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QUALITY CHARACTERISTICS OF DOUGLAS FIR STEMS (*Pseudotsuga menziesii*) FOR THE PRODUCTION OF MASSIVE WOOD MATERIALS

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ABSTRACT

The expansions of the raw material base for solid wood materials production are particularly important in terms of wood deficit and increased consumption. The aim is to use solid wood materials production like replacement wood, which doesn't deteriorate the performance of the finished products, as well as technical and economic production parameters. The Douglas fir (*Pseudotsuga menziesii*) is non popular wood species for Republic of Bulgaria. The studies for our country show that this tree species well adapted in these conditions, particularly in areas with high humidity. This gives reason to believe that this tree species is perspective for the production of solid wood materials.

This report presents the results of studies about the size and quality characteristics of Douglas fir stems.

Key words: Douglas fir (*Pseudotsuga menziesii*), trunks, dimensional and quality characteristics, solid wood materials.

INTRODUCTION

The Douglas fir is one of the most introduced wood species and is grown in Europe since 1827. In Bulgaria are created forest crops at many places and in suitable conditions are received good results.

The Douglas fir wood is nuclear with a clear cut border between early spring and late summer wood, it contains resin channels and has good physical-mechanical properties (Bluskova 2004). It has wide distribution in the furniture industry, is well processed and in good cohesion.

The area of growth of the green Douglas fir comprises the Western Coast parts of North America and that is why in its homeland it is known as a Coastal Douglas Fir. In our country the green Douglas fir is used for forestation in many forestry enterprises but the results are not good everywhere. It is a fast growing tree species. The height growth in young age could reach more than 1m. This is one of the most productive conifer tree species (Dimitrov 1989).

In a number of countries its cultivation is a priority for the forestry policy. In France the Douglas fir has turned into a basic type for forestation. (Popov 2011). In Germany it is cultivated since the 19th century which in particular conditions has reached a common productivity at 90 years of age.

From the conifer tree species distributed in our country, the Douglas fir has seven place approximately as a forested area or hardly 0,2% from the territory of the forests in Bulgaria (Petkova 1999). According to data from the International forestry agency by 2015 this tree species comprises 9078 ha forested area.

Concerning the size-quality characteristics of the Douglas fir trunks, data in literature have not been found as well as wood for logging with the aim of production of materials from massive wood. There are no data concerning the diameter of the Douglas fir logs, consistency and thickness of the bark. There are no data for the location of the zones with knots on the surface and the inside of the trunks. The data for the humidity and density of the wood in the specialized literature are from the mean values. They show the distribution of these points by the height of the trunk.

All this requires the accumulation of actual information concerning the size and the disadvantages of the Douglas fir trunks.

With the present study is aimed to present the results of the carried out research on the size and distribution of the defects in the knots and Douglas fir logs. They are going to be an important basis and a prerequisite for the definition of optimal methods and schemes for a more effective cutting of the round wood and the application of corresponding technologies and machines for the primary processing of the round wood.

METHODOLOGY

In an execution of the set aim has been put the following tasks:

1. The sample area has been defined from which sample trunks from green Douglas fir have been harvested.
2. According to preliminary methods the sample trunks were measured and researched for the presence of defects of the wood and the form.
3. To define the change in the diameter, consistency, and thickness of the bark from the base to the top.
4. To define the number, diameter and location of the knots on the surface of the trunks.
5. The received results to be summarized and to formulate a conclusion concerning the possibilities for application of Douglas fir logs for the production of Materials from Massive Wood.

For a sample area was chosen the forestry locality territory of Burzia, municipality of Montana (The Balkan mountain).

The choice of sample trees was carried out according to the requirements of the BDSISO 4471, five trunks were pruned and cut in sections with the length L_{TP} =4 m. The received sections were suitably numbered with the aim to keep their natural order and location in the contents of the trunk by defining the direction North-South in the contents of the trunk. The chosen samples of trees were of 25 years of age with mean sizes by height and diameter for the seedling with straight and slim trunks and without ostensible outer defects. On figure 1 are presented work moments from the choice and harvest of sample trunks.

Figure 1: Work moments from the harvest and definition of the size-quality characteristics of sample trunks

On each and every sample trunk was worked out a work scheme on millimeter paper. On each and every line meter from the trunk were measured: the two perpendicular to each other diameters with and without bark. It was found out the presence/absence of defects of the wood and the form of the trunks. Each section with the length of 1 m was researched for the presence, distribution and measures of defects according to the

BDSEN 1927-3 as: knots (size, type), decays, crooked in growth (slant of the fibers); cracks from freezing, traces from insects, colorings, curves. The data from the research of the trunks were put on the scheme on the corresponding tables. Schematically, the methods of research and a layout of the sizes and defects have been reflected on fig. 2 and fig. 3.

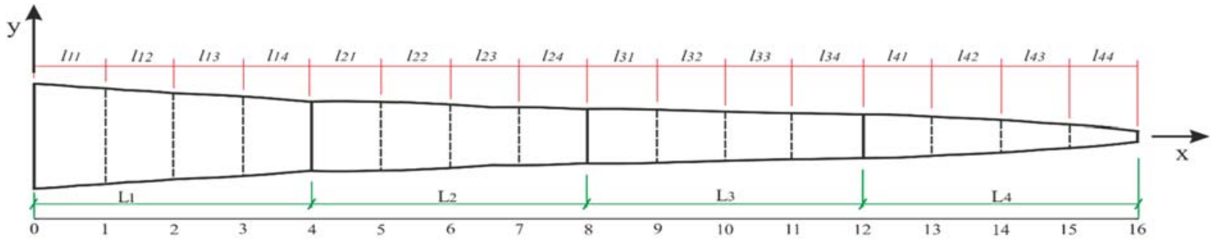

Figure 2: A scheme for the definition of the size characteristics of sample trunks from green Douglas fir

On the trunks and sections were defined the following size characteristics: the length of the trunk, the mean diameter of every linear meter from the length of the trunk, the mean diameter and the consistency of every section with a length of 4 m, the width of the bark of each and every linear meter. The following formulas are used:

- for mean diameter of the cross section of the parts with a length of 1m through the measured two mutually perpendicular diameters d_1 and d_2

$$\boldsymbol{d}_{\text{cp}\,\boldsymbol{i}} = \frac{\boldsymbol{d_{i\,1} + d_{i\,2}}}{\boldsymbol{2}}, \boldsymbol{cm} \qquad \textbf{(1)}$$

- for the mean diameter of the section with the length 4m

$$\boldsymbol{d_{av\,i}} = \frac{\boldsymbol{d_j + D_j}}{\boldsymbol{2}}, \boldsymbol{cm} \qquad \textbf{(2)}$$

- for the consistency of the sections

$$\boldsymbol{s} = \frac{\boldsymbol{D - d}}{\boldsymbol{L_s}}, \boldsymbol{cm.m^{-1}} \qquad \textbf{(3)}$$

- for the volume of the sections without the bark with the length 4m (formula of Huber)

$$\boldsymbol{d_s} = \frac{\boldsymbol{\pi.d^2_{av\,j}.L_s}}{\boldsymbol{4}}, \boldsymbol{m^3} \qquad \textbf{(4)}$$

- for the sections with a bark

$$\boldsymbol{d_{s\,b}} = \frac{\boldsymbol{\pi.d^2_{bav\,j}.L_s}}{\boldsymbol{4}}, \boldsymbol{m^3} \qquad \textbf{(5)}$$

- for the 100 contents of the bark in the volume of the sections

$$\boldsymbol{K} = \frac{\boldsymbol{100.(q_{s\,b} - q_s)}}{\boldsymbol{q_{s\,b}}}, \% \qquad \textbf{(6)}$$

In the upper formulas are used the following values:

$d_{i\,1}, d_{i\,2}$ – the two perpendicular to each other diameters of the –section with the length 1m;

d_j, D_j – the diameters correspondingly in the thin and thick end of the j-section with a length of 4m;

L_s – the length of the sections from the contents of the stem(4 m);

$d_{b\,j}, D_{b\,j}$ – the diameters of the j-section with a bark correspondingly in the thin and the thick end.

The received results were summarized and presented in a table and graphic form.

After the measurements done on the pruned trunks from Douglas fir, one of the model trunks was cut into sections with the lengths of 1m by each and every linear meter from the base to the top was taken one wheel (Fig. 3) with a width 70 mm. The aim of this study is to trace how the humidity and the density of the wood in the different parts of the trunk change.

Figure 3: Work moments from the taking of sample wheels

The methods for the definition of the physical indicators humidity and density were according to the accepted standards: BDS ISO 3130, BDS ISO 3131.

On each of the sample trunks were measured the length and the two perpendicular to each other diameters of each linear meter from the bottom to the top. In the measurements were considered the measurements of the bark too. The aim was to trace the form of the trunk and the contents of bark in the different parts of the trunk and to create a possibility of the form of the trunks and the sections of them.

The received results were summarized and presented in a tabular and graphical form.

In all of the sample trunks after cutting in sections with length 4 m, they were measured as length and the mutually 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 presence of defects on outer traces on the Douglas fir trunks are given in tables from 1 to 5.

From them could be made some more significant conclusions, related to the technology for production of massive wood materials. The chosen sample trunks at the age from 26 to 29 reach the height of 16m in the accepted border diameter 10cm in the thin end. The measured diameters at the base of the trunks are in the borders between from 23 to 32 cm.

From the presented results it could be seen that in the 5 researched trunks the consistency is not equally distributed according to their height. It is the highest at the ground sections (from 0 to 4m) and in the top sections reaches up to 1.7–2.1 $cm.m^{-1}$. In the left middle for the trunk sections it is in the borders between 0.9 to 1.6 $cm.m^{-1}$. The data show clearly that in the correct conduction of the proper forestry activity, the Douglas fir forms trunks with a big value. In combination with the lack of curves (in these trunks are not found simple and complex curves) these data mean lower quantities of the large waste from the cutting of the round wood.

The bark of the Douglas fir represents a comparatively high percentage from their common volume. For 2 of the trunks (*I-II*) the bark represents from 9.20 to 9.92%. For the trunks (*III-V*) this percentage is from 11,81 to 13.37. From the data it could be seen that the percentage of the bark in the lower and higher sections of the trunk as well as he middle is the smallest.

The distribution of the knots on the surface of the trunks is also uneven. As can be seen from the presented results the biggest is the number of the found knots in the top 1–2 sections. The biggest is the middle diameter of the open knots which is in the borders between 2–3 cm but higher values predominate.

The defects of the wood as decays, double heartwood, slant of the fibers and colorings according to outer signs and appearance, limited by the BDS EN 1927-2 were not found. On the surface of some of the stems (*II* and *V*) were noticed traces of wood resin, but they are not from resin channels but from bruised wood, caused by harvest activity.

From the received results it could be said that with the highest quality are the sections from the ground part of the trunks (0 to 4 m). According to the actual standard they could be qualified with a quality A. They are with the biggest diameter. In connection with this these materials should be processed by the classical methods of cutting and to produce materials with high requirements concerning the quality of the wood.

With the highest quality could be evaluated the top sections. They are with the biggest presence of knots (by number and diameter), with the highest consistency, with the highest diameter. These facts make the wood from these sections unattractive for the wood-processing because of the reaching of low quantity and quality harvest of ready production.

Table 1: Size points of *I* model trunk (*L*=12 m, age 26 years)

№ trunk/ section	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	*s*, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	ingrown/not ingrown	*q*, [m³]	*K*, [%]
I.1	25.0	20.8	0.84	69	17	13.7	57/12	0,16	11,44
I.2	20.8	17.0	0.95	87	22	18.9	0/87	0,11	6,25
I.3	17.0	10.4	1.65	72	18	22.9	72/0	0,05	8,57
						Volume of the trunk		*Q*=0.32	*K*=9.20

From the measurements made of the number and size of the knots of the first sample knot it has been found that from 0 to 4 meters the knots are seventeen by linear meter, whereas almost all were grown into the wood. From 4 to 8 meter was observed the largest number of knots around 20–22 by linear meter and the mean diameter among them was from1–2 cm. Big part of the knots in this zone of the trunk were decayed. In the top parts of the trunk, the number of knots are of the 16–18 by linear meter, by all were grown in and with the size 2–3 cm.

Table 2: Size points of *II* model trunk (*L* = 16 m, age 27 years)

№ trunk/ section	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	*s*, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	in-grown/not ingrown	*q*, [m³]	*K*, [%]
II.1	27.0	23.2	0.76	80	20	11.1	64/16	0,20	10,47
II.2	23.2	19.0	1.05	87	22	17.0	0/87	0,14	9,70
II.3	19.0	14.5	1.13	72	18	21.1	0/72	0,09	8,75
II.4	14.5	7.7	1.70	72	18	25.1	72/0	0,04	10,52
						Volume of the trunk		*Q*=0.47	*K*=9.92

In the second sample trunk the number of knots was bigger than the previous. In the first section from 0 to 4 meters big part of the knots were ingrown again. Here is observed almost equal distribution of the knots along the whole height of the trunk, whereas the middle parts (4–12m) their number is the biggest with the biggest diameter 2 cm and more, and almost all were decayed. In the top parts the number of knots by linear diameter reached up to 17–18, with a diameter around 2–3 cm whereas all were ingrown.

Table 3: Size points of *III* model trunk (*L* = 16 m, age 29 years)

№ trunk/ section	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	*s*, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	ingrown/not ingrown	*q*, [m³]	*K*, [%]
III.1	32.0	25.2	1.36	64	15	10.5	55/9	0.27	14.79
III.2	25.2	21.2	1.00	79	20	18.0	0/79	0.17	10.89
III.3	21.2	14.6	1.65	82	21	23.2	0/82	0.10	11.39
III.4	14.6	6.4	2.05	88	22	28.6	88/0	0.04	20.71
						Volume of the trunk		*Q*=0.58	*K*=13.4

Table 4: Size points of *IV* model trunk (*L* = 16 m, age 28 years)

№ trunk/ sec-tion	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	*s*, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	in-grown/not ingrown	*q*, [m³]	*K*, [%]
IV.1	31.5	26.5	1.00	62	15	12.0	50/12	0,26	13,32
IV.2	26.5	23.0	0.87	81	20	19.0	0/81	0,19	11,75
IV.3	23.0	15.0	2.00	85	21	25.0	0/85	0,11	12,73

№ trunk/ section	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	*s*, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	in-grown/not ingrown	*q*, [m³]	*K*, [%]
IV.4	15.0	9.3	1.43	86	22	29.0	86/0	0,05	14,27
						Volume of the trunk		Q=0.61	K=12.8

Table 5: Size points of *V* model trunk (*L* = 16 m, age 29 years)

№ trunk/ section	Diameter of the sections		Change of diameter	Availability of knots				Volume of the logs	Bark
	in the thick end	in the thin end		common numb.	number by linear meter	diameter	type		
	D, [cm]	*d*, [cm]	s, [cm.m^{-1}]	[br.]	[1.m^{-1}]	*d*max, [mm]	ingrown/not ingrown	*q*, [m³]	*K*, [%]
V.1	32.0	24.3	1.54	52	13	12.2	41/11	0.25	8,68
V.2	24.3	21.2	0.76	67	17	18.3	0/67	0.16	14,79
V.3	21.2	15.4	1.45	63	16	23.0	0/63	0.11	14,21
V.4	15.4	9.0	1.60	66	17	28.0	66/0	0.05	12,68
					Volume of the trunk			*Q*=0.57	*K*=11.8

In the third, fourth, and fifth sample trunk the availability of knots was similar. In the knot parts of the trees from 0 to 4 m almost all knots were ingrown, with a diameter up to 1 cm, whereas their number by linear meter reached up to 13–15. With the increase of the height of the trunk, the number of knots increased and reached 19–20 and a mean diameter 1–2 cm. What is characteristic of all the trees is that in this part of the trunk (4–12 m) almost all the knots were decayed. In the top sections12–16 m, their number reached up to 21–22 by linear and middle diameter 2–3 cm.

In graphic outlay (Fig.4 and Fig. 5) are presented the results how the humidity changes and the density of the wood by height of the sample trunk.

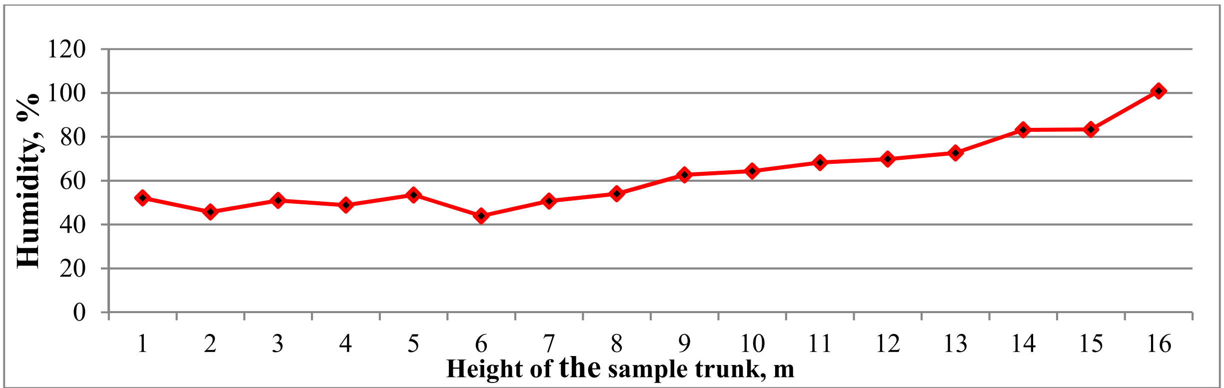

Figure 4: Change of the humidity of the wood from Douglas fir by the height of the trunk

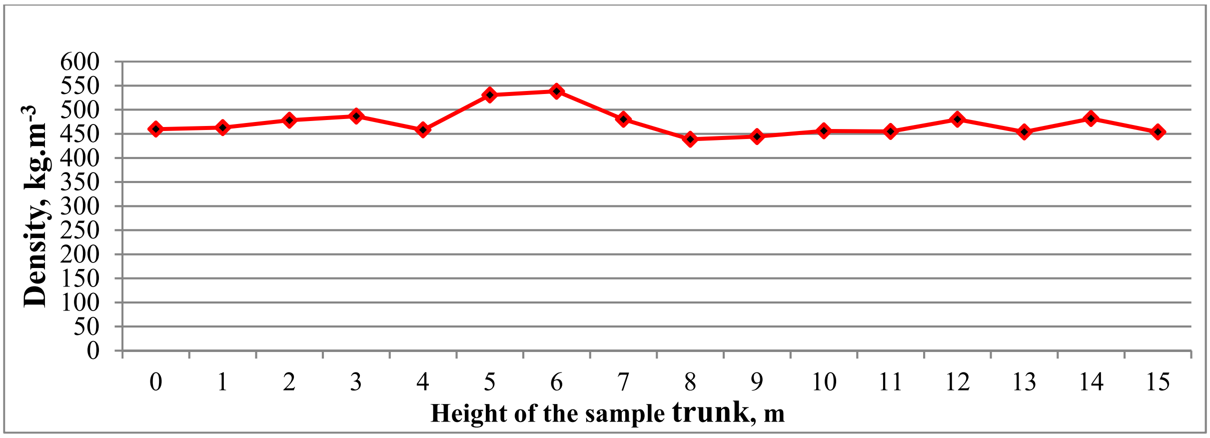

Figure 5: Change of the density of the wood from Douglas fir by the height of the trunk

CONCLUSION

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

1. The diameter of the trunks in the researched sample trees changes from 25 to 32 cm in the thick part of the trunks and reaches the border diameter from 8–10 cm of height 12–16 cm. The researched sample trees could reach cutting maturity in 40–50 years.
2. In all the researched trunks is observed highest consistency in the ground and top sections. In them the consistency is in the borders between 0.8 to 1.7 and in some of the trunks it reaches up to 2.1 cm. Higher are the values in the top sections. In the middle sections the consistency is with higher values from 0.8 to 1.6 $cm.m^{-1}$.
3. The mean percentage of the bark in the researched trunks from Douglas fir is from 9.20 to 13.37%. It is not with the same height along the height of the trunk. The first and the last sections are with the highest percentage of the bark, whereas in some trunks it reaches up to 20.71% in the top sections. The ground sections are also with a high percentage of the bark and reach up to 14.79%. The mean sections (2–3rd sections) are with the lowest percentage of the bark and they are in the borders between 8.75 to 14.79%.
4. The wood density in the ground parts of the trunks from Douglas fir is in the borders from 450 $kg.m^{-3}$ to 490 $kg.m^{-3}$ and in the mid parts it varies from 439 $kg.m^{-3}$ and 540 $kg.m^{-3}$ and in the tops it is in the range from 454 $kg.m^{-3}$–482 $kg.m^{-3}$.

The humidity of the trunks in the ground parts is from 45% to 54% and in the mid sections it is -43 %- 73%, in the top sections it is the biggest from 83% to 101%.

In the research made on the humidity and density of the trees from Douglas fir it is seen that the density of the trunk is the highest in the mid parts of the trunk from 5m to 12m and the humidity is the highest in the top sections from 13 m to 15m where there are the most live branches at a linear meter.

The carried out research on the sizes, the form and the defects of the Douglas fir trunks , the analyses made and the conclusions give the reason to state that the round wood from Douglas fir is one very good raw material for the production of massive wood materials. For the production of large scale materials with a high quality should be used the ground sections, which are with the highest diameter and with the smallest defects of the wood and form.

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