were recorded for Sokołów (FBF) (49.71 MPa) and Gizycko (FBF) (48.40 MPa).
5. For the whole of the analysed material, on both transverse and radial sections, the mean values of wood hardness increased with tree age.
6. In birch stands in all parts of Poland, trees with very high and low wood hardness
grow alongside each other, irrespective of geographical location, tree age and thickness, and habitat type.Taking account of tree age, the lowest mean hardness value (59.38 MPa) was obtained for 30 year old trees in Rudziniec forest district (FBF), and the highest (72.05 MPa) for 50 year old birches in Giżycko (FMBF), a difference of 21.34%. Depending on location, the lowest mean hardness for silver birch wood (63.11 MPa) was obtained in Bobolice forest district (FBF), and the highest (70.51 MPa) in Giżycko (FMBF), a difference of 11.72%.

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