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CHARACTERISTICS OF THE TRUNKS OF SCOTS PINE (PINUS SYLVESTRIS) FOR PRODUCTION OF SOLID WOOD MATERIALS

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ABSTRACT

The results from the studies on the dimensional and qualitative characteristics of model trunks of Scots pine have been presented in this report. The following dimensional characteristics: diameter, length and taper have been determined. The presence, type and dimensions of knots on the outer surface of the tree trunks and inside the wood have been determined. The presence of decay, spiral grain and other defects of wood and trunk shape have been established. The results have been analysed and relations to the existing standards, possible application of wood and requirements to the solid wood materials have been made. Relevant methods and techniques for efficient processing have been suggested.

Key words: Scots pine (*Pinus sylvestris*), trunks, dimensional and qualitative characteristics, solid wood materials.

INTRODUCTION

The timber of the Scots pine (Pinus Sylvestris), together with the wood of spruce and fir is one of the most commonly spread in Republic of Bulgaria and has wide economic significance. It is widely used in construction for framework materials, binding elements, outside net canvasses, for the interior of dwelling and public buildings, for the production of furniture, floor coverings, wood boards, in the construction of railway lines and mining, in the chemical and pharmaceutical industry, widely used in ship building and plane building. Apart from the broad distribution, the big application of Scots pine timber is due to its physical, mechanical, technological, exploitational and aesthetic qualities. It is comparatively light and with high strength points, is processed without difficulty and is with high durability.

The area of the Scots pine comprises large localities in Europe and Asia. To the North it reaches 72 Northern latitude, and in the South it reaches up to 2200 meters altitude. The Scots pine forests are widely spread in Bulgaria. Their natural area comprises the mountains Rila, Pirin, Osogovo and more limited in Central Balkans, Plana, Vitosha, Lozenska, Slavyanka, Ograjden at an altitude between 800 and 2000 m. It is in largest quantities and with best conditions for the development of the Scots pine in The Rhodope mountains and more specially in The Western and Central Rhodope. The natural forests of Scots Pine in Bulgaria take comparatively large territories (Fig. 1a).

The Scots pine is the most widely spread conifer tree species not only around the world, but also in Bulgaria. Considering this fact and its big economic importance for the country, the drive to increase the cares for its management and forest breeding, for research and more effective utilization is natural. The data from the National Forest Agency show that in comparison with past decades the Scots Pine areas that have been kept are even on the rise. Only the forest age structure has changed. On Table 1 are shown the data for forested areas from the widest spread conifer tree species in Bulgaria, distributed by class or age.

From the data above it could be seen that the areas forested with Scots pine represent almost 50 % of the common area with conifers. At the same time, it should be noted that the biggest areas are with Scots pine at the age 20–40 years-44.8 %. The areas of class at the age 41–60 years represent 16.7 %, these from class 81–100 are 10.9 and the rest are in considerably smaller quantities. The Scots pine reaches monthly maturity at the age – 90–100 and more years. These facts show clearly that: 1. in the following 40–50 year period the big timber raw materials from Scots pine will be very scarce;

Table 1: Distribution of the forested area from conifer species and their distribution by class of age

Tree species	Afforested area [ha] – grouping by age [years]								
	Total	1–20	21–40	41–60	61–80	81–100	101–120	121–140	over 140
Scotch pine	**554408**	**62517**	**248375**	**92766**	**53553**	**60658**	**30041**	**5546**	**952**
Spruce	160408	12595	36202	13838	17241	35754	28794	12218	3766
Fir tree	30682	1496	4210	2164	3587	6917	6375	3718	2215
Black pine	284146	38451	144527	73050	12406	7856	4903	1877	1076
Another coniferous species	37582	3680	14099	5409	2264	3927	3584	1949	2670
Total coniferous species	1067226	118739	447413	187227	89051	115112	73697	25308	10679

2. Our country will harvest and process round wood from this same tree species with considerably lower diameters. These conclusions and facts give us the reasons for reconsidering many issues concerning the effective wood-processing of the Scots pine, the methods, technologies and equipment for that purpose [6].

Having in mind the above, the drive the forests and wood from Scots Pine to be an object of study and research, to look for ways for more effective and reasonable utilization is only natural. The Scots pine timber is one of the most commonly researched in the present studies. The basic aim in most studies is finding out its physical and mechanical points, research on technological regimes in its cutting with different cutting equipment and machines, establishing optimal regimes for cutting, milling, defibering, gluing, drying, etc. The data for research on the sizes, form and the presence of defects in the trunk of the Scots pine are few. Tamadjiev, L. (1946) has carried out an extensive research on the trunk knots of the scots pine trunk. The distribution and size of the knots by height of trunk of Scots pine trees from different regions and mountains in Bulgaria has been found. These data give a considerable impression for the knot zones of the trunks and the distribution of knots in the Scots pine trees. The fact is, however that these studies were carried out 70 years ago and do not permit argumentative conclusions in the present day conditions. The viewed period is enough time for considerable changes in the forests because of the carried out forestry activity-different types of cuttings, wood-harvesting, forestation which change the contents and conditions for forest development, and consequently the size and quality of wood. The norms for accessibility and the limits for the availability of disadvantages of timber in the legislation acts (standards and technical requirements) have been changed considerably. All this requires accumulating of actual information concerning the sizes and disadvantages of the Scots pine trunks.

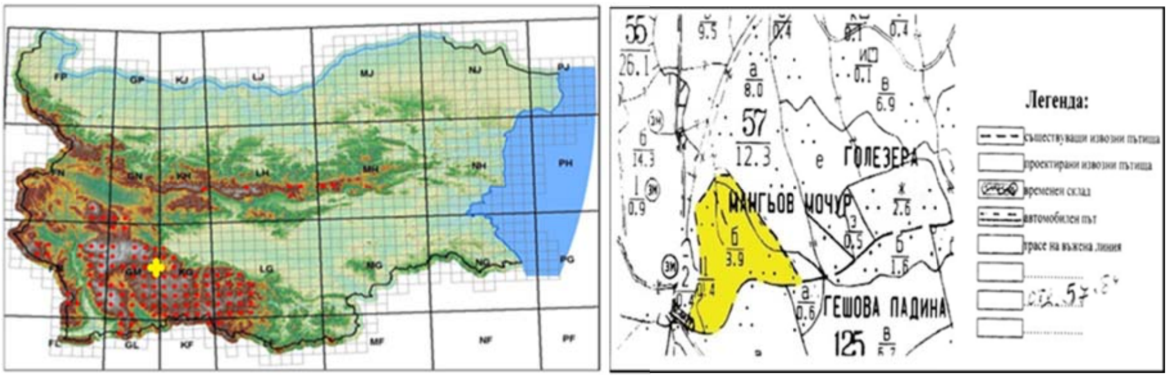
With the present study is aimed to present the results from the carried out research on the sizes and distribution of the disadvantages in trunks and Scots pine cut pieces. They will be an important base and prerequisite for the defining of optimal methods and schemes for more effective cutting of round wood and for the application of the respective technologies and machines in the first processing of round wood.

METHODS

In the execution of the set aim are carried out the following tasks:

1. Definition of the experimental area from which are harvested sample trunks from Scots pine;
2. The defined sample trunks were felled, cut from branches and cut in sections;
3. According to a preliminary defined method, the sections from the model trunks were measured and researched for the presence of defects of the wood and form;
4. The received sections were cut to boards with an equal thickness;
5. The boards from each section were researched for the presence, location and sizes of the wood defects.

In the choice of location for the harvesting of sample trunks a drive for location with characteristics possibly closest to the natural growth characteristics of the growth location of the Scots pine. For an experimental area was chosen the forest locality from the mountain Rhodope (fig.1), situated in the territory of the Experimental Forestry station Yundola from department-57, subdepartment b. The terrain is with altitude 1700 m, northern exposition with a slope 16˚.



a) b)

Figure 1: Map of the location of the department from which are harvested the sample trunks: a) forested areas with Scots pine (in red) (Dimitrov, M., V. Rusakova – [4]), location of the sample area (in yellow); b) map of the department from which the sample trees are harvested

The choice of sample trees has been carried out according to the requirements of the BSS-Bulgarian state standard ISO 4471[8]. 5 trunks were felled, which were consecutively cut from branches and then cut in sections with length L_{TR} = 4 m. the received sections were suitably numbered with the aim of preserving their natural order and location in the contents of the trunk, which was signified with the direction north-south in the contents of the trunks. The chosen samples of trees were of an age from 82 to 91 with average size in height and diameter for the planting, with upright and slim trunks and without visible outside defects. On fig. 2 are presented the working moments from the choice and harvest of the sample trunks.

Figure 2: Working moments from the addition of the sample trunks

On every sample trunk was worked out a working scheme on millimeter paper. On every linear meter from the trunk were measured: two self-perpendicular diameters with bark d_{k1} and d_{k2} and without bark d_1 and d_2. It was discovered the presence/absence of defects of timber and the form of the trunk. Each section with length 1 m was researched for the presence, distribution and measure of defects according to BDS EN 1927-2 [7] such as knots (type and size), decays, crooked growth (fibre slope); cracks from freezing, spots from insects, colorings, curves. The data from the research of the trunks were put on the scheme and in the corresponding tables. Schematically the methods for research and reflection of the sizes and defects was reflected in fig. 3 and fig. 4.

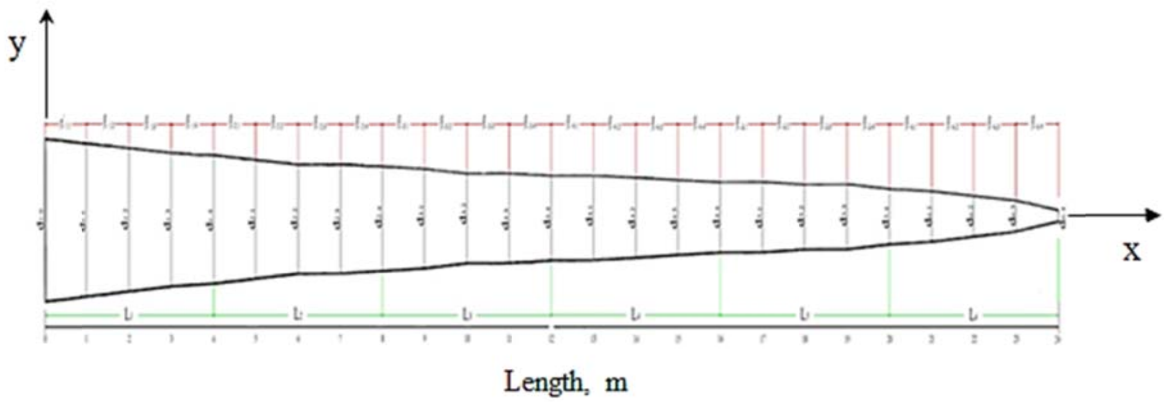


Figure 3: Scheme for the distribution of size characteristics of sample trunks from Scots pine

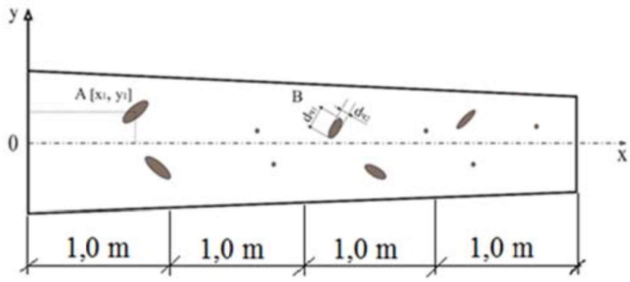


Figure 4: Scheme for the finding out of the presence, sizes and type of defects: A – definition of the location of defects; B – definition of sizes

On the trunks and sections were defined the following size characteristics: the length of the trunk, the average diameter of every linear meter from the length of the trunk, the difference of diameter in every section with length 4m,the thickness of the bark of every linear meter. The following formulas are used:

- For the average diameter of the cross section of the sections with length 1m through the measured two self perpendicular diameters d_1 and d_2

$$\overline{d_{cp\,i}} = \frac{d_{i\,1}+d_{i\,2}}{2}, \text{cm}; \quad (1)$$

- For the average diameter of the section with length 4 m

$$d_{av\,j} = \frac{d_j+D_j}{2}, \text{cm}; \quad (2)$$

- For the difference in diameter of the sections

$$s = \frac{D-d}{L_s}, \text{cm/m}; \quad (3)$$

- For the volume of the sections with length 4 m (Huber Formula – [1])

$$q_s = \frac{\pi . d_{av\,j}^2 . L_s}{4}, \text{m}^3; \quad (4)$$

- For the volume of the sections with bark

$$q_{s\,b} = \frac{\pi . d_{bavj}^2 . L_s}{4}, \text{m}^3; \quad (5)$$

- For the percentage contents of bark in the sections

$$K = \frac{100.(q_{s\,b}-q_s)}{q_{s\,b}}, \ \%; \quad (6)$$

In the above formulas are used the following significations:

D_{i1}, d_{i2} – the two self perpendicular diameters of the *i* section with length 1m; cm;

D_j, d_j – the diameters respectively in the thick and thin end of the j section with length 4m, cm;

L_s – the length of the sections of the contents of the trunk, m;

d_{bj}, D_{bj} – the diameters of the *j* section with bark respectively in the thin and thick end, cm.

The received results were summarized and presented in a table and graphical type.

On two of the sample trunks after cutting in sections with length 4 m, they were measured as length and the self perpendicular diameters of each linear meter from the base to the top. In the measurements were considered the sizes of the bark too. The aim was to follow the form of the trunk and the contents of bark in the different parts of the trunk and to create an opportunity for a mathematical description of the form of the trunks and sections from them.

RESULTS AND DISCUSSION

Summarized, the results from the carried out research on the sizes and the presence of defects on outer signs of trunks from Scots pine are given in tables 2–6.

Table 2: Size points of I sample trunk (L=24m, age 91 years)

№ trunk/ section	Diameter of sections in the thin end		Change of diameter	Availability of knots			Volume of the logs	Bark
	in the thin end d, cm	in the thick end D, cm	s, cm.m^{-1}	number 1.m^{-1}	diameter d_{KN}, cm	type	q, m³	k, %
I,1	29.0	37.0	1,8	2	1	ingrown	0.342	13.97
I,2	26.5	29.0	0,6	5	2	ingrown	0.242	6.05
I,3	24.0	26.5	0,6	6	4	not ingrown	0.200	2.91
I,4	19.5	24.0	0,9	7	4	not ingrown	0.148	3.34
I,5	17.0	19.0	0,6	9	4	ingrown	0.102	7.74
I,6	10.0	17.0	1,9	11	5	ingrown	0.057	8.81
			Common for the trunk:				Q=1.091	K=6.80

From them could be made some more significant conclusions, having relation to the technology for the production of massive wood materials. The chosen model trunks of the age 82–91, reach the height up to 24 m in the accepted border diameter 10 cm in the down thin part. When they reach logging maturity 110–120 years and normal average annual growth, the trunks could reach the height up to 30–32 m. the measured diameters at the base of the trunks are from 28 to 37 and in normal growth and reaching logging maturity up to 50–55. These facts mean that in average length of the sections from 4 m, from every trunk could be received from 6 to 8 sections with sizes responsible to the standards for production of massive wood materials.

Table 3: Size points of II sample trunk (L=20 m, age 82 years)

№ trunk/ section	Diameter of sections		Change of diameter	Availability of knots			Volume of the logs	Bark
	in the thin end d, cm	in the thick end D, cm	s, cm.m^{-1}	number 1, m^{-1}	diameter d_{KN}, cm	type	q, m³	k, %
II,1	24	28	0.8	0–2	1	ingrown	0.212	22.32
II,2	21	24	0.8	5	4	ingrown	0.159	11.13
II,3	18	21	0.7	7	3	not ingrown	0.119	7.21
II,4	16	19	0.8	9	3	ingrown	0.096	4.31
II,5	11	15	1.3	11	6	ingrown	0.053	7.10
					Common for the trunk:		Q=0.640	K=10.41

From the applied results it could be seen that in the 5 researched trunks, the difference in diameter is not equally distributed by their height. It is the highest in the ground sections from 0 to 8 m and in the tops 1–2 sections reaches 1.8–2 cm/m. In the remaining average for the trunk sections it is of the borders 0.6–0.8 cm/m. The data clearly show that in the correct carrying out of the right forestry activity, the Scots pine forms trunks with a big slimness. With the lack of crooks (in these trunks simple and complex crooks haven't been discovered) these data mean lower quantities of the huge waste from the cutting of the round wood.

Table 4: Size points of III sample trunk (L=20m, age 87 years)

№ trunk/ section	Diameter of sections		Change of diameter	Availability of knots			Volume of the logs	Bark
	in the thin end	in the thick		number	diameter	type		

	d, cm	end D, cm	s, cm.m^{-1}	1.m^{-1}	d_{KN}, cm		q, m³	k, %
III,1	28.0	34	1.8	0-1	1	ingrown	0.302	22.51
III,2	25.5	28	0.6	5	6	ingrown	0.225	10.34
III,3	21.5	25	0.8	6	5	ingrown	0.170	9.06
III,4	17.5	21	0.9	6	5	ingrown	0.116	4.97
III,5	12.0	17.5	1.3	10	6	ingrown	0.068	10.97
				Common for the trunk:			Q = 0.881	K=11.57

Table 5: Size points of IV sample trunk (L=24m, age 84 years)

№ trunk/ section	Diameter of sections in the thin end	in the thick end	Change of diameter	Availability of knots number	diame ter	type	Volume of the logs	Bark
	d, cm	D, cm	s, cm/m	1./m	d_{KN}, cm		q, m³	k, %
IV,1	27	32	1.3	0–1	1	ingrown	0.273	23.60
IV,2	25	27	0.4	5	5	ingrown	0.212	11.37
IV,3	22	26	0.8	5	6	not in-grown	0.181	9.61
IV,4	19	23	0.8	7	4	not in-grown	0.139	6.82
IV,5	15	19	1.1	11	6	ingrown	0.091	9.55
IV,6	9	14	1.3	10	6	ingrown	0.042	13.51
				Common for the trunk:			Q=0.938	K=12.19

Table 6: Size points of V sample trunk (L=24m, age 89 years)

№ trunk/ section	Diameter of sections in the thin end	in the thick end	Change of diameter	Availability of knots number	diame ter	type	Volume of the logs	Bark
	d, cm	D, cm	s, cm/m	1./m	d_{KN}, cm		q, m³	k, %
V,1	28	36	2.0	0–2	1	ingrown	0.322	23.20
V.2	25	28	0.7	8	4	ingrown	0.221	10.67
V.3	22	25	0.7	9	6	not in-grown	0.173	9.21
V.4	19	22	0.7	8	5	not in-grown	0.132	7.52
V.5	15	19	1.0	8	6	ingrown	0.091	8.95
V.6	9	16	1.8	11	6	ingrown	0.049	13.31
				Common for the trunk:			Q=0.988	K=11.91

The bark of the Scots pine represents a comparatively high percentage of their common volume. For 4 of the trunks (№№ II-V) the bark represents from 10.41 to 12.19 %. For a trunk № I this percentage is 6.80. From the data it could be seen that the percentage of the bark in the ground sections is higher and lower in the height of the trunk.

The distribution of the knots on the surface of the trunks is also uneven. As is seen from the applied results. the biggest is the number of discovered knots in the upper 1-2 sections. The biggest is the average diameter of the discovered knots. which are in the borders from 3 to 6 cm. but higher values predominate.

Defects of timber like decay. double heartwood. slope of fibres. colourings on outer signs and appearance. limited by BDS EN 1927-2 were not found. On the surface of some of the trunks (I. III. IV) were noticed spots of timber clay. but they are not from resin channels. but from damaged wood. caused by harvesting activity.

From the received results it could be claimed that the highest quality are the sections from the ground part of the trunks (from 0 to 8). According to the acting standard they could be given quality A. They are with the highest diameter. In connection to this. these materials should be reworked by the classical methods of cutting and materials with high requirements of quality of wood should be manufactured. With lowest quality could be evaluated the top sections. They are with the biggest availability of knots 9 in number and diameter). with highest diameter change. smallest diameter. These facts make wood from these sections unattractive for the wood-processing because of the reaching of low quantity and quality harvests of ready production.

The executed measurements of the trunk diameters permitted to carry out math's models for the formation of the round surface of the trunks. The calculations showed that the experimental results with the highest precision approximate to a polynomial model from 6 degrees (coefficient of determination with value above 0.9). The carried out math's models for the forming around surface of the logs with and without bark are:

Equation of the forming the stems with bark

$$y = 3E\text{-}07x^6 - 3E\text{-}05x^5 + 0.0015x^4 - 0.0357x^3 + 0.4649x^2 - 3.4006x + 24.531;\ R^2 = 0.9978 \quad \textbf{(7)}$$

Equation of the forming the stems without bark

$$y = 1E\text{-}06x^6 - 0.0001x^5 + 0.0035x^4 - 0.0612x^3 + 0.5991x^2 - 3.3649x + 21.561;\ R^2 = 0.995 \quad \textbf{(8)}$$

On fig. 5 is shown a graphic model of the round surface of the trunk. received by math's models.

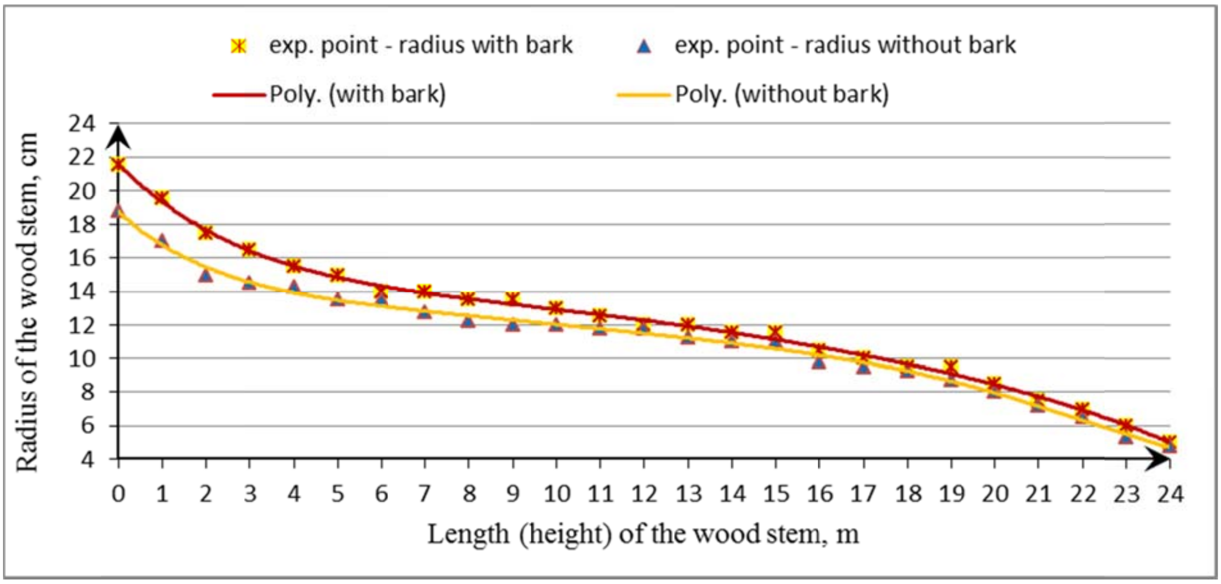


Figure 5: Graphic model of the round surface of the trunk. received by math's models

CONCLUSION

From the carried out research could be made the following more important conclusions and summary:

1. The Scots pine forms comparatively upright and slim trunks. and the received sections from it (logs for cutting) are straight and with low diameter change (under 1 cm/m).

This means the reception of small quantities of large waste from the outer zones of the logs and from the cornering of the boards. e.g. the reception of higher quantity additives. This fact is mainly due to the good forest management;

2. The diameter of the trunk in the researched samples of trees changes from 28 to 37 cm in the thick part of the trunks (the ground part –up to 30 cm of the base) and reaches the border diameter of 10 cm of the height 20–24 m the researched samples of trees will reach logging maturity after 20–30 years. In an average increase this means that the diameter in the ground part will reach sizes from 45–55 cm height of the trunk in the border diameter 28–32 m and in these sizes the values diameter and lack of curves lines will be kept;
3. In all researched trunks is observed the highest diameter change in the ground and top sections. In them the diameter change is in the borders from 1.3 to 1.8 and in some of the trunks up to 2.0 cm/m higher are the values in the ground sections. In the mid sections the diameter change is with lower values from 0.6 to 0.8 cm/m;
4. The average percentage of the bark in the researched trunks from Scots pine is from 6.80 to 12.20 %. It is not with an equal thickness by the height of the trunk. The first 2–3 sections are with the highest percentage of the bark. and in some trunks it reaches up to 23.60 % in the ground sections. The top sections are also with a higher percentage of the bark and reaches up to 13.51 %. The mid sections (4–5) are with a lower percentage of the bark and are in the borders between 4.31 to 9.55 %;
5. From the disadvantages of wood, the highest frequency of visitation are the knots (remnants of branches). The research on the presence of knots according to outside (signs from branches) on the surface of the trunks shows that their number. diameter. and type is not equally shown and distributed according to the height of the trunks. The smallest is their number and diameter in the ground sections-on average from 0 to 2 numbers/m with diameter around 1 cm. the most spots from branches are registered in the top sections – average 10–11 numbers/m with a diameter average 6 cm. in the ground and top sections the spots are of healthy branches. which form ingrowth knots in the inner side of the timber. In the middle sections are discovered mainly signs of dried branches. which form falling decayed knots in the inside of the timber;
6. Disadvantages of the wood like decay. crooked growth. double heart. signs of insect damages and so on weren’t discovered;
7. Disadvantages in the form of the trunk as one sided and complex curves and elypses of the cross section were also not discovered.
8. The carried out research on the size. form and disadvantages of trunks from Scots pine. the analyses done and the summaries give the ground to state that the round wood from Scots pine is very good raw material for the production of

materials from massive wood. For the production of large size materials with high quality the ground sections should be used. which are with the biggest diameter and the smallest defects of wood and its form.

The top sections are with the smallest diameter. with the biggest availability of knots. with the lowest physical-mechanical properties of wood. For these sections it follows to apply specialized methods of cutting. the corresponding technologies and equipment. They should be directed to the production of works with a big degree of accessibility of these defects or to the preliminary disposal and ensuing adhesion of the quality details. e.g. to production of engineered wood.

The received information concerning the sizes of the trunks from Scots pine is a necessary prerequisite for their more effective processing. The data for the presence of defects of wood are not enough. They are received by outside signs and could not be considered enough and final. Many of the disadvantages are in the inside of wood. Other disadvantages like decay. traces of insects are received after the cutting of the round materials in the storages of the manufacturing enterprises. That is why it is necessary the present studies and results to be continued and added by research about the availability of defects in the inside of the trunks.

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