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INFLUENCE OF KNOTS ON CLASSIFICATION OF TIMBER ASSORTMENTS OF SILVER FIR INTO QUALITY CLASSES

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ABSTRACT

The classification of timber assortments of silver fir into quality classes depends on the occurrence of wood defects. Knots are the most common defects appearing on fir assortments. The aim of this research was to establish the influence of size of knots and their position/height on fir trees (*Abies alba*, Mill.) on classification into quality classes of timber assortments that can be processed from the stem. Heights above ground, where maximum knot diameters can be found, increase with the increase of tree diameter at breast height. Only lower parts of stem of fir-trees can be used for processing veneer logs. Timber assortments processed from upper parts of trees with smaller-breast height diameter can be classified as saw logs of the highest quality (Class 1), but the quality class depends on the stem diameter. With larger breast height diameter trees timber assortments processed from the lower third of the stem meet the criteria for saw logs of the highest quality (Class 1).

KEY WORDS: knots, timber assortment, quality class, *Abies alba*

INTRODUCTION

From the point of view of harvesting, forests or trees represent the object of work. The tree consists of the underground part (root) and aboveground part, made of butt, stem and crown.

The crown is the upper part of the tree made of branches, leaves (needles) and buds. The structure of the crown is characterised by the arrangement, shape and size of branches. The crown expansion and its proportion to the other parts of the tree have a strong impact on the development of the tree, especially the stem (Dubravac 1998). It is highly important to know the structure of the crown for practical purposes. The appearance of the crown is a significant factor in determining the degree of the tree health, and the arrangement, size and shape of branches affect the usability and technical characteristics of stem wood or timber assortments.

The places on the stem that represent the remaining parts of branches in the wood, i.e. the bases of living and dead branches, are called knots. The knots are considered as wood defects, which lower the quality of timber assortments processed from the stem. The knot diameter on the stem cover represents the limiting factor in classifying the processed assortments into quality classes. This must be taken into consideration in cross-cutting timber assortments so as to obtain timber assortments of the best possible value from the stem. Consequently the higher the cleanness of the stem the higher its technical usability and value of the wood volume. Also, processing time of timber assortment from stem wood is affected by the length of crown, cleanness of stem, frequency and size of knots. Trees with the highest cleanness of stem require the shortest processing time (Rebula 1987).

Scientific researches tried to show the influence of the crown expansion or stem knottiness of certain species of trees on classification of processed wood assortments into quality classes. The influence of knots on the quality of assortments is estimated based on their size and frequency (Lipoglavšek 1980). Thus, Carmean and Boyce (1973) investigate the cleanness of stem wood as well as size and shape of knots of some hardwood non-coniferous species of North American Continent.

Barszcz (1989) estimates the influence of defects on the quality of wood in mixed coniferous stands. The occurrence of some wood defects (knots, rot, internal cracks, insect damage, sweep, butt swelling) is shown by assortments of specific quality classes.

Fischer (1994) investigates the quality characteristics of Douglas Fir on trees whose branches have not been pruned and determines a significant influence of the crown expansion and knottiness on wood quality.

This research is aimed at establishing the influence of size of knots and their position/height on fir trees (*Abies alba*, Mill.) on classification into quality classes of timber assortments that can be processed from the stem. According to Rebula (1998) the basic indicator of the influence of knottiness on the value of fir timber assortments is the total number of knots or total knot area on the assortment.

Silver fir (*Abies alba*, Mill.) is one of the most important and most valuable species of trees in the Croatian forestry. The annual allowable cut of fir trees is approximately 350 000 m^3, which is about 12 % of the total production of timber assortments. The crown of young fir tree is conical, when elder it becomes cylindrical and with old trees the top becomes disc-shaped. The branches are held out horizontally and arranged in whorls around the stem creating more or less regular layers of branches at a right angle to the stem axis. Branch whorl is the place where several branches grow from the stem at about the same level. Fir trees have the capability of natural shedding of branches from the stem (Vidaković 1993).

The basic criteria for classifying timber assortments are: size and wood defects. When applying the Croatian standards for classifying timber assortments in quality classes, the key criteria are wood defects on the assortments, so that an individual defect is decisive in determining the quality class of an assortment.

Knots are the most common defects appearing on fir assortments. As according to the standards, a series of knots represented by a maximum knot diameter is considered as an individual defect, research was made of knots with the largest diameter in the whorls depending on the height of the knot on the stem. In his investigation of fir-tree knottiness, Furlan (1975) concludes that the diameter of the largest knots in a whorl increases linearly with the tree diameter at breast height, and the number of knots and whorls of knots increases with the height above ground level.

According to the Croatian standards, for the classification of fir timber assortments the following knot sizes are permissible:

- Veneer logs – sound knot not exceeding 20 mm in diameter, one per meter
- Saw logs, highest quality (Class 1) – sound small knots, not exceeding 20 mm in diameter with no limits, and medium-size knots or a whorl of knots not exceeding 40 mm, one per meter
- Saw logs, lower quality (Class 2) – sound knots, small and medium-size knots not exceeding 40 mm with no limits, and large knots, or whorl of knots, not exceeding 60 mm in diameter, one per meter

MATERIAL AND METHODS

The research was carried out in the management unit "Belevine" of the educational-experimental forest site Zalesina, of the Faculty of Forestry Zagreb. The area of the management unit is 293.94 ha, of which 283.20 ha is covered with growth. The management unit Belevina is located on the slopes of proper exposition and moderate inclination (up to 20 %). The altitude ranges between 720 m and 870 m. According to Köppen classification it is situated in climate zone C, i.e. temperate humid climate, type "Cfsbx".

The management unit Belevina is mostly covered by fir forest with hardfern (*Blechno-Abietetum* Ht.) on acidophilic, deep, silicate soil, which represents stand site class II. The stands are mixed high forests of beech and fir, of high silvicultural form and selection management system. Sustainable forest management is implemented with a 10-year rotation and felling diameter of 70 cm. Group selective felling is carried out. The growing stock in the management unit is 457.14 m^3/ha, of which fir accounts for 382.37 m^3/ha. The share of fir in the mix is 86 % of the growing stock, and according to the number of trees only 57 %. Ten-year annual allowable cut is approximately 25 000 m^3.

The basis for this research was a sample of fir trees cut in the regular felling of the allowable cut under a rotation period. Diameter at breast heights of standing trees were measured before felling, and after felling and delimbing the length (height) of the fallen tree was measured (from the base to the top of the stem).

Measuring of knots was carried out on a sample of 100 trees. Maximum knot diameter of the stem was measured on each branch whorl, as well as the distance between the branch whorl and stump. Knot diameters were measured to the nearest 1 millimetre by use of a movable measuring scale.

According to the German classification system sample trees were grouped into 5-cm diameter classes, with means of classes at 22.5 cm, 27.5 cm, 32.5 cm, etc.

For each diameter class a measurement data base was established containing maximum knot diameter of each whorl, absolute height of the knot from the stump at a specific diameter at breast height and tree height.

Based on the measured heights of the sample trees, a height curve was made by use of Mihajlo's function (Pranjić and Lukić 1997):

$$h = b_0\, e^{-a1/d} + 1.3 \tag{1}$$

(d – tree diameter at breast height; h – tree height)

The research involves the determination of the dependence of knot diameter on the distance from the stump. With the equalisation of knot diameters in respect of the distance from the stump, large data dispersion occurred as the distance from the stump depends on the tree height. The equalisation was, therefore, carried out based on the knot diameter against relative tree heights. Regression analyses were performed by use of second-degree equations for each diameter class.

$$D = a_0 + a_1\,(h/H) + a_2\,(h/H)^2 \tag{2}$$

D – maximum knot diameter of the whorl
h – height of the knot above ground level or distance between the knot and stump
H – tree height

Fig. 1: Stem of fir tree

The adjusted values of heights for mean trees of diameter classes (diameter at breast height of 32.5 cm, 37.5 cm etc.) were then inserted into obtained regression equations. In this way the knot diameters were expressed against absolute values of the distance from the stump.

Roemer-Orphal scale (Kump et al. 1970) was used for performing the regression analyses for establishing the correlation strength between the adjusted independent and dependent variable (Fig. 2).

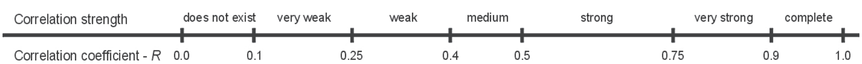

Fig. 2: Roemer-Orphal scale

RESULTS AND DISCUSSION

Research was carried out on 100 fir trees, of diameter at breast height ranging between 30 cm and 70 cm. Trees were divided into diameter classes between 32.5 cm and 67.5 cm. A total of 3.845 diameters were measured of the largest knots of branch whorls (Table 1). Based on the measured heights of all sample trees, the following form of Mihajlo's function was derived:

$$h = 47.2\, e^{-22.12/d} + 1.3$$

($r = 0.85$; $r^2 = 0.72$; $n = 100$)

(d – tree diameter at breast height; h – tree height)

Based on the height curve, the heights of mean trees of diameter classes were determined.

Tab. 1: Tree heights, number of trees and measured knots

Diameter class	Tree height	Number of trees	Number of measured knots
cm	m		
32.5	25.2	10	342
37.5	27.5	10	350
42.5	29.3	15	532
47.5	30.9	15	543
52.5	32.3	15	579
57.5	33.4	15	616
62.5	34.4	12	516
67.5	35.3	8	367
Total		100	3845

Sample trees are of different heights and they differ over the arrangement of knots with respect to height above ground. For the purpose of data processing of all trees, the dependence was investigated of maximum knot diameters in branch whorls on the relative tree height.

By adjusting the data by the curve of the second degree (2), the dependence was established of maximum knot diameters in branch whorls on relative tree height for each diameter class (Table 2). A large number of measured branches resulted in a wide range of data, and hence the correlation data are between 0.58 and 0.76, still indicating a strong correlation (Kump et al. 1970).

Tab. 2: Regression data of dependence of maximum knot diameter on relative height of mean trees of diameter class

	Diameter class, cm							
	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5
Parameters of regression equations								
a_0	10.72	-16.99	-13.13	-30.06	-24.74	-24.99	-36.77	-38.39
a_1	82.46	202.59	191.71	304.67	268.16	283.61	341.03	347.65
a_2	-72.52	-160.74	-150.55	-233.90	-186.82	-204.99	-249.00	-256.68
Statistical parameters								
r	0.63	0.76	0.70	0.58	0.72	0.65	0.72	0.63
r^2	0.40	0.58	0.50	0.34	0.52	0.43	0.52	0.40
n	342	350	532	543	579	616	516	367

Based on regression equations and heights of mean trees of diameter classes, the dependence is shown of maximum knot diameters in branch whirls on absolute values of height above ground (Figure 3).

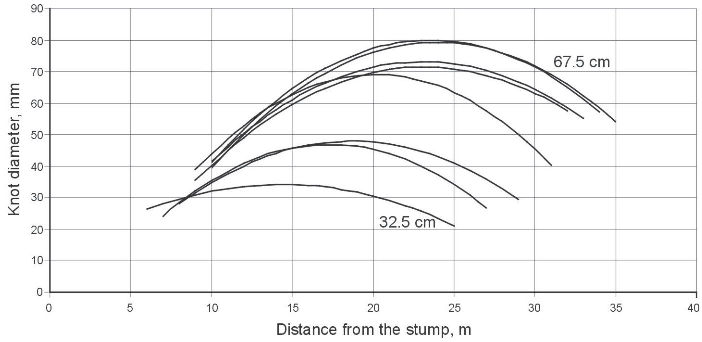

Fig. 3: Dependence of maximum branch diameter on the distance from the stump

Difference can be observed between small and large breast height diameter trees. Maximum knot diameters of trees of diameter classes between 32.5 and 42.5 cm get considerably smaller with the increase of height above ground. The values of maximum branch diameters of trees with larger breast height diameter are almost the same up to a height of 15 metres, and then they are divided according to diameter classes. Trees of 47.5 cm diameter class have no large knot diameters in higher sections. Trees of 62.5 cm and 67.5 cm diameter class show the largest knot diameters, and considerably large in higher parts of the tree, as a result of a disc-shaped top with stronger branches. With trees of 52.5 cm and 57.5 cm diameter class, it can be concluded that maximum knot diameters can be found at the stage of change of higher parts of trees or the stage of the development of a disc-shaped top.

The heights above ground, where maximum knot diameters can be found, increase with the increase of tree diameter at breast height. Trees of 32.5 cm diameter class have the largest knot diameters at the height of 15 m, trees of 37.5 cm diameter class at 17 m, trees of 42.5 cm and 47.5 cm diameter class at 19 m and 20 m, respectively. With the diameter classes that follow maximum knot diameters are found at the height of 23 or 24 metres.

The occurrence of sound knots is related to the beginning of the crown or appearance of live branches. Hence, sound knots have no effect on the classification of assortments processed from the part of stem up to the height of 6 metres above ground. However, knots larger than 2 cm in diameter appear at a height exceeding 6 m and 7 m from the stump for trees of 62.5 cm and 67.5 cm diameter class. Therefore, parts of stem higher than 6-7 metres can hardly be used for the production of veneer logs.

Maximum knot diameters with 32.5 cm diameter class do not exceed the diameter of 4 cm, which means that all timber assortments processed from the tree of the said diameter class can be classified into saw logs of the highest quality, but the quality class is conditioned by the stem diameter. With respect to maximum knot diameters, saw logs of the highest quality can be produced from trees of 37.5 cm and 42.5 cm diameter class up to a stem height of 12 metres (knot diameters smaller than 4 cm), and further on saw logs of lower quality (Class 2). However, the quality of processed assortments on higher parts of trees depends on the stem diameter.

Maximum branch diameters with other diameter classes exceed 4 cm at a stem height of 10 metres and 6 cm at a stem height of 15 metres. This means that, with respect to knot size, timber assortments processed from the part of stem up to the height of 10 metres, meet the criteria for saw logs of the highest quality (Class 1), and up to 15 metres the criteria for saw logs of lower quality (Class 2).

CONCLUSIONS

Classification of fir wood assortments into quality classes depends on the occurrence of tree defects. Knots are the most common defects appearing on fir assortments. As according to the standards, a whorl of knots represented by a maximum knot diameter is considered as an individual defect, research was made of maximum measured knot diameters in the whorls depending on the height of the knot on the stem.

Smaller-diameter trees have considerably smaller maximum knot diameters with the increase of the height above ground. Larger-diameter trees have almost the same values of maximum knot diameters up to one-half of the stem height, and then they are divided according to diameter classes. Heights above ground, where maximum knot diameters can be found, increase with the increase of tree diameter at breast height.

Veneer logs can only be processed from lower parts of the stem of fir-trees. Timber assortments processed from higher parts of smaller-diameter trees can be classified as saw logs of the highest quality (Class 1), but the quality class is conditioned by the stem diameter. With larger-diameter trees, timber assortments processed from the lower third of the stem meet the criteria for saw logs of the highest quality (Class 1).

REFERENCES

1. Barszcz, A., 1989: Analysis of the frequency of occurrence of wood defects in standing coniferous trees as an extension to evaluations of the quality of the raw material base. Sylwan 133 (3): 31-38
2. Carmean, W.H., Boyce, S.G., 1973: Hardwood log quality in relation to site quality. USDA Forest service research paper, 7 pp.
3. Dubravac, T., 1998: Istraživanje strukture krošanja hrasta lužnjaka i običnog graba u zajednici *Carpino betuli – Quercetum roboris* / Anić 1959 / Rauš 1969. Radovi 33 (2): 61-72
4. Fischer, H.W., 1994: Investigation on the quality properties, especially strength, of Douglas (*Pseudotsuga menziesii*) lumber production produced from non-pruned stems. Mitteilungen der Forstlichen und Versuchsanstalt, Rheinland-Pfalz, pp. 29-94
5. Furlan, F., 1975: Grčavost jelovine in njen vlpliv na kakovostnost opredelitev hlodov (Knottiness of european fir stemwood and its influence on grading rules for logs). Gozdarski vestnik 33 (6): 312-318
6. Kump, M. et. al., 1970: Poljski pokusi (Metodika postavljanja i statistička obrada). Centar za primjenu nauka u poljoprivredi SR Hrvatske, Zagreb, 86 pp.
7. Lipoglavšek, M., 1980: Gozdni proizvodi. Biotehniška fakulteta. VTOZD za gozdarstvo. Ljubljana, 209 pp.
8. Pranjić, A., Lukić, N., 1997: Izmjera šuma. Udžbenik. Šumarski fakultet Sveučilišta u Zagrebu, 405 pp.
9. Rebula, E., 1987: Čas sečnje in obdelave iglavcev po rastiščnih (Cutting time and timber manufacturing of coniferous in view of forest sites). Gozdarski vestnik, 45 (8): 381-388
10. Rebula, E., 1996: Sortimentne i vrijednosne tablice za deblovinu jele (Assortment/value tables for the fir logs). Mehanizacija šumarstva 21 (4): 201-222
11. Rebula, E., 1998: Vrednost jelovih hlodov, njeni kazalci in njihova uporabnost pri razvrščanju hlodov (The value of silver fir logs, its criteria and their applicability for categorization of logs). Zbornik gozdarstva i lesarstva 55: 151-199

12. Vidaković, M., 1993: Četinjače, morfologija i varijabilnost. Grafički zavod Hrvatske i "Hrvatske šume" Zagreb, 741 pp.
13. Croatian standards for forest harvesting products. II edition. State Department for standardization and measuring. Zagreb, 1995

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