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Harmonization of Piece-by-Piece Measurement Methods of Roundwood Approved by Latvian Standard LVS 82:2003 "Apaļo kokmateriālu uzmērīšana"

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***Abstract*. This paper analyses the volume differences of mixed pine and spruce roundwood loads and logs (roundwood assortiments) devided in to sample clusters according to the species, diameter, lenght and stem/log surface shape, stem zones and measured by the methods approved by standard LV 82:2003 „Apaļo kokmateriālu uzmērīšana". The volumes of roundwood loads/logs determined by these methods were compared with the most precisious determination of the volume by Measuring Diameter in Short Intervals and the Top and Butt Diameter Measurement method.**

The volume of mixed pine and spruce round timber load determined by Measuring Diameter in Short Intervals using harvester measurement system is 2.44% higher than the volume determined by manual comparative the Top and Butt Diameter Measurement method. The volume deviation is in the range of accepted 3% measuring accuracy.

The volumes of roundwood assortiments from neiloid zone of spruce stems determined according to the Mid Diameter Measurement method are 3.96% lower than the volumes determined by careful manual the Top and Butt Diameter Measurement method. The volume deviation surpass the acceptable measuring 3% accuracy.

The volumes of roundwood assortiments from paraboloid zone of spruce and pine stems determined according to the Mid Diameter Measurement method are lower than the volumes determined by the Top and Butt Diameter Measurement method. The deviation is in the range of acceptable 3% measuring accuracy.

This paper gives recommendations for adjusting the application area of different measurement methods for achieving the volume deviation in the range of accepted measuring accuracy.

***Keywords*: roundwood, piece-by-piece measurement method, volume.**

I INTRODUCTION

Different volume value results are often the reason of doubts about its accuracy and reflecting also relationships between suppliers and processors of wood. The term „true volume" of roundwood is equally actual for both sites.

Every determination of log volume based on the calculation of the volume of geometrical bodies (cyllinder, truncated neiloid, truncated paraboloid) represents only approximation to reality but not its expression. The logs are an irregular body the form and volume of which can be determined by manual or automatical measurement methods or with each other only approximately. The roundwood volume can be calculated using a logical cubic formula and a value achieved by this way represents only "comercial" volume of roundwood. But it is not the same as „true volume" of roundwood. Cubic metre of roundwood measured by the national standard in one country may be different if measured by the national standard of another country.

Some national and subregion roundwood measuring standards treat the log as a cylinder with a diameter of the small end of the log; assume the log forms as a cylinder with the diameter that exists in the middle of the log lenght; or use assumed taper rates to establish diameters other than the small- end of the log; assume the log form is a cylinder with the diameter that exists in the middle of the log lenght; or use assumed taper rates to establish diameters other than the small-end. Some national standarts (Finland, Ireland, UK Hardwood) calculate the over bark volume.

All of these differences can lead to variation in roundwood volume (fig. 1) [3] The figure shows veneer log volumes calculated using thirteen different roundwood measurement standarts[3; 2; 10; 6; 11; 12; 7; 16; 19]. The veneer log size parameters used for volume calculation are following: actual lenght (5.02m); top diameter (232/227mm); middle diameter (253/255mm); butt diameter (278/281mm).

The difference between measuring results by using different national and subregion roundwood measuring standards reaches 40%.

It is known that many of the countries (Finland, Sweden and United States) are going to atjust their national roundwood measuring standard volume to a „true volume" for accuracy, comparability and harmonization of the measurement methods [3].

According to the results of investigation [17] the rate of decline of roundwood volume achieved according to national standard of each country compared with the volume of logs determined by the most precisious determination of the volume by Measuring Diameter in Short Intervals (intervals as cylinders of a length of 10 cm and diameter given in mm) varies from (-) 5.5% (German Rahmenvereinbarung fur die

Werksvermessung von Stammholz, logs of medium diameters) to (-) 9% (Austrian O-Norm L 1021, mid diameter value given in whole cm). Procedures, which give lover deviations are following: (EN 1309-2) from (-) 1.5 to (+) 3%, ONORM L 1021, mm version from (-) 0.7 to (+) 3%, or the ČSN 480050 Standard 480050-1 from (+) 0.3 to (+) 0.8%.

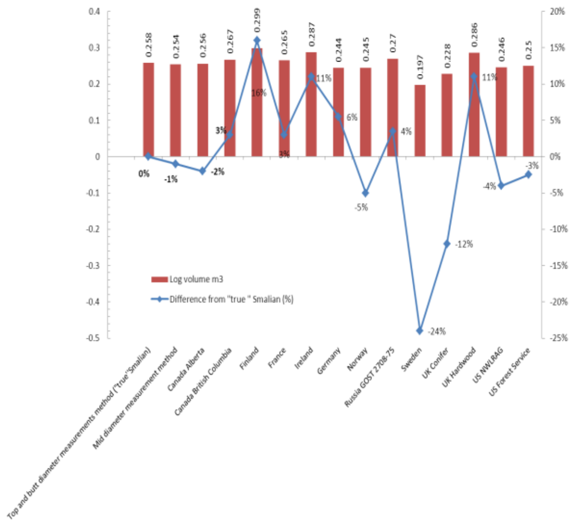


Fig. 1. Veneer log volume comparison between national roundwood measuring standards, where:

NWLRAG – Northwest Log Rules Advisory Group; GOST 2708-75 standard for domestically consumed roundwood in the Russion Federation; UK Conifer- top diameter method, UK Hardwood-mid diameter method

The same problems related to measuring accuracy exist also in Latvia.

The figure 2 shows spruce log (from neiloid zone of stem) volumes calculated using four different measuring methods approved by standard LVS82:2003 [1]. The volume deviation between the measuring results reaches 5%.

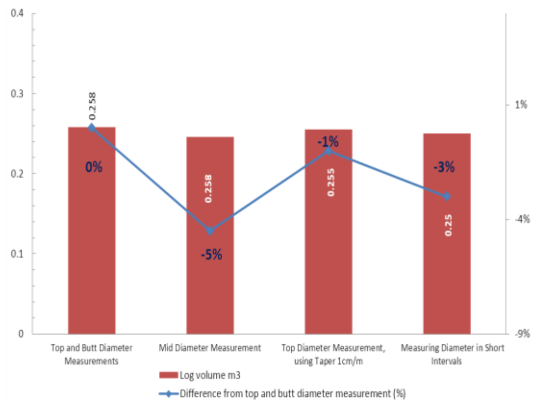


Fig.2. Spruce log volumes calculated using four measuring methods approved by standard LVS 82:2003

When using the measuring methods approved by the standard LVS 82:2003 the term „true volume" of roundwood remain actual for suppliers and processors of wood. The permitted roundwood volume deviation from the actual volume according to standard requirements, using piece-by-piece measurement method, is 3%. In practise, because of some factors it is impossible to carry out this requirement. The factors are following:

A. Stem/ log surface shape

The tree stem/log is a body, the form which is mostly compared to trunckated cone, paraboloid, neiloid or cylinder. The real form does not correspond to any regular geometric body, which is affected by considerable individual diversity given by tree position in the stand, various taper, sweep, flattening, root swelling, buttress and cracks.

According to requirements of standard LVS 82:2003 for automatical piece - by - piece measurement, it is not necessary to identify the log shapes. The piece - by-piece measurement method, approved by standard LVS 82:2003, is used for all frustums of the geometric figure they resemble. Because of simplification of the log surface shape and ignorance of the geometric figure of log the acceptable deviations (+/-) 3% usually are exceeded. The satisfactory results are obtained only for the wide average of the large number of logs but not for particular logs.

B. Stem zone

When the log shape is not a paraboloid the errors given by determination of the volume according to the Mid Diameter Measurement are proportional to log length and the square of the difference between the two diameters, i.e. the longer the log and the greater the taper, the greater is the error. Errors in the volume estimate increase rapidly when the interval between measurements is greater than 5m.

For conic or neiloidic frusta, determination of the volume according to the Mid Diameter Measurement or determination of the volume according to the Top and Butt Diameter Measurements under and over estimate volume respectively. The method undervalues the volume of butt logs while top logs are overvalued [20; 13; 14; 12; 15; 13; 14].

A. The technical parameters of automatical measurement equipment

In Latvia forest sector there are no legislative norm that would determine the requirements for technical parameters of scanning devices, methods of processing the measured data and methods of calculating the logs volume.

The volume of the logs determined by the 2D system are 0,4-0,5% higher than the volume determined by manual comparative measurement. The deviation is in the range of accepted measuring accuracy. The log volume determined by the 3D system are 2.5-5.5% lower than by manual measurement.

The measurement values are affected also by the way of filtration of taken data. Through various types of filtration applied at the same taken data on logs even about 2% deviations are achieved [8].

B. The technical parameters of harvester measurement equipment

Different calculation methods are used in harvesters for estimation butt end diameter values from the first measured values. Butt end values are creating using either linear or non linear functions or diameter coefficient tables. Different harvester models start diameter measuring at different heights of stem. Tests in Latvia have shown that the butt diameters of neiloid zone of stem are not predicted well enough, expecially for spruce species. Because of that the diameters are often underestimated and as the result - the volumes of logs are underestimated [8; 9; 4].

C. Bark thickness and condition according to actual bark type

Because of the different methodology in estimation of the bark thickness in harvesting process and in roundwood processing, the different volume values are obtained. Bark thickness and condition represents the separate problem at the measurement of roundwood [7; 21; 1].

It is impossible to eliminate the differences of measurement results even theoretically. Through the practicable procedure of measurement it is possible to achieve the volume deviation only in the range of accepted measuring accuracy.

For harmonization of the measurement methods approved by standard LVS 82:2003 the adequate tasks have been handled:

To calculate the volumes of mixed spruce and pine rounwood loads and logs devided in to sample clusters according to species, diameter, stem/log surface shape, stem zone and measured by the methods (1; 2; 3; 4.2) (fig. 7) approved by standard LV 82:2003 „Apaļo kokmateriālu uzmērīšana".

To compare the calculated volume values with the results of the most precisious measurement methods by Measuring Diameter in Short Intervals and the Top and Butt Diameter Measurements. To investigate the reasons of the volume deviations.

3. To give the recommendations for achieving the volume deviation in the range of accepted measuring accuracy in each technological stage of roundwood processing.

II MATERIALS AND METHODS

To achieve the aim of the research, three objectives were stated:

1. To control the measurement accuracy of the manual and automatical measuring devices (calliper, girthing tape to measure circumference, log measuring ruler, automatic device etc.) according to requirements of standard LVS 82:2003 and the technical requirements for automatical and harvester measuring systems.
2. To control the estimated thickness of the bark at the point of measuring.
3. To control the algorithm of the volume calculation in each technological stage of roundwood processing.

All calibrated measuring devices ensured measuring accuracy appropriate to requirements of standard LVS 82:2003 and the technical requirements for automatical and harvester measuring systems (fig.3; 4; 5; table1). The length was determined with an accuracy 1cm for manual and automatical measurement devices and 3cm for harvester measuring devices; the diameter was determined with an accuracy 1 mm for manual and automatical measurement devices and 3mm for harvester measuring devices.

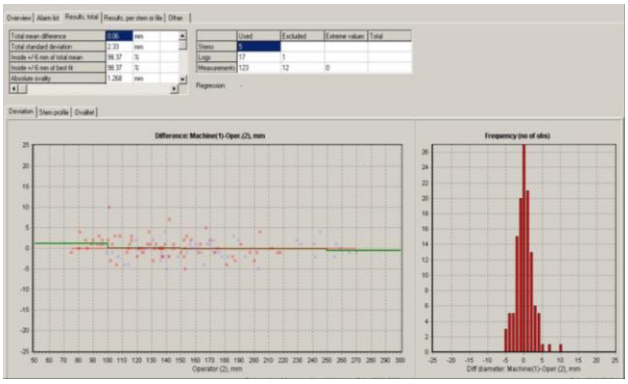


Fig.3. The example of control of the harvester measuring system, where: Stem – 5 control stems; Measurements-123 diameter measurements; Logs- 17 round wood assortiments; Standard deviation- 2.33mm diameter standard deviation

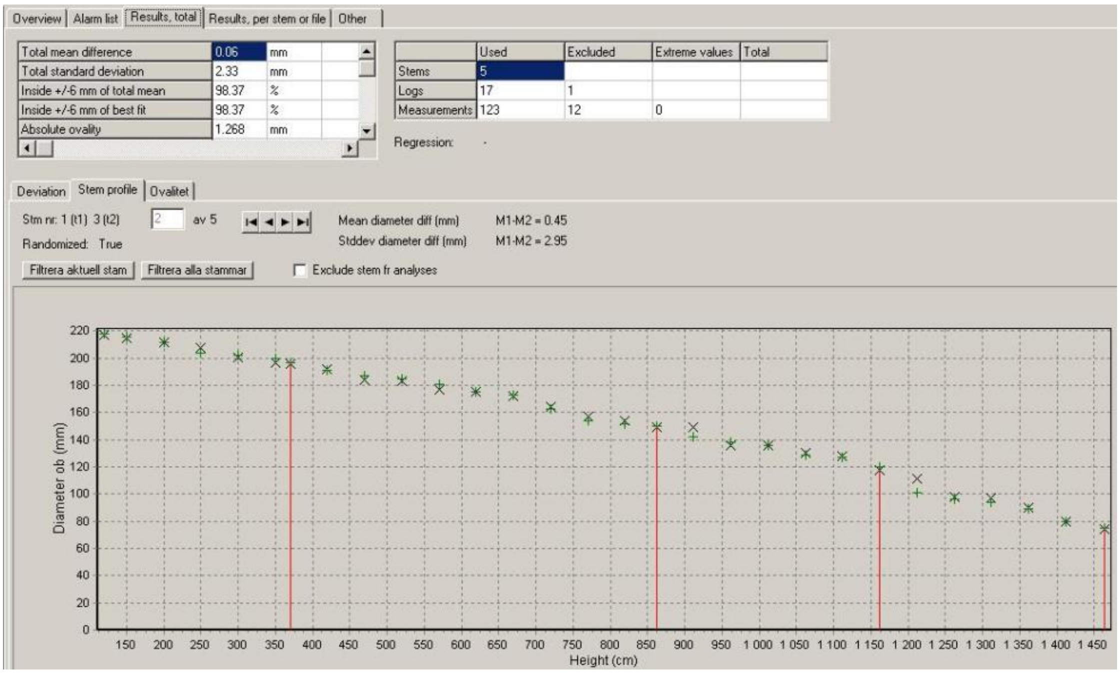


Fig.4. The example of control of the harvester measuring system, where MI- measuring data from harvester measuring system; M2- manual measuring results; Stddev-2.95mm diameter standard deviation

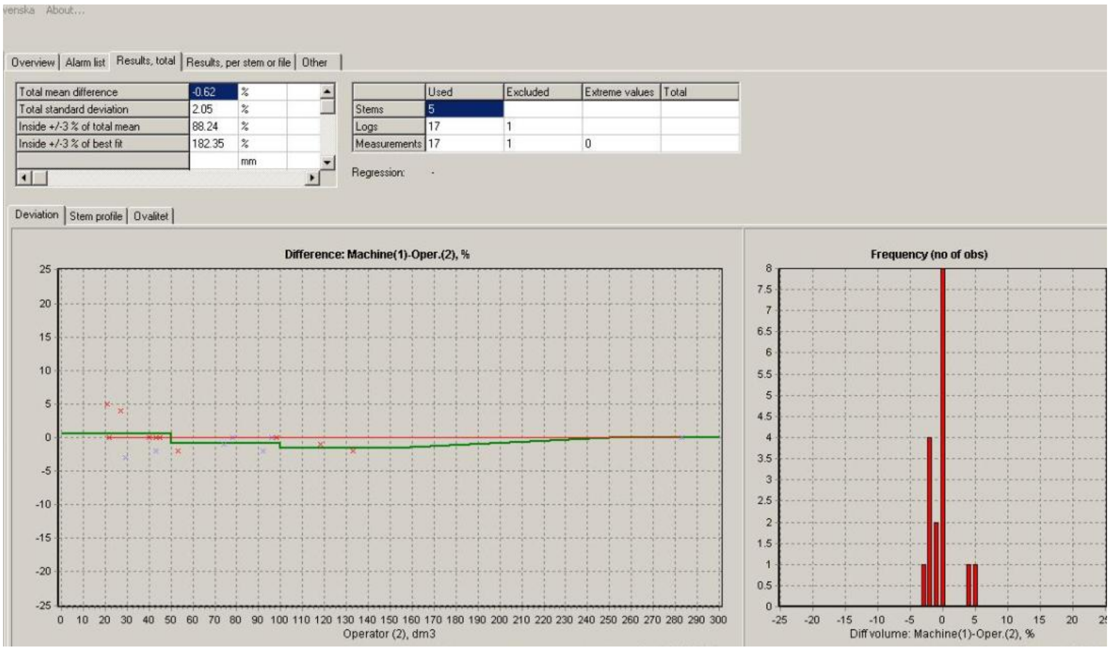


Fig.5. The example of control of the harvester measuring system towards roundwood volume calculation, where volume standard deviation is 2.03%

TABLE 1.

THE EXAMPLE OF CONTROL OF THE AUTOMATICAL MEASURING SYSTEM

Measurement Nr	Etalon Nr /Etalon diameter (mm)						
	51011630	51011730	51011830	51011630	51011730	51011830	
	110.3	200.7	315.5	110.3	200.7	315.5	
1	110.6	200.4	315.0	0.3	-0.3	-0.5	
2	111.1	200.1	314.7	0.8	-0.6	-0.8	
3	111.1	200.1	314.9	0.8	-0.6	-0.6	
4	110.8	200.3	315.0	0.5	-0.4	-0.5	
5	111.4	200.0	314.5	1.1	-0.7	-1.0	
6	110.9	200.0	314.8	0.6	-0.7	-0.7	
7	110.9	200.0	314.8	0.6	-0.7	-0.7	
8	111.1	200.1	314.7	0.8	-0.6	-0.8	
9	110.9	199.8	314.6	0.6	-0.9	-0.9	Accepted (mm)
10	111.0	199.8	314.2	0.7	-0.9	-1.3	
			Average:	0.7	-0.6	-0.8	+/-1
			Standard deviation	0.2	0.18	0.23	
			Maximal positive:	1.1	-0.3	-0.5	+2
			Maximal negative :	0.3	-0.9	-1.3	-2

To achieve the objective, the analitical and experimental investigations, based on different measuring methods (fig. 7), have been performed for spruce and pine logs volume calculation. The logs were devided in to sample clusters according to the top diameters, stem/log surface shape and stem zone which was used for cut-to-lenght logging (fig. 6).

The calculations of deviations betweeen automatical and manual comparative measurement methods were made respectively.

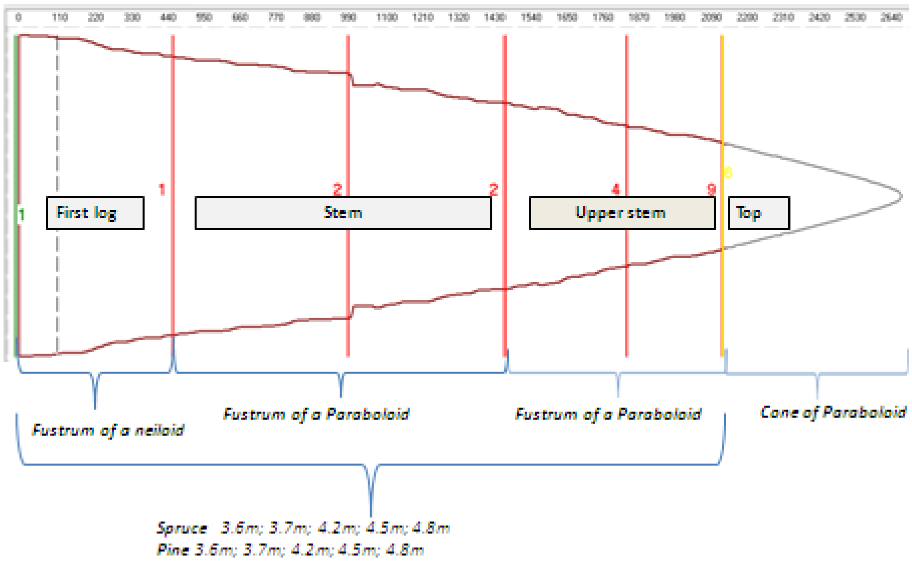
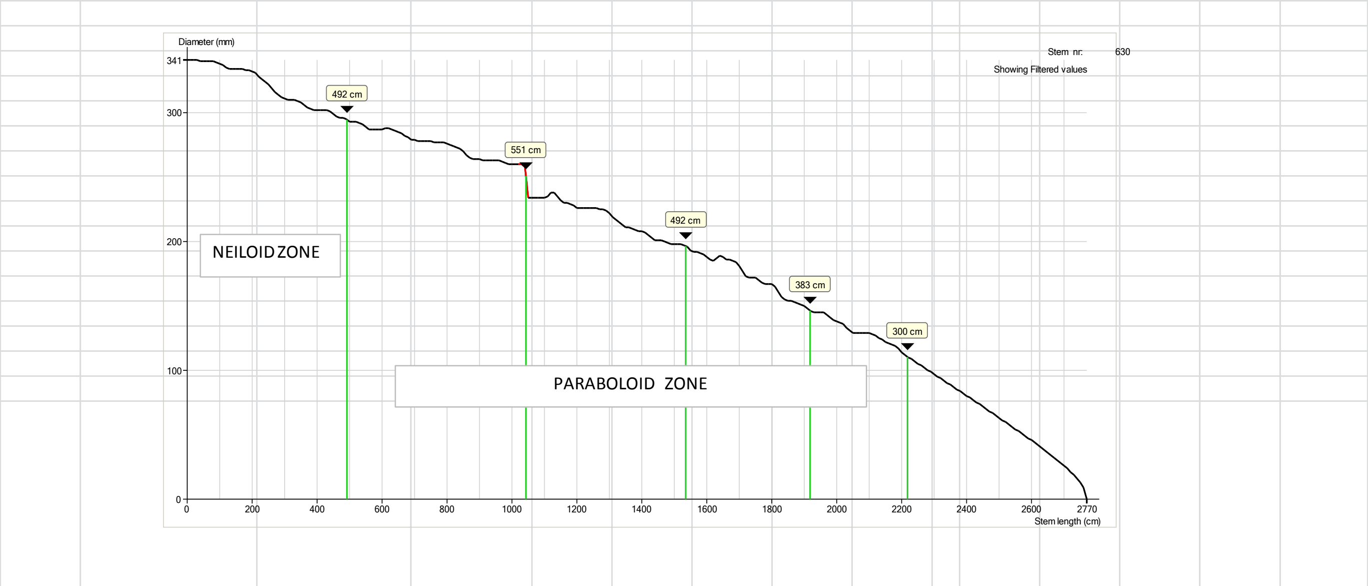


Fig.6. Specification of roundwood assortiments from different stem zone



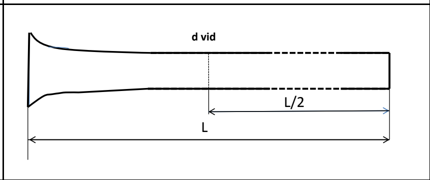
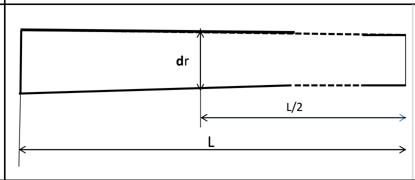
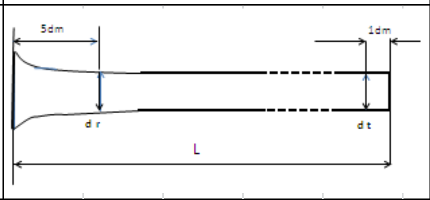
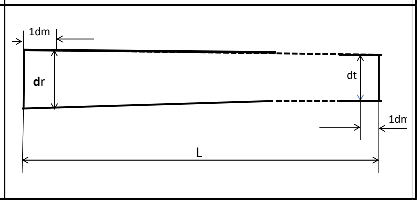
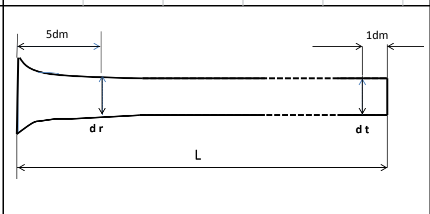
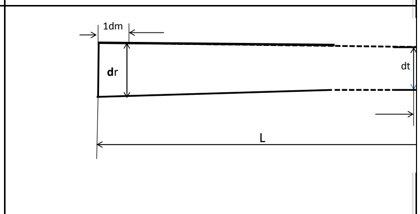
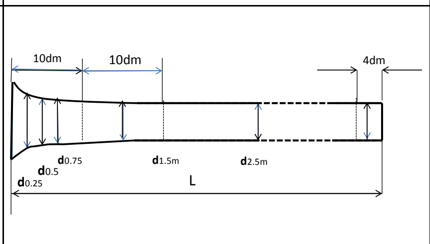
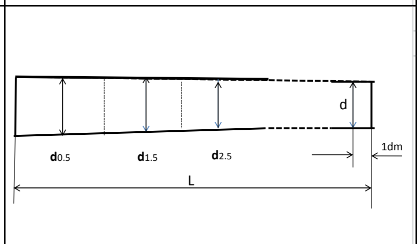
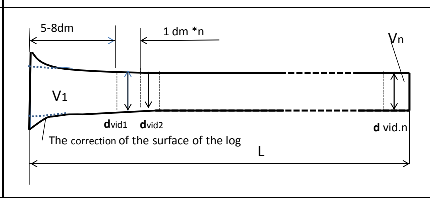
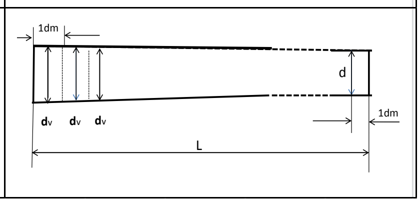
Method	Determination of the Volume	The formula	Measurement method for neiloid zone logs	Measurement method for paraboloid zone logs
1	According to the Mid Diameter Measurement	$V_v = \frac{\pi \times d_v^2 \times l}{4 \times 10000}$		
2	According to the Top Diameter Measurement, Using Taper	$V_t = \frac{\pi \times \left[d_t^2 + (d_t + s \times l)^2\right] \times l}{4 \times 2 \times 10000}$ $s = \frac{d_r - d_t}{l}$		
3	According to the Top and Butt Diameter Measurements	$V_{tr} = \frac{\pi \times (d_t^2 + d_r^2) \times l}{4 \times 2 \times 10000}$		
4.1.	By Measuring Diameter in Short Intervals using electronic 3D systems	$V_s = \frac{\pi \times (d_t \times d_t + d_t \times d_r + d_r \times d_r) \times l}{120000}$		
4.2.	By Measuring Diameter in Short Intervals using harvester measurement systems	$V = V1 + (\frac{\pi \times d_{v1}^2 \times 1}{4 \times 10000}) + (\frac{\pi \times d_{v2}^2 \times 1}{4 \times 10000}) + Vr$		

Fig.7. Methods of measurement approved by standard LVS 82:2003

III RESULTS AND DISCUSSION

The volume values of mixed pine and spruce roundwood assortiments from different zone of stems were calculated according to the measuring methods approved by standard LVS 82:2003. The results were compared with the volume values calculated according to the Top and Butt Diameter Measurements**.**

For volume estimation the different measuring methods were applied (fig. 8) by using manual measuring equipment, harvester measuring system (harvester T1386LH; measuring equipment TimbermaticH 1.13.14.; caliper version: SKALMAN 5.16) and automatical measuring system (3D scanner SAWCO POS A181).

The volumes of roundwood assortiments measured on bark were estimated without bark by using the sequential formulas (1; 2.).

For spruce roundwood assortiments the double bark thickness at the point of measuring were determined:

$$B=3{,}08+0{,}0404Xd \qquad (1)$$

where: D – diameter of roundwood assortiment, mm.

For pine roundwood assortiments the double bark thickness at the point of measuring were determined:

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

where: D – diameter of roundwood assortiment, mm.

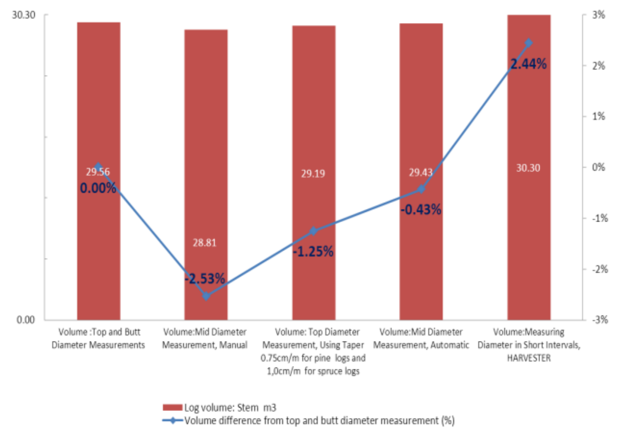


Fig.8. Roundwood load volume comparison using measuring methods approved by standard LVS 82:2003, where the taper values for pine assortiments (14-17.9cm; 18-27.9cm)-0,75cm/m; for spruce assortiments (14-17.9cm; 18-27.9cm)-1.0cm/m

The results of measuring are sequential:

The volume of roundwood assortiments determined according to the Mid Diameter Measurement method was 2.53% lower than the volume determined by the Top and Butt Diameter Measurement method.

The volume of roundwood assortiments determined according to the Top Diameter Measurement method, using Taper was 1.25% lower than the volume determined by the Top and Butt Diameter Measurement method.

The volume of roundwood assortiments determined according by Measuring Diameter in Short Intervals was 2.44% higher than the volume determined by the Top and Butt Diameter Measurement method.

The volume of roundwood assortiments determined according to the Mid Diameter Measurement method was 4.97% lower than the volume determined by Measuring Diameter in Short Intervals.

The volume of roundwood assortiments determined according to the Top Diameter Measurement method, using Taper was 3.69% lower than the volume determined by Measuring Diameter in Short Intervals.

For the volume estimation of debarked pine roundwood assortiments according to stem/ log surface shape the sample cluster was prepared. The log surface were trunckated paraboloid. The volume of sample cluster was estimated by automatical measuring system Sick Optik Electronic 5000079. The volume of the roundwood assortiments arranged in to diameter groups were calculated automatically according to the algorithm approved by the measuring methods (1; 3) (fig. 7). The results are given (fig. 9).

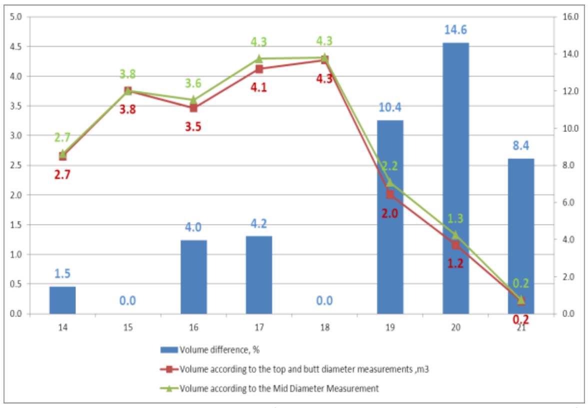


Fig.9. The volume results of pine roundwood assortiments from paraboloid zone of stems, devided in to diameter groups and estimated according to the Mid Diameter Measuring method and the Top and Butt Diameter Measuring method

The roundwood volume values from paraboloid zone of stems estimated according to the measuring method (1; 3) (fig. 7) are given (fig. 10)

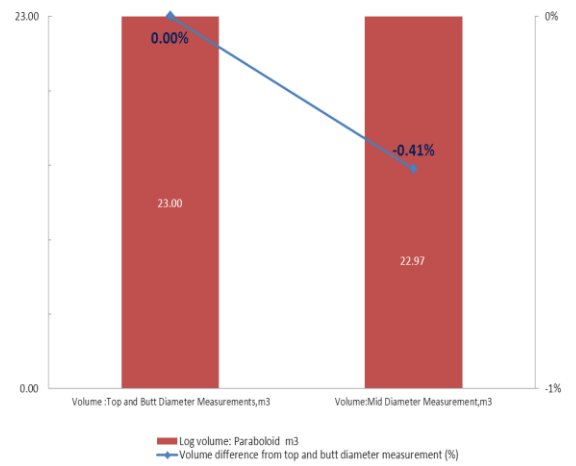


Fig.10. The roundwood volume values from paraboloid zone of stems estimated according to the Top and Butt Measuring method and the Mid Diameter Measuring method

a. The results of measuring are sequential:

The volume of debarked pine logs from paraboloid zone of stems in all diameter groups determined according to the Mid Diameter Measurement method was 0.41% lower than the volume determined by the Top and Butt Diameter Measurement method.

For the volume estimation of spruce roundwood assortiments according to stem/log surface shape the sample clusters were prepared. The log surface were trunckated neiloid and trunckated paraboloid. The spruce roundwood assortiments were devided in to sample clusters according to log surface shape. The volume of sample clusters were estimated by automatical measuring system Rema Control 9000 according to the algorithm of the measuring method 1(fig. 7). The volume of the roundwood assortiments were calculated also according to the algorithm of the measuring method (3) (fig. 7). The top diameter values of logs for volume calculation were taken from automatical measuring system Rema Control 9000 and the butt diameter parameters were measured manually.

The volume results are given (fig. 11; 12; 13)

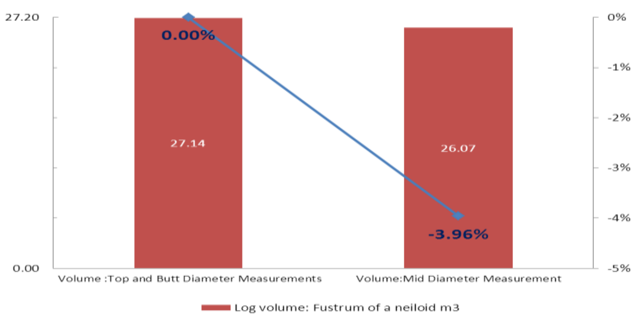


Fig. 11. The volume results of spruce roundwood assortiments from neiloid zone of stems measured by the Top and Butt Measuring method and the Mid Diameter Measuring method

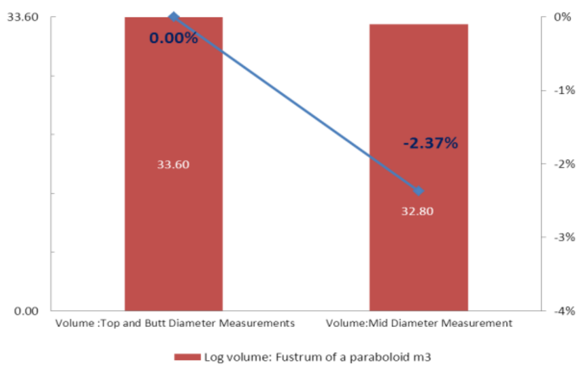


Fig. 12. The volume results of spruce roundwood assortiments from paraboloid zone of stems measured by the Top and Butt Measuring method and the Mid Diameter Measuring method

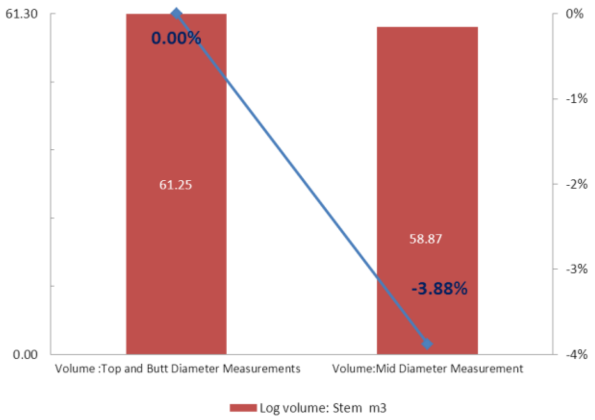


Fig. 13. The volume results of spruce roundwood assortiments from all parts of stems measured by the Top and Butt Measuring method and the Mid Diameter Measuring method

b. The results of measuring are sequential:

It is impossible to reach accurate volume results using determination of the volume according to the Mid Diameter Measurement for spruce logs from neiloid zone of stems.

The volume of spruce roundwood assortiments from neiloid zone of stems determined according to the Mid Diameter Measurement method was 3.96% lower than the volume determined by the Top and Butt Diameter Measurement method. The greater are the differences in diametre between the log ends the less reliable will be the volume values.

The volume of spruce roundwood assortiments from paraboloid zone of stems (measured under bark) determined according to the Mid Diameter Measurement method was 2.37% lower than the volume determined by the Top and Butt Diameter Measurement method.

The volume of spruce stems determined according to the Mid Diameter Measurement method was 3.88% lower than the volume determined by the Top and Butt Diameter Measurement method.

IV CONCLUSION

Determination of the volume according to the Mid Diameter Measuring is an accurate method for pine roundwood assortiments, but for spruce assortiments approach the form of truncated neiloids the results are unaccurate compared to the most precisious determination of the volume according to the Top and Butt diameter measuring.

To increase the accuracy of volume values, to decline of commercial profability by using different measurement methods and to remove differences originating among particular procedures of measurements, it is proposed to base manual measuring on determination of the volume according to to the Top and Butt Diameter Measuring method, but automatic measuring on determination of the volume according to to the Top and Butt Diameter measuring or Measuring Diameter in Short Intervals.

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