Slavko Govorčin, Tomislav Sinković, Jelena Trajković

Distribution of properties in use for oak, beech and fir-wood in a radial direction

Raspored svojstava u radijalnom smjeru pri upotrebi hrastovine, bukovine i jelovine

Izvorni znanstveni rad - Orginal scientific paper
Prispjelo - recived: 23. 12. 1998.• Prihvaćeno - accepted: 25. 02. 1999.
*UDK 630*0.812*

Summary • *The purpose of this article is to present distributions, that is variations of wood properties from pith to bark with the aim of predicting and determining the zones (areas) of highest quality in wood of the three most commercial species in Croatia: oak (Quercus robur L.), beech (Fagus silvatica L.) and fir (Abies alba Mill.). Variations of wood density, radial and tangential shrinkage, bending strength and compression strength parallel to the grain were observed and analysed. The results showed zones of highest quality with the respect to the tested properties in beech-wood, oak-wood and fir-wood. In connection with this the optimal moment of felling is discussed with respect to the predicted (assumed) quality of tested wood species grown in the forests of Croatia.*

Key words: *beech (Fagus silvatica L.), oak (Quercus robur L.), fir (Abies alba Mill.), density of oven dry wood, radial and tangential shrinkage, bending strength, compression strength parallel to the grain*

SAŽETAK • *Svrha ovog rada je prikaz rasporeda, tj. varijacija svojstava drva od srčike prema kori, tj. u radijalnom smjeru, s ciljem prognoziranja i određivanja najkvalitetnijih zona drva triju najkomercijalnijih vrsta u Hrvatskoj: hrasta lužnjaka (Quercus robur L.), bukve (Fagus silvatica L.) i jele (Abies alba Mill.). Promatrane su i analizirane varijacije gustoće drva, radijalnog i tangencijalnog utezanja, čvrstoće na savijanje i čvrstoće na tlak paralelno s vlakancima. Rezultati ispitanih svojstava odredili su najkvalitetnije zone u drvu bukve, hrasta i jele. S time u vezi raspravlja se o odabiru najpovoljnijeg trenutka sječe s obzirom na predviđenu (postignutu) kvalitetu ispitanog drva iz šuma Hrvatske.*

Authors are an assistant professor, assistant and assistant lecturer at the Faculty of Forestry of the Zagreb University
Autori su docent, asistent i viša asistentica na Šumarskom fakultetu u Zagrebu

Ključne riječi: *bukva (Fagus silvatica L.), hrast (Quercus robur L.), jela (Abies alba Mill.), gustoća u apsolutno suhom stanju, radijalno i tangencijalno utezanje, čvrstoća na savijanje, čvrstoća na tlak paralelno s vlakancima*

1. INTRODUCTION
1. UVOD

The usage properties of wood are determined by its structural, chemical, physical and mechanical qualities. Although the properties of certain wood species are genetically determined, they vary within a certain species, and also in an individual tree as a result of external and internal factors affecting its growth. Especially significant is the distribution, namely the variation of the wood properties when observed from the pith towards the bark, in a radial direction. The variations of wood properties in a radial direction have been known for a long time (Panshin and De Zeeuw 1970, Petrić 1960) and the classification of wood species with the respect to the type of distribution of properties has been made. It is still worth noticing the tendencies of wood properties observed in a radial direction, so that they could direct and help in determining the top-quality zones in the use of wood, within an individual tree in a wood species.

The distribution, as well as the variation of wood property values in a radial direction show a marked dependence on a wood species and a tree's age. This enables a reasonably successful assessment of the usage value of wood of some species as regards the position in the trunk and the tree's age (Govorčin and Sinković 1991, 1994; Pearson 1988). There is also the possibility of assessing the optimal age for felling an individual tree in order to get the wood of the best use, that is, the highest quality.

It is especially significant and valuable to know the distribution of properties in the most commercial wood species. Therefore, three of the most significant and most commercial wood species in Croatia were chosen: oak (*Quercus robur* L.), beech (*Fagus silvatica* L.) and fir (*Abies alba* Mill.).

2. MATERIALS AND METHODS
2. MATERIJAL I METODE

The samples have been made in such a way as to have the largest possible number of testing samples in a radial direction, from pith to bark, with losses in material only in the places of saw kerf, between the samples. The maximal number of testing samples and the precise location of each sample as regards the position in the trunk, facilitated the provision of reliable data which then resulted in property functions from which it is easy to observe the necessary tendencies or changes in property trends. All measurement and testing were lead according to ISO standards.

For the testing of oak wood, the material taken was obtained from small testing logs of 12 trees from the area of Eastern Slavonia. Of these 12, three logs were taken from the Forester's Office Lipovac, the forest area Topolovac, forest compartment 6a, and nine logs from the Forester's Office Vrbanja, the forest area Boljkovo, compartment 130b. The trees were chosen to represent the structure of the forest stand with their age, size, habit, dendrometric elements and external characteristics of the trunks. The trees were healthy, with normal crowns, with trunks as straight as possible, with an average cleanness and cylindricity of the stem and straightness of the grain. In all 12 trees, the small testing logs were taken from the middle height between the ground and the first living branch.

Table 1.
Review of relevant parametars of test trees • Pregled relevantnih pokazatelja modelnih stabala.

WOOD VRSTA DRVA	DIAMETAR CLASS DEBLJINSKI RAZRED	NUMBER OF TREES BROJ STABALA	AVERAGES AGE SREDNJA STAROST STABALA	AVERAGES MEAN BREST DIAMETAR SREDNJI PRSNI PROMJER	AVERAGES TREE HIGHT SREDNJA VISINA STABALA
	cm		RING GOD	cm	m
OAK HRAST	<50	3	111	46	30,1
	50-60	7	119	53	32,4
	>60	2	125	61	33,9
BEECH BUKVA	15-25	3	92	21	12,9
	25-35	3	183	33	15,9
	35-45	3	208	39	19,8
	45-55	3	218	51	15,5
	>55	3	233	60	25,8
FIR JELA	25-30	4	90	28	19,6
	31-40	2	115	38	27,5
	41-50	2	117	48	29
	>60	2	120	61	33,5

The material for testing beech wood was taken from 15 small testing logs from the area of Gorski Kotar, namely from the area of Bjelolasica mountain covered by the Forester's Office Mrkopalj, from the management unit Bjelolasica, compartment 47, at an altitude of 1120 –1300 m. The trees were healthy, with regular crowns and straight trunks, chosen from six diameter classes. The small testing logs were taken from a height of 1.3 m.

The fir wood, necessary for the research, was taken from the small testing logs of 10 trees from the area of Gorski Kotar, the Forester's Office Zalesina, the management unit Belevine, compartment 6. The trees were chosen from four diameter classes. The small testing logs were taken from a height of 1.3 m.

On the basis of the small testing logs gathered from the three wood species, samples were made for determining the density in oven dry condition, total shrinkage in a radial direction, total shrinkage in a tangential direction, bending strength and compression strength parallel to the grain.

3. RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

The average values of the tested properties in the three wood species and the statistic data are shown in Table 2. The originally data were taken from privies article (Govorčin 1995, Sinković 1995, Govorčin 1996).

It is shown that the polynomial functions of the third grade agreed with the values obtained, and at the same time enabled the observation of the tendencies of the tested properties as well as the changes of the property trends.

The functions of the density distribution in the oven dry condition for the three wood species are shown in Figure 1. The forms of the functions are characteristic of an individual wood species and in accordance with previous knowledge (Govorčin and Sinković 1991, Govorčin and Sinković 1994, Govorčin 1995, Sinković 1995, Govorčin 1996) on the distribution of the wood density from the pith towards the bark. They are also in accordance with the recent research on the distribution of the structural properties of the three chosen wood species (Petrić et al. 1990, Petrić and Šćukanec 1982, 1980). Changes in function trends have been observed in the area after the 40th – 60th growth rings from the pith, in other words, after the transition from the juvenile to the adult wood. The areas of adult wood in beech and oak obviously expand more than in fir. The changes in the trend of the density function in beech wood occur around the 200th growth ring, in oak wood around the 80th growth ring and in fir wood around the 100th growth ring.

The radial shrinkage is indicated with functions in Figure 2. In beech wood, the value of radial shrinkage decreases almost continuously from the pith towards the bark; in oak wood, at the beginning, it mildly increases up to nearly the 50th growth ring, and

PROPERTY SVOJSTVO	WOOD VRSTA DRVA	NUMBER OF SAMPLES BROJ UZORAKA	MIN MINIMUM	AVERAGE VALUE SREDNJA VRIJEDNOST	MAX MAKSIMUM	STANDARD DEVIATION STANDARDNA DEVIJACIJA s
Density of oven dry wood Gustoća u apsolutno suhom stanju (g/cm^3)	beech bukovina	444	0,5210	0,6748	0,9099	0,0583
	oak hrastovina	371	0,2527	0,6031	0,8219	0,0710
	fir jelovina	436	0,3097	0,4355	0,5638	0,0412
Radial shrinkage Radialno utezanje (%)	beech bukovina	223	4,11	6,19	9,58	0,9605
	oak hrastovina	371	1,99	5,04	8,43	1,0420
	fir jelovina	420	2,72	4,25	6,48	0,5758
Tangential shrinkage Tangencijalno utezanje (%)	beech bukovina	219	7,69	11,12	13,37	0,9343
	oak hrastovina	371	3,95	9,09	13,94	1,2806
	fir jelovina	420	4,26	8,44	10,11	0,9910
Bending strength Čvrstoća na savijanje (MPa)	beech bukovina	245	79,33	121,96	171,86	15,453
	oak hrastovina	371	11,16	93,30	134,71	16,487
	fir jelovina	380	41,52	80,92	106,31	11,652
Compression strength parallel to grain Čvrstoća na tlak paralelno s vlakancima (MPa)	beech bukovina	576	48,17	67,54	88,66	6,5637
	oak hrastovina	371	13,86	54,96	77,96	8,6299
	fir jelovina	387	23,27	35,63	45,23	4,6732

Table 2.

Review of statistical data on density of oven dry wood, radial and tangential shrinkage, bending strength and compression strength parallel to the grain for beech, oak and fir-wood • Pregled statističkih podataka gustoće u apsolutno suhom stanju, radialnog i tangencijalnog utezanja, čvrstoće na savijanje i čvrstoće na tlak paralelno s vlakancima za bukovinu, hrastovinu i jelovinu.

Figure 1.

Distribution of density of oven dry wood in radial direction for beech, oak and fir- wood • Raspored gustoće u apsolutno suhom stanju u radialnom smjeru za bukovinu, hrastovinu i jelovinu

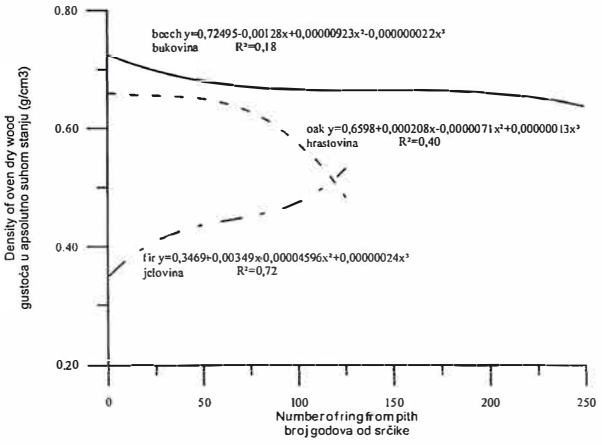


Figure 2.

Distribution of radial shrinkage in radial direction for beech, oak and fir-wood • Raspored radialnog utezanja u radialnom smjeru za bukovinu, hrastovinu i jelovinu

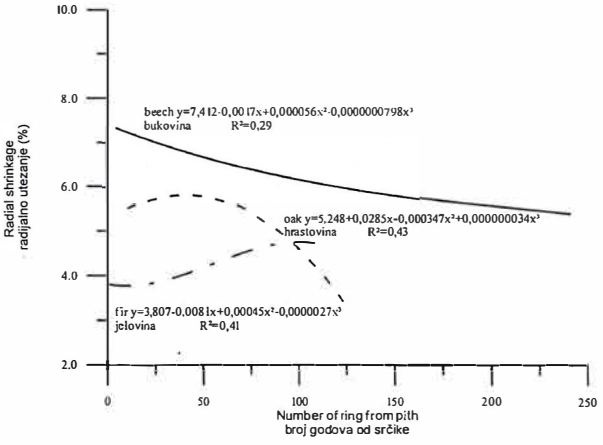


Figure 3.

Distribution of tangential shrinkage in radial direction for beech, oak and fir-wood • Raspored tangencijalnog utezanja u radijalnom smjeru za bukovinu, hrastovinu i jelovinu

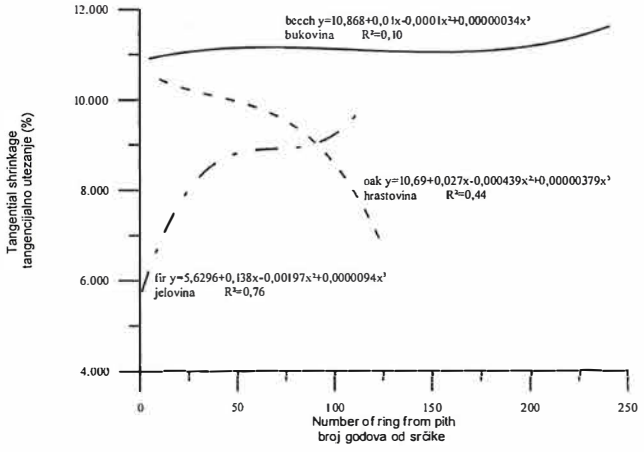
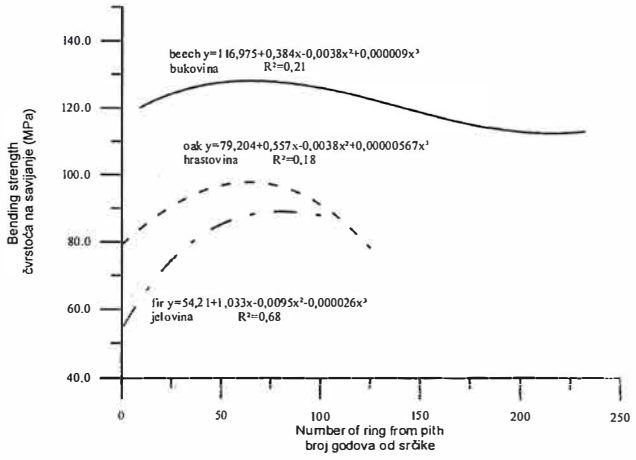


Figure 4.

Distribution of bending strength in radial direction for beech, oak and fir-wood • Raspored čvrstoće na savijanje u radijalnom smjeru za bukovinu, hrastovinu i jelovinu



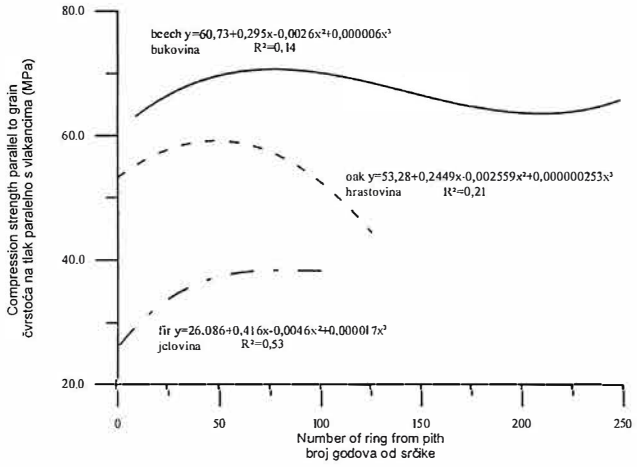


Figure 5.
Distribution of compression strength parallel to grain in radial direction for beech, oak and fir-wood • Raspored čvrstoće na tlak paralelno s vlakancima u radijalnom smjeru za bukovinu, hrastovinu i jelovinu

then decreases rather abruptly; and in fir wood, it generally increases from the pith towards the bark.

Figure 3 shows the tangential shrinkage indicating that in beech wood it is almost uniform from the pith to the bark with a slight increase in sample taken close to the bark. In oak wood, it slightly decreases from the pith up to nearly the 70th growth ring, and after that, the function decreases more drastically close to the bark point. In fir wood it increases from the pith to the bark with an emphasised value increase in the zone of juvenile wood.

The bending strength functions are shown in Figure 4. The function of the bending strength in beech shows a general tendency to decline from pith to bark but with emphasized increase in the juvenile wood. In oak there is a tendency of a slight increase of the bending strength from the pith to approximately the 80th growth ring and after that the bending strength declines towards the bark. The values of the bending strength in fir steeply increase in juvenile wood and then they are uniform.

The distributions of the compression strength parallel to grain are shown in Figure 5. If the functions of the bending strength and the compression strength are compared, one can see that their or forms are almost identical for the specific wood species and the alterations of strength values occur at nearly the same distance from the pith.

4. CONCLUSION
4. ZAKLJUČAK

Based on the evidence concerning the properties and their distributions from the pith towards the bark in three wood species and using the polynom functions of the third degree one can see the well known variability (Govorčin and Sinković 1991, Govorčin and Sinković 1994, Govorčin 1995, Sinković 1995, Govorčin 1996) of the properties. The tendencies of the property functions are particularly recognisable in the zones of juvenile wood as well as in the transition zones of adult and well matured wood.

If the most reliable indicators of the wood use are accepted to be its mechanical properties, or in this case the observed distribution of the bending strength and compression strength parallel to the grain, beech wood can be taken as the top quality wood after the beginning of the adult wood zone. With wood growing older, or with samples taken closer to the bark, the quality is gradually decreased.

Regarding the distribution of the mechanical properties and also the wood density in oak wood one can say that it is of uniform quality from the pith to approximately the 80th growth ring. Then a more intensive decline of the property values begins which indicates a decrease of the oak wood quality from a mechanical point of view.

In fir wood the most intensive changes are in juvenile wood with respec to all the tested properties. The values of the tested properties and particularly the mechanical properties become uniform after the end of the juvenile wood formation. One can conclude that the fir wood of highest quality is formed after its transition into the adult.

According to the results obtained on the distribution of properties from the core to the bark in the three wood species, one could decide on the optimal moment for felling trees to obtain the material of the highest quality. Nevertheless, it should be mentioned that these are just partial indicators, based primarily on the values of the mechanical properties, and not the only indicator in the total value, quality and use of wood as a material.

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