WOOD RESEARCH
55 (1): 2010
59-66

INTERCONNECTIONS AMONG THE RATE OF GROWTH, POROSITY AND WOOD WATER ABSORPTION

Inna Varivodina, Nikolai Kosichenko, Viacheslav Varivodin
Voronezh State Academy of Forestry,
Faculty of Wood Technology Engineering, Russia

Ján Sedliačik
Technical University, Faculty of Wood Sciences and Technology,
Zvolen, Slovak Republic

ABSTRACT

The definitions of wood porosity and maximal moisture content are long and energy-expensive processes. The idea is to describe the relation among wood porosity, water absorption and rate of growth and it seems to be very interesting.

Three types of wood kinds (soft, ring-porous woods and diffuse-porous woods) were investigated for determination of the rate of growth, porosity and water absorption. The functional dependence between maximal moisture content of wood and number of growth rings in one centimeter is identical to the one between wood porosity and number of growth rings in one centimeter. This dependence for pine (*Pinus sylvestris*) and birch (*Betula pendula*) is inversely proportional and for oak (*Quercus robur*) is directly proportional.

KEY WORDS: porosity, rate of growth, density, water absorption, permeability

INTRODUCTION

The wood porosity is one of the main physical properties in wood science. This property has special importance in processes of cellulose manufacturing, wood impregnation, gluing of wood, wood drying and other technologies, Haruk (1976).

Wood porosity was deeply investigated by Perelygin (1954), Vihrov (1954), Ugolev (1986) and Požgaj et al. (1997). Relations between wood and water were described by Skaar (1987). Historically, we can distinguish three methods in the development of wood porosity definitions. First, the best known and the oldest one was worked out by Vihrov (1954), who defines the area of separate cell by the photo of the growth ring. Also, Yacenko-Hmelevsky (1954) put forward his idea of linear method which became widely used in wood science. In the beginning of the 70's, Höster and Spring (1971) worked out their new point method for the vegetable cell structure definition.

The natural oven-dry wood is a capillary-porous material consisting of cell walls volume ($V_{w.s.}$) and the pores between them (V_p):

$$V_0 = V_{w.s.} + V_p \qquad (1)$$

Then porosity can be expressed by formula:

$$P = \frac{V_0 - V_{w.s.}}{V_0}.100 \qquad (2)$$

Usually, wood pores are presented by big cavities of anatomical elements and intercellular space, their diameter exceeds 10^{-5} m. Free water is contained in the pores. The water absorption and water permeability depend on the quantity of free water, Kolosovskaja et al. (1989). The wood being immersed into water reaches the maximal moisture content W_{max}. Therefore maximal moisture content is a sum of maximal quantity of bound water (limit of cell wall saturation $W_{l.s.}$) and maximal quantity of free water ($W_{f.w.}$):

$$W_{max} = W_{l.s.} + W_{f.w.} \qquad (3)$$

As the exact value of bound water density is unknown, therefore the definition of cell wall saturation limit ($W_{l.s.}$) is not easy. From two formulas used for maximal moisture content definition, we tend to choose the one, which does not take into account the above mentioned limit:

$$W_{max} = \frac{(\rho_{w.s.} - \rho_b).\rho_{w.}}{\rho_{w.s.}.\rho_b}.100 \qquad (4)$$

where: $\rho_{w.s}$ – density of wood substance, (g.cm^{-3}),
ρ_b – basic density of wood, this is the ratio of absolutely dry wood mass to the maximal volume, (g.cm^{-3}),
$\rho_{w.}$ – density of water, (g.cm^{-3}).

Wood porosity is defined as the relative volume of emptiness in oven-dry wood and it is calculated according to the formula:

$$P = [1 - \frac{\rho_0}{\rho_{w.s.}}].100 \qquad (5)$$

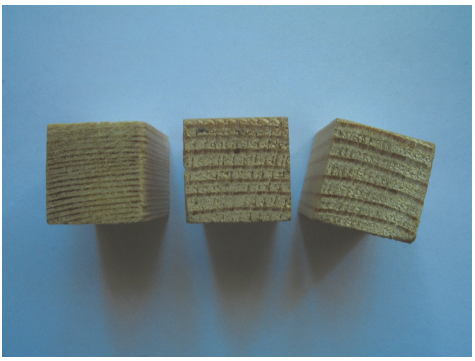
where: P – porosity of wood, (%),
ρ_0 – density of absolutely dry wood, (g.cm^{-3}),
$\rho_{w.s}$ – density of wood substance, (g.cm^{-3}),
$\rho_{w.s}$ = 1,53 (g.cm^{-3}) according to Ugolev (1986).

It is known that wood porosity varies between 40 and 80 %. At detailed study, this formula proves that calculation of porosity is in fact reduced to the definition of absolutely dry wood density, because the wood substance density is a constant value. However, this is a long and energy-expensive process, as samples at determination of absolutely dry wood density must be kept in drying chamber for 10-12 hours under the temperature of 103 ± 2 °C.

Therefore, we tried to find less expensive way of solving this problem. In our experiments, we define wood porosity relatively to the notion of growth rate (in wood science this is the number of growth rings in one centimeter). We consider this idea to be very perspective, Kosichenko et al. (2007).

MATERIAL AND METHODS

The experiment was carried out in the following way. Firstly, twelve samples of different wood species were taken from the Scientific-educational forestry subdivision of the Voronezh State Academy of Forestry Engineering. The common pine was chosen as an example of soft wood, the European silver birch – diffuse-porous hardwood and the common oak – ring-porous hardwood. The samples presented all diapason of rate of growth from narrow annual rings to coarse-ringed. The samples with standard basic dimensions of 20 x 20 x 30 mm according to the international standards ISO 4470-81, Russian state standard 16483.1-84 and EN 844-4: 1997 are presented in the Fig. 1. All samples were cut out from the heart wood part, in one-half distance of the wood trunk radius.



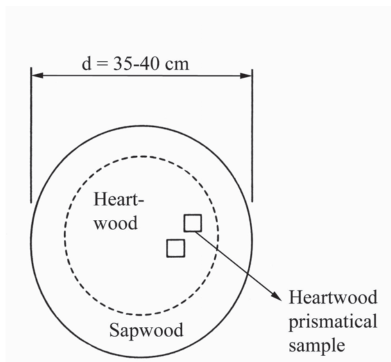


Fig. 1: Sample of pine wood (Pinus sylvestris) from narrow annual rings to coarse-ringed

Then density of all samples was defined in oven dry state (ρ_0) and the porosity (P) was calculated according to the formula shown above. Then the number of growth rings per one centimeter ($n_{g.r.}$/1 cm) was defined.

Finally, the experiments for maximal moisture content (W_{max}) definition were carried out.

RESULTS AND DISCUSSION

The results of this work are presented in the Fig. 2-4. These graphs are based on received data and show the dependence between wood porosity and number of growth rings in one centimeter.

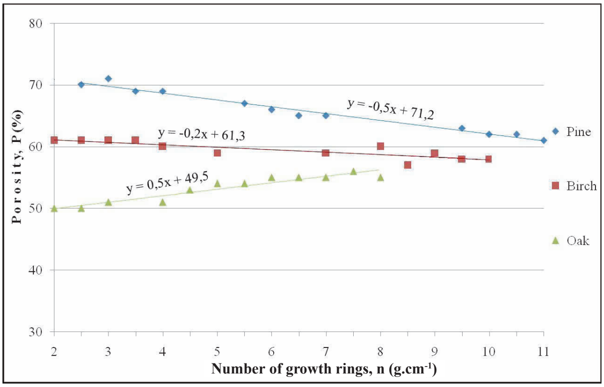


Fig.2 Dependence between wood porosity and number of growth rings in one centimeter

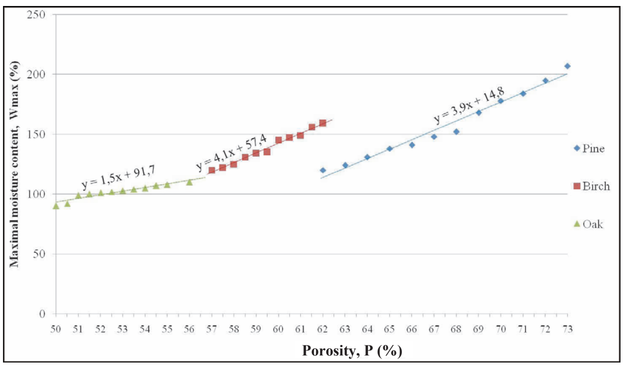


Fig. 3 Dependence between maximal moisture content and wood porosity

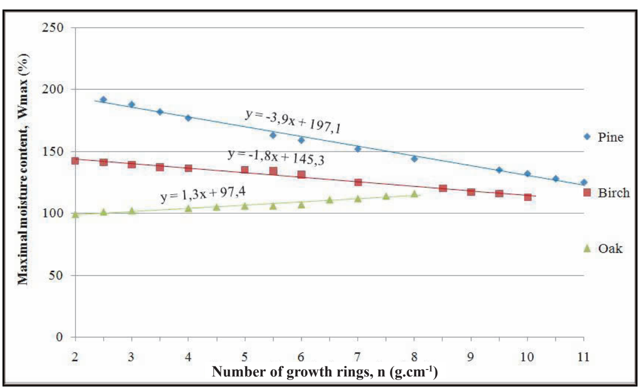


Fig. 4: Dependence between maximal moisture content and number of growth rings in one centimeter

This dependence has a straight-linear and proportion character. The equation of regressive dependence has a form of:

for pine: $P = 71{,}2 - 0{,}5 \cdot n$; $R^2 = 0{,}982$
for birch: $P = 61{,}3 - 0{,}2 \cdot n$; $R^2 = 0{,}828$
for oak: $P = 49{,}5 + 0{,}5 \cdot n$; $R^2 = 0{,}897$

This dependence is indirectly proportional for pine and birch and directly proportional for oak.

How can we interpret these results? It should seem that results are strongly affected by plants anatomy, genetics and ecology. It is well known that the change of growth ring occurs during the period of tree growth. The change of growth ring happens at the expense of early wood reduction of soft wood. The late wood does not change during the tree growth and remains under strong genetic control.

On the other hand, the contrary occurence of wood forming is observed at ring-porous hardwood. The change of growth ring happens at the expense of late wood reduction. The early wood does not change during the tree growth and remains under strict genetic control, Yacenko-Hmelevsky (1954) and Kosichenko (2000).

Therefore we assume that if there is a close functional correlation between the number of growth rings in 1 cm and porosity then the similar relation may exist for the maximal moisture content of wood. The Fig. 3 and 4 show the results of these researches.

The Fig. 3 demonstrates the relationships between maximal moisture content of wood and porosity of different wood species. This connection, as expected, has a straight-linear and proportion character for all of the three wood species with the only difference concerning the variation limits of wood porosity and maximal moisture content. The pine has them wide, while for broad-leaved species they are narrow.

The equation of regressive dependence has a form of:

for pine: $W_{max} = 14{,}8 + 3{,}9 \cdot P$; $R^2 = 0{,}976$
for birch: $W_{max} = 57{,}4 + 4{,}1 \cdot P$; $R^2 = 0{,}984$
for oak: $W_{max} = 91{,}7 + 1{,}5 \cdot P$; $R^2 = 0{,}904$

The functional dependence between maximal moisture content of wood and number of growth rings in 1 centimeter is identical to the one between wood porosity and number of growth rings in 1 cm. This dependence is indirectly proportional for pine and birch and directly proportional for oak (Fig. 4).

The equation of dependence between maximal moisture content and number of growth rings in one centimeter has a form of:

for pine: $W_{max} = 197{,}1 - 3{,}9 \cdot n$; $R^2 = 0{,}990$
for birch: $W_{max} = 145{,}3 - 1{,}8 \cdot n$; $R^2 = 0{,}978$
for oak: $W_{max} = 97{,}4 + 1{,}3 \cdot n$; $R^2 = 0{,}958$

CONCLUSIONS

The simple equations of received functions allow defining the maximal water absorption by wood on the basis of growth rate with sufficient exactness and scientifical reliability. The current research may be useful for wood science theory and practical implementation. As for the theorit gives the interpretation of high-quality wood forming. From the practical viewpoint it significantly reduces the labour and energy expenses at determination of such characteristics of wood as porosity, maximal moisture content and wood density.

The preliminary results prove the perspectiveness of our approval to this problem. The proposed method is highly probably saving the time and energy. Moreover, the methodology is very clear-cut, simple and efficient.

However, it should be noted, that the results published in this paper are valid for sites of Russian European regions with the exception of the Far North with extreme plant growing. To prove the general validity of our functions for the investigated wood species, the experiments should be carried out on wood material from several different sites.

ACKNOWLEDGEMENT

The authors wish to express their thanks to the Russian State project No. 01.2.00105361 – "The investigation of technological wood working processes and wood properties", Federal project No. 7B-02 – "The development and organization of resource conserving, ecologically safe technology manufacture of wood purveyance and deep processing" and the Slovak agency VEGA to the project No. 1/0517/09 for financial support.

REFERENCES

1. Haruk, E.V., 1976: Wood permeability by gas and liquid. Science. Novosibirsk, 190 pp.
2. Höster, H., Spring, C., 1971: Zur Bestimmung von Zellartenanteilen im Holzgewebe. Microscopie, 27, Pp. 220-225
3. Kolosovskaja, E.A., Loskutov, S.R., Chudinov B.S., 1989: Physical foundations of interaction among wood and water. Science. Novosibirsk, 216 pp.
4. Kosichenko, N.E., 2000: The wood structure and density forming in ontogeny. In: Wood Structure, Properties and Quality. Petrozavodsk, Russia, Pp. 58-61
5. Kosichenko N.E., Varivodina I.N., Varivodin V.A., 2007: Interconnection between wood porosity and rate of growth. In: Dendrology and forest economy. Krasnoyarsk, Russia, Pp. 69-71
6. Perelygin, L.M., 1954: Wood structure. Science academy, Moscow, 200 pp.
7. Požgaj, A., Chovanec, D., Kurjatko, S., Babiak, M., 1997: Štruktúra a vlastnosti dreva. Príroda, Bratislava, 488 pp.
8. Skaar, Ch., 1987: Water in wood. Syracuse. Syracuse University Press, 218 pp.
9. Ugolev, B.N., 1986: Wood science and bases of forest commodity science: Textbook for higher educational institution of forestry engineering. MGUL Moscow, 351 pp.
10. Vihrov, V.E., 1954: Diagnostic signs of wood. Science academy, Moscow, 132 pp.
11. Yacenko-Hmelevsky, A.A., 1954: The bases and methods of anatomic wood research, Moscow, 335 pp.

Inna Varivodina
Voronezh State Academy of Forestry
Faculty of Wood Technology Engineering
Russia
Timiryazeva Street 8
Voronezh
Russia
E-mail: varivodinna@rambler.ru

Nikolai Kosichenko
Voronezh State Academy of Forestry
Faculty of Wood Technology Engineering
Russia
Timiryazeva Street 8
Voronezh
Russia

Viacheslav Varivodin
Voronezh State Academy of Forestry
Faculty of Wood Technology Engineering
Russia
Timiryazeva Street 8
Voronezh
Russia

Ján Sedliačik
Technical University
Faculty of Wood Sciences and Technology
T.G. Masaryka 24
960 53 Zvolen
Slovak Republic
E-mail: janos@vsld.tuzvo.sk