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THE ANALYSIS OF CONIFEROUS LOGS TOP DIAMETER MEASUREMENT ACCURACY USING HARVESTER AND 3D SYSTEMS

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Abstract: *High productivity and more value-added production are the main strategies of the Latvian sawmills as sawing the appropriate products from each log has always been actual for each sawmill. The requirements of sawn timber specification have been used for the preparation of the roundwood specification, where top diameters, maximum diameters and length parameters have been determined. These parameters have been studied in a harvesting task where, for each top diameter group, the appropriate length dimensions were identified. Log recovery was organized by adjusting the cuts to each log according to sawn timber specifications. Therefore, almost all larger sawmills in Latvia are presorting the logs by the top diameter values divided in groups, often resulting in rejection or size reduction when the parameters measured by the sawmill's 3D systems do not agree to the specifications. The goal of this study was to evaluate the effect of a harvester calibration system on the accuracy of coniferous logs top diameter measurements (under bark) by measuring the diameters in short intervals using electronic 3D systems.*

Key words: *harvester calibration, coniferous logs, top diameters.*

1. Introduction

The successful use of both, harvester measurement system and electronic 3D measurement system in sawmills is dependent on regular control, calibration and maintenance. Control process includes checking and correcting by measuring the same logs with the above-mentioned measuring systems and then with a tape and caliper. Data from measurement systems as under-bark volume is used for payment of contractors and forest owners. Because of that, measurements are made as over bark (o.b.) volume and converted to under bark (u.b.) data using bark thickness equations. The results of such measurements are used to optimize bucking in relation to a given price list. A good correspondence between order and delivery is crucial for the roundwood value.

Skogforsk has recently developed new instructions [3], which regulate the accuracy requirements of the harvester measurement system (Table 1).

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The accuracy requirements Table 1

Variable	Require-ments
Diameter (o.b.) [mm]	
Systematic max. diameter deviation [mm]	3
Measurements within 4.0 mm, Min. Level [%]	50
Standard deviation. Max.level [mm]	7
Actual lenght [cm]	
Systematic lenght deviation [cm]	2
Measurements within 2.0 cm, min. Level [%]	70
Standard deviation. Max.level [cm]	3

Previous studies have shown that serious deviations between the diameter and length measurements appear when the same roundwood assortments are measured by harvester and 3D measurement systems [3], [4] and [5]. Most of the sawlogs harvested according to a pricelist result into a different diameter group following the measurements done in sawmills. As a result, the probability of diameter group parameters as being specific to the harvested roundwood to correspond to diameter groups measured by electronic measurement systems is sequential (Table 2) [3].

Measurement conformity Table 2

Species	Diameter group interval [mm]					
	5	10	20	30	40	50
	Conformity of harvested logs [%]					
Scots pine	24	45	69	79	85	87
Norway spruce	32	55	77	85	89	91

According to Skogforsk's research [3] the main reasons, which impact the measurement accuracy, are shown in Table 3.

The main sources, which generate errors of the harvester measurement system are the following:

A. The algorithm used by the measuring system

For instance, John Deere harvesters use a system of measurement that measures diameters every centimeter while the volume is calculated based on 1-dm sections from the smallest diameter of each section (Fig. 1).

When stems with shape defects are harvested it could be possible that the smallest diameter measured in any section of a log to be smaller than the log's top diameter.

Sources of errors Table 3

		Standard deviation on diameter group [mm]				
Scots pine		**Diameter group [mm]**				
Source of error		**125-175**	**176-225**	**226-275**	**276-325**	**Average**
Harvester measuring and feeding equipment		6.3	7.2	7.1	6.7	7
Scratch of bark	summer	2-4	2-4	2-4	2-4	2-4
	winter	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2
Thickness of bark		0.5-2	0.5-2	0.5-2	0.5-2	0.5-2
Ovality		1.8	2.1	2.5	3.4	2.3
Norway spruce		**Diameter group [mm]**				
Source of error		**125-175**	**176-225**	**226-275**	**276-325**	**Average**
Harvester measuring and feeding equipment		5.5	5.5	5.5	5.5	5.5
Scratch of bark	summer	2-3	2-3	2-3	2-3	2-3
	winter	0-1.5	0-1.5	0-1.5	0-1.5	0-1.5
Thickness of bark		0-2	1.5-2.5	2-3	3-4	2.4
Ovality		1.4	1.5	1.7	2.3	2.1

Fig. 1. *Example of Timbermatic principles of controlling head diameter measuring, where* $D_{min} \geq D_{top}$

B. Thickness of bark

According to research related to the bark thickness estimation for different species of pine [9] and [12], intraspecific bark thickness variability is influenced by genetics, tree size, position along the bole and site factors. The research results [10] show that latitude as a factor is significant to predict Scots pine bark thickness. Also, the bark thickness is usually larger in summer time than in winter when the trees are frozen [7]. Unfortunately, the studies addressing the bark thickness are limited for coniferous species in Latvia [2] and [5]. Therefore, the bark thickness Equations (1-4) designed in Sweden are used in Latvian forest industry.

When Scots pine roundwood is manufactured, the results of under bark measurements are always doubtful because bark thickness varies on different parts across a stem [11]. Commonly, a thicker bark is found near the base of the stem and it decreases with the increasing height on the stem. Bark thickness depends on the type of wood and genetic features of each individual tree. Nevertheless, the harvester measurement system uses the Equation 2 and 4 to estimate the middle double bark thickness.

In sawmills, the same logs are the subject of measurements done according to the methods of appreciation of bark type, bark presence on logs surface (Table 4) and the use of three double bark thickness Equations (1-3):

- thin double bark thickness - *Bp*, mm (smooth texture):

$$Bp = 2{,}07+0{,}0175 \times D \qquad (1)$$

- middle double bark thickness - *Bv*, mm (intermediate texture):

$$Bv = 1{,}97+0{,}0354 \times D \qquad (2)$$

- thick double bark thickness - *Bb*, mm (strong or very coarse texture):

$$Bb = 5{,}23+0{,}0477 \times D \qquad (3)$$

where:

D is the diameter of round wood measured over bark [mm].

When Norway spruce round wood is manufactured, the middle double bark thickness Equation (4) is used:

$$Bv = 3{,}08+0{,}0404 \times D \qquad (4)$$

Table 4

Appreciation of actual bark type

Species	**Scots pine**			
Bark type	Without bark	Thin bark	Middle bark	Thick bark
Thin bark [%]	0	60<		
Middle bark [%]	0	30<	90<	
Thick bark [%]	0	30<	60<	90<
Species	**Norway spruce**			
Bark type	Without bark		Middle bark	
Middle bark [%]	0		60<	

C. Bark presence on logs surface

Harvester measurement system calculates the bark thickness using the over bark diameter and double-bark thickness equations. Then, it uses the results to estimate the diameter of a given roundwood assortment and its under-bark volume. However, in many stages of roundwood processing assortments are being debarked by the feeding rollers, prunning equipment etc.

Therefore, in sawmills each of the incoming logs is being appreciated according to actual bark type and its presence on the log surface (Table 4) [12].

2. Study Goal

The goal of this study was to evaluate the impact of the harvester calibration on the accuracy of coniferous logs top diameter measurements by taking into account the sources of errors specific to the harvester measurement system. The following objectives were set to achieve the study goal:

(i) to check the measurement accuracy of the harvester John Deere 1470D ECO111 measuring system (harvester head: HD 758; measuring equipment: TimbermaticH 300; caliper version: SKALMAN 5.16) and electronic 3D scanner Microtec according to requirements of model of volume calculation developed for Swedish roundwood [6], technical requirements of harvester measuring systems (Ktr-file) and electronic 3D scanners;

(ii) to evaluate the bark type according to methodology (Table 4) in the process of roundwood measuring in sawmill;

(iii) to investigate the bark thickness impact on roundwood volume estimates;

(iv) to check and evaluate the measurement accuracy of harvester measuring system by collecting and analyzing the measurement data of each log processed on site (Pri-file) in relation to the measuring results of the identified logs in sawmill by measuring diameter in short intervals using 3D systems;

(v) to collect and analyze the harvester measurement (Pri-file) data in connection with automatically measured parameters of all coniferous logs harvested according to the specifications (Table 3) and

(vi) to analyze the measurement results.

3. Materials and Methods

A field study was carried-out in august of 2016, in Kurzeme region of Latvia. A felling area was chosen - Myrtillosa mel - where the following tree species were harvested: 60% spruce, 10% pine, 10% birch, 10% black alder.

A John Deere 1470D ECO111 harvester equipped with a HD 758 head and a Timbermatic H300 productionmanagement system was used to fell and process the trees.

4. Results and Discussion

A specification of the roundwood assortments is given in Table 5.

All of the calibrated measuring devices ensured a measuring accuracy in line with the requirements of LVS 82: 2003 standard and with the technical requirements of 3D and harvester measuring systems. The log-length was determined with an accuracy 1cm in case of 3D systems and with an accuracy 3cm for the harvester measuring devices; the diameter was determined with an accuracy 1mm in case of 3D systems and with an accuracy of 3mm in case of harvester measuring devices. The results of the 3D scanner control measurements are given in Table 6.

The harvester measuring system was checked by an independent auditor and the results were as follows: 53% of all diameter measurements were included in ±2mm deviation; 82% of all diameter measurements were included in ±4mm deviation; 96% of all diameter measurements were included in ±6mm deviation. For the evaluation of measurement accuracy of harvester and 3D measuring systems, seven Scots pine stems were selected. Following the harvesting, all the logs were numbered to help their identification (Figure 1). The identified logs were recovered according to the specifications (Table 5). The bark type of each log was evaluated according to the methodology used in the process of roundwood measuring at sawmills (Table 4). An example of bark evaluation according to the bark presence on log surface is given in Figure 2.

In the case shown in Figure 2, the top diameter u.b. was of 226mm, bark presence on log surface was of 60-90%, double bark thickness *Bv*, measured by the harvester measuring system was of 10mm (middle) and the double bark thickness *Bp*, measured by the 3D measuring system was of 6mm.

Table 5

Specification of roundwood assortments

Species	**Diameter group [mm]**	**Nominal length [m]**
Scots pine	0 - 100	4.2, 4.5
	100 - 140	3.6
	140 - 150	3, 3.6, 4.5
	150 - 250	3, 3.6, 4.5
	250 - 419	3.6, 4.5
Norway spruce	0 - 100	3.0, 3.6, 4.5
	100 – 140	3.6
	140 - 150	3, 3.6, 4.5, 6.0
	150 - 250	3, 3.6, 4.5, 6.0
	250 - 419	4.2, 4.5

Control measurements of 3D scanner Microtec Table 6

Etalon No.	**VW1182**	**VW1183**	**510173050**	**510174050**	
Etalon length [mm]	3046	4962			
Etalon diameter [mm]			140.5	240.1	
Average [mm]	3044	4964	140.6	240.4	**Accepted [mm]**
Standard deviation [mm]	2.5	2.9			±10
Standard deviation [mm]			0.5	0.6	±1
Maximal positive [mm]	0.3	0.7	0.5	0.6	2
Maximal negative [mm]	0.8	0.2	0.4	- 0.1	- 2

Fig. 2. *An example of evaluation of the bark type according to bark presence on logs surface*

Data of the harvester measurement system was analyzed by comparing it to the measurement results (diameters measured on short intervals using the electronic 3D systems) of the logs identified in the sawmill (Table 7).

The deviation of measured diameter groups using the 3D and harvester measurement systems of the recovered assortments according to the specifications given in Table 5 are shown in Table 8.

The measurement results of identified logs Table 7

Number of Scots pine	7	**Diameter (o.b.) [mm]**	
Number of logs	24	Average	245.3
Number of butt assortments	7	Median	246.5
Net volume by harvester (u.b.) [m^3]	4.6	Standard deviation	6.5
Net volume by 3D scanner (u.b.) [m^3]	4.71	Standard error	1.2
DBH = 1.3 m [mm]			
Average	257	**Diameter (u.b.) [mm]**	
Median	261	Average	219.4
Double bark thickness [mm]		Median	222
Average	7.7	Standard deviation	6.4
Median	6	Standard error	1.2
Standard deviation	2.1		
Standard error	1.4	**Volume (u.b.) [m^3]**	
Actual length [cm]		Average	0.196
Average	452	Median	0.
Median	492	Standard deviation [%]	3.36
Standard deviation	2.2	Standard error [%]	0.64
Standard error	0.4		

The deviation of measured diameter groups Table 8

Species	Diameter group [mm]	Nominal length [m]	3D measurement results [m^3/ pcs]	Harvester measurement results [m^3/ pcs]	Harvested diameter groups [%]	Deviation [%]
Scots pine	0 - 100	4.2, 4.8	0.45/ 11		0	0.457
	100 – 139	3.6	0.07/ 1		0	0.07
	140 - 180	3, 3.6, 4.8	5.17/ 58	7.43/ 86	18.82	- 2.265
	180 - 280	3, 3.6, 4.2, 4.8, 6	30.91/ 148	30.66/ 144	77.67	0.245
	280 - 419	3.6, 4.8	3.061/ 8	1.38 / 3	3.51	1.681
Norway spruce	0 - 100	3, 3.6, 4.8	0.377/ 6		0	0.377
	100 – 140	3.6	0.219/ 3		0	0.219
	140 - 180	3, 3.6, 4.8, 6	12.66/ 137	14.1/ 152	24.34	- 1.441
	180 - 280	3, 3.6, 4.2, 4.8, 6	36.07/ 194	33.67/ 178	58.2	2.399
	280 - 419	3, 3.6, 4.8	9.23/ 26	10.12/ 29	17.46	- 0.893
Total amount [m^3/ pcs]			98.21/ 592	97.35/ 592		

5. Conclusion

The results of this study indicated the following:

- For the calibrated harvester measuring system, the control results which pointed out that 53% of all measured diameters were included in the ±2mm deviation, 82% of all measured diameters were included in the ±4 mm deviation and 96% of all measured diameters were included in the ±6 mm deviation, were in line with the determined measurement accuracy. Standard deviations reached 6.5mm in diameter (o.b.) measurements when the maximum level of 7mm was determined, 2.2cm in length measurements when the maximum level of 3cm was determined and 2.1mm in double bark thickness measurements when the 2.4mm was proposed [6];
- The measurement conformity of Norway spruce in the diameter group of 140-180mm reached 98.53%, in the diameter group of 180-280mm it reached 102.44% and in the diameter group of 280-419mm it reached 99.09%;
- The measurement conformity of Scots pine in the diameter group of 140-180mm reached 97.69%, in the diameter group of 180-280mm it reached 100.25% and in the diameter group of 280-419mm it reached 101.71%.

References

1. Hannrupo B., Lundgren C., 2012. Evaluation of Skogforsk's new bark equations for Scots pine and Norway spruce. Arbetsrapport. Fran Skogforsk No. 759.
2. Līpiņš L., Liepa I., 2007. Roundwood measurement (in Latvian). In: Jelgava, pp. 18-25.
3. Moller J., Sondell J., 2000. Customer driven assortments call for better diameter measuring: Improvements possible in the forests. In: Resultat – SkogForsk 15(4). The Forest Research Inst. of Sweden, Uppsala, Sweden, pp. 1-4.
4. Nordmark U., 2002. Integrating the bucking operation with production control in sawmilling. Licentiate Thesis. Lulea University of Technology, Sweden.
5. Nordmark U., 2005. Value recovery and production control in bucking, log sorting, and log breakdown. In: Forest Products Journal, vol. 55(6), pp.73-79.
6. Räsänen T., Poikela A., 2007. Spp-file in StanForD.
7. Rongxia L., Aaron R., 2011. Estimating and predicting bark thickness for seven conifer species in the Acadian Region of North America using a mixed-effects modeling approach: comparison of model forms and subsampling strategies. In: European Journal of Forest Research, vol. 130(2), pp. 219-233.
8. Stephens S., Libby W., 2006. Anthropogenic fire and bark thickness in coastal and island pine populations from Alta and Baja California. In: Journal of Biogeography, vol. 33(4), pp. 648-652.
9. Strandgard M., Walsh D., 2011. Improving harvester estimates of bark thickness for radiata pine (Pinus radiata D. Don). In: Southern Forests: a Journal of Forest Science, vol. 73(2), pp. 101-108.

10. Wilhelmsson L., Arlinger J., 2002. Models for predicting wood properties in stems of *Picea abies* and *Pinus sylvestris* in Sweden. In: Scandinavian Journal of Forest Research, vol. 17(4), pp. 330-350.
11. Zweifel R., Hasler R., 2000. Frost-induced reversible shrinkage of bark of mature sub alpine conifers. In: Agricultural and Forest Meteorology, vol. 102(4), pp. 213-222.
12. ***, 2015. SDC instructions for timber measurement (in Swedish).