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QUANTITATIVE YIELD IN SAWING THIN LOGS OF SCOTS PINE (*PINUS SYLVESTRIS* L.) FOR PRODUCTION OF DIMENSIONAL LUMBER WITHOUT DEFECTS

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ABSTRACT

This paper presents experimental work results on establishing the quantitative yield of sawing thin round Scots pine (*Pinus sylvestris* L.) logs for production of dimensional lumber without defects. The experimental work was performed on thin logs obtained from the top part of tree stems. These were examined for the presence of the wood defects, their size and number. Following the normal production sequence, the thin logs were sawn into lengths of 500, 800, 1000 and 1200 mm. These, in turn, were plain sawn into boards and after that into dimensional lumber with widths of 3, 6 and 9 mm. The obtained pieces were analysed and conclusions were drawn on the quantitative wood yield depending on pieces' thickness and length. The data allow to evaluate more accurately and objectively the technology and machinery in order to ensure more efficient processing of thin roundwood.

Key words: Scots pine (*Pinus sylvestris* L.), stems, dimensional quality characteristics, materials of solid wood.

INTRODUCTION

In recent years there has been a continuous increase in wood consumption in Bulgaria, resulting in a shortage of wood raw material with the necessary dimensional quality characteristics in some spheres of the wood and furniture industry. Many studies have been carried out by many authors and forecasts predict that large construction timber shortages can be expected in the coming decades (Bonev 2002). By contrast, in the next few decades medium-sized and small construction timber (8–20 cm) is expected to increase its share.

Bogdanov and Tonchev (2011) carried out extensive studies on the structure of the forest territories in Bulgaria for the period 2000–2009. From the obtained data the authors summarized some more important conclusions: during the studied period the coniferous forests decreased their relative share of 33.5% (2000) to 30.6% (2009); the share of broadleaved high-stemmed forests increased slightly (by 1.6%).

One of the most commonly used tree species for the production of solid wood material is Scots pine (*Pinus sylvestris* L.). Given this fact and its great economic importance for Bulgaria, it is natural to aim at better care and management of these forests, at researching and ensuring their more efficient wood utilization.

Recent data from the Executive Forest Agency show that only for a period of half a decade (2010–2015) the area of Scots pine plantations, as well as the area of almost all coniferous trees in Bulgaria, has not only not been preserved, but has even, to a certain extent, decreased. At the same time, the age structure of forests has changed. Table. 1 presents data on forest areas of the most common coniferous tree species in Bulgaria, by age class.

Table 1: Distribution of the forest area of coniferous trees and their distribution by age class for the period 2010–2015

Tree species	Distribution by age class (as of 31.12.2010), ha								
	total	**1–20**	**21–40**	**41–60**	**61–80**	**81–100**	**101–120**	**121–140**	**over 140**
Scots pine	**555123**	**62530**	**248901**	**92942**	**53553**	**60658**	**30041**	**5546**	**952**
Spruce	160408	12595	36202	13838	17241	35754	28794	12218	3766
Austrian pine	287460	38967	146913	73462	12406	7856	4903	1877	1076
Total conifers	1071283	119273	450339	187824	89051	115112	73697	25308	10679
	Distribution by age class (as of 31.12.2015), ha								
Scots pine	**553612**	**50104**	**215514**	**132465**	**51907**	**61437**	**33916**	**7165**	**1104**
Spruce	161298	9272	31891	19457	17042	33923	31157	14060	4496
Austrian pine	275470	21010	118695	103632	15306	8370	5329	2006	1122
Total conifers	1054350	84126	379820	265094	89916	113610	80550	28796	12438

The data presented show that the area planted with Scots pine forests represents 52.5% of the total area of coniferous species. For the period under review (2010–2015) the total area decreased by approximately 1510 ha. At the same time, however, it should be noted that the largest area of Scots pine was in the 20–40 age group – 38.9%. The age class of 41–60 years represented 23.9%, and the class of 81–100 years – 11.1% and the rest of the age classes had a significantly lower share.

Under the conditions of intensive reduction of the tree diameter, it is necessary to look for methods and technologies for efficient utilization of thin roundwood in order to obtain products that satisfy the needs of the market.

A major drawback of undersized logs is the presence of multiple knots, the large percentage of juvenile wood (Blaskova 2005) and others. It should be noted that the quantitative and qualitative yields after processing are very low and therefore such timber is not particularly preferred by consumers.

This paper aims at presenting the results of investigation on the size and availability of defects in thin pine logs. They will be an important foundation and prerequisite for defining optimal methods and schemes for more efficient sawing of thin roundwood and for the application of technologies and machines for initial roundwood processing.

METHODOLOGY

The following tasks have been accomplished to meet the stated goal:

- The top sections (L = 4 m) of Scots pine stems were cut into boards and checked for the presence, location and size of wood defects;
- The obtained longitudinal sections were further sawn using the following methods: *longitudinal-transverse* sawing and *transverse-longitudinal* sawing, into pieces with widths of b = 30, 60 and 90 mm and lengths of l = 500, 800, 1000 and 1200 mm.
- Depending on the width and length of the pieces, calculations were made of the quantitative yield for all pieces

and for the pieces without defects relative to the volume of the longitudinal sections as well as to the volume of the logs.

Technological processes for dimension lumber production can be divided into three phases according to the obtained dimension after each phase. The first technological operation involves initial sawing of logs into boards. The second phase covers sawing the boards into the required length. The third technological phase focuses on formation of the dimension of thickness (width). The final quantitative yield will depend on wood losses during the formation of each dimension (Trichkov 1993).

The experimental work was carried out on the territory of Yundola Training and Experimental University Center. After the initial measuring of the dimensional characteristics of the thin logs, they were plain sawn, following the normal technological sequence, into boards of equal thickness (Figure 1).

Figure 1: Experimental samples of roundwood and resulting longitudinal sections

The presence of a large number of defects in thin roundwood leads to difficulty in obtaining lengths of $l \geq 25 \div 30$ cm without defects using the traditional sawing methods in the production of glued wood materials.

For this reason, the adopted methodology involved sawing longitudinal sections using the following methods: *longitudinal-transverse* sawing and *transverse-longitudinal* sawing (Figures 2 and 3), into pieces with predetermined lengths of l = 500, 800, 1000 and 1200 mm. The results of the two methods were compared and presented in tables.

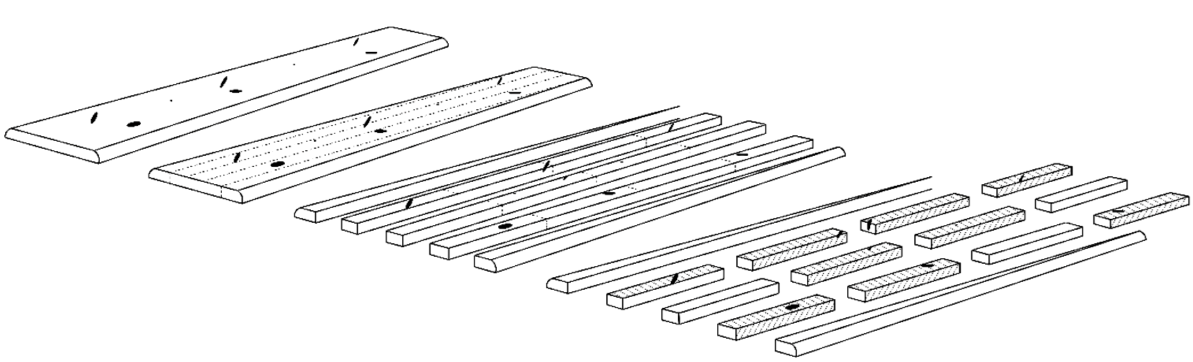

Figure 2: Longitudinal-transverse sawing

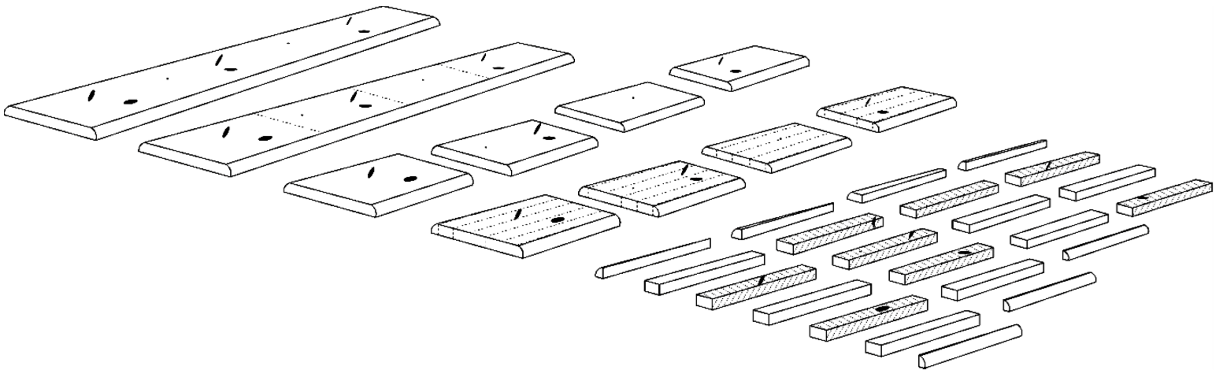

Figure 3: Transverse-longitudinal sawing

The practice is to calculate the width of an unedged board at its two ends as half of the total of the widths of its outer and inner sides.

$$\boldsymbol{b}_{\text{cp}} = \mathbf{0,5}(\boldsymbol{b_1} + \boldsymbol{b_2}),$$

where:

b_1 – the width of the inner side of the board at its narrow end, m;

b_2 – the width of the outer side of the board at its narrow edge, m.

In order to achieve maximum yield in sawing edged boards into dimension lumber, it is necessary for the following conditions to be met:

$$B = \sum_{i=1}^{m} (b_i + H + t) = m(b + H) + (m + l)t,$$

$$L = \sum_{j=1}^{n} \left(l_j + H_l + t_1\right) = n(l + H_l) + (n + l)t_1,$$

where:

b_i – width of the pieces, m;

l_j – length of the pieces, m;

H – shrinkage allowance and allowance for shrinkage and further board width processing, m;

H_l – provisional allowances for board length processing, m;

t – saw width of transverse sawing, m;

t_1 – saw width of longitudinal sawing, m;

B – board width, m;

L – board length, m;

m, n – number of pieces after transverse and longitudinal sawing.

Quantitative yield will depend on the transverse and longitudinal saw widths, on the board width and on the respective allowances. It can be calculated with the equation:

$$\boldsymbol{R} = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} \boldsymbol{b_i l_j}}{\boldsymbol{BL}} \mathbf{100}, \%$$

For unedged boards the thickness of the pieces is predetermined and the optimal lengths following *transverse-longitudinal* sawing can be determined on the basis of the number of pieces, *n*.

Fig. 4 presents the sawing technique using the adopted methodology:

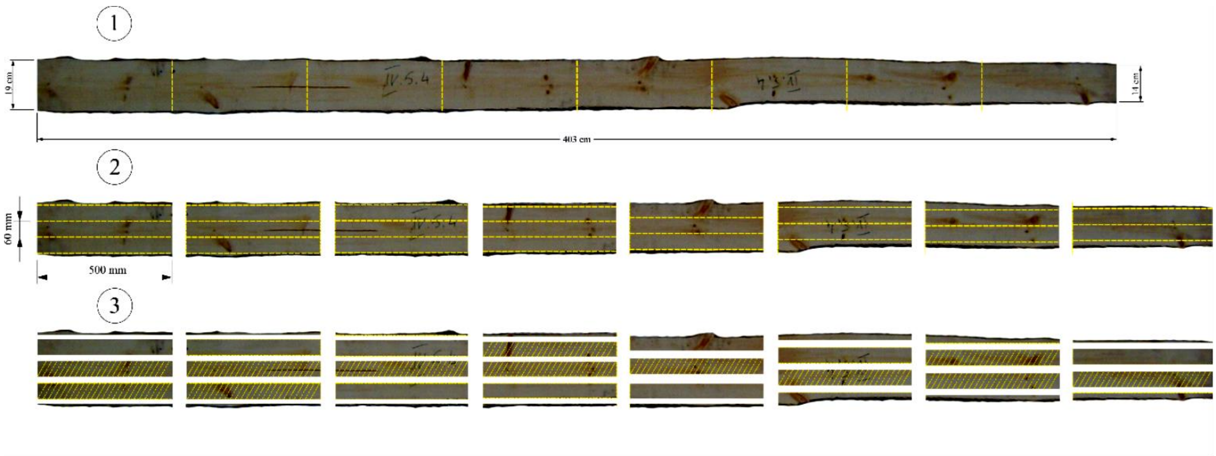

Figure 4: Sawing technique using the adopted methodology (transverse-longitudinal sawing)

In the discussed case the quantitative yield of pieces without defects reaches R = 31.4%. In this case all pieces have the same length (l = 500 mm), which greatly facilitates their grading and subsequent processing. It is obvious, from Fig. 4, that a considerable part of the pieces has defects unacceptable by the standard for the production of engineered wood. It is possible to use such pieces (with defects) as intermediate layers for the purpose of maximum and efficient wood utilization.

RESULTS AND DISCUSSION

The summarized results on the quantitative yield for all pieces and for the pieces without defects by pieces' width and length for the different sawing sequences are presented in Table. 2. The results are calculated for the top part of a tree stem, *I*, with a height of 20 - 24 m. The log dimensional characteristics are d_{TK} = 10 cm и q = 0.056 m^3. The data for other parts have similar values.

The data analysis after sawing the top section of an *I* tree stem (Table 2) shows that the greatest number of pieces and pieces without defects was obtained using the *transverse-longitudinal* sawing method. When sawing longitudinal sections into pieces with width and length of b = 30 mm and l = 500 mm, the results show that in the case of *transverse-longitudinal* sawing, the quantitative yield (R_{all} = 65.8% – 100 pieces) increased by 10% compared to that of *longitudinal-transverse* sawing (R_{all} =56.1% - 86 pieces). The tendency is the same for qualitative yield: for the *transverse-longitudinal* sawing method – $R_{without\ defects}$ = 30.9% (47 pieces) and $R_{without\ defects}$ = 20.4% (31 pieces) for the *longitudinal-transverse* sawing method.

Table 2: Quantitative yield by pieces' width and length for the different sawing sequences

b, mm	l, mm	Pieces: total amount, [number of pieces]	Pieces: without defects, [number of pieces]	Quantitative yield, [%]: to volume of boards R_{all}	to volume of boards $R_{without\ defects}$	to volume of logs R_{all}	to volume of logs $R_{without\ defects}$
		Sawing method: ***Longitudinal - transverse method***					
30	500	86	31	65.0	23.7	56.1	20.4
	800	54	15	65.3	18.9	56.8	15.8
	1000	40	8	64.5	13.1	56.6	10.5
	1200	34	6	62.8	12.3	55.1	9.7
		Sawing method: ***Transverse – longitudinal method***					
30	500	100	47	76.4	37.2	65.8	30.9
	800	54	15	72.0	30.6	62.1	25.3
	1000	45	12	68.1	19.4	59.2	15.8
	1200	37	9	67.7	18.2	58.8	14.6
		Sawing method: ***Longitudinal – transverse method***					
60	500	36	6	53.9	8.9	47.4	7.9
	800	21	1	51.4	2.2	45.1	2.1
	1000	16	1	50.1	2.6	44.7	2.6
	1200	14	1	49.9	3.2	44.2	3.2
		Sawing method: ***Transverse – longitudinal method***					
60	500	44	11	66.7	16.9	57.9	14.5
	800	24	3	58.2	6.8	50.5	6.3
	1000	16	1	50.1	2.6	44.7	2.6
	1200	16	2	59.1	7.0	50.5	6.3
		Sawing method: ***Longitudinal – transverse method***					
90	500	21	1	47.3	3.3	41.4	2.0
	800	12	-	41.5	-	37.9	-
	1000	9	-	43.9	-	37.1	-
	1200	6	-	37.6	-	33.2	-
		Sawing method: ***Transverse – longitudinal method***					
90	500	26	3	60.2	7.4	51.3	6.1
	800	16	-	59.1	-	50.5	-
	1000	12	-	55.5	-	47.4	-
	1200	10	-	55.5	-	47.4	-

The differences in the relative share of the total amount wood pieces for the sawn pieces with widths of 30 mm, 60 mm and 90 mm are insignificant. In the case of sawn pieces with a width of *b* = 30 mm and a length *l* = 500 mm, the total amount of wood pieces (R_{all}) is 65.8% (100 pieces), of *b* = 60 mm – 57.9% (44 pieces) and of *b* = 90 mm – 51.3% (26 pieces). This reduction in quantitative yield for pieces with different widths but with a constant length is due to the fact that the longitudinal boards have a very high degree of tapering (s = 1.8÷2.0 cm.m^{-1}) and the narrow end of the board does not allow obtaining pieces with the required width, especially when the width is 60 and 90 mm. For this reason, part of the wood is lost in the form of trimmings and slabs.

CONCLUSIONS

The following major conclusions can be drawn from the investigation:

- Traditional sawing methods for the production of engineered wood are not particularly suitable. A large number of pieces with a very small length is obtained, which makes it difficult for subsequent technological operations.
- By applying the adopted methodology for sawing thin roundwood for

the production of dimension lumber without defects, more efficient wood utilization is achieved using the *trans-verse-longitudinal* sawing method.

- The highest quantitative yield is obtained for pieces with a width of b = 30 mm and a length of l = 500 mm. The total number of pieces in this case reaches 100, the quantitative yield in relation to the wood volume of the logs being R = 67.6%, and for the pieces without defects – 46 pieces and R = 31.3%.

In order to efficiently and profitably process thin and undersized roundwood, several things have to be taken into account. On the one hand, thin logs with a diameter of 10–14 cm are relatively more accessible and cheaper. On the other hand, their processing is associated with low productivity, respectively high labor costs and low quantitative yield. It is necessary to calculate precisely enough the cost of sawing.

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