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Differences in volume of round timber caused by different determination methods*

Razlike u vrijednostima obujma trupca kao posljedica različitih metoda njihova određivanja*

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ABSTRACT • *Different methods of measuring and calculating the volume of logs in the forest after felling ("hand measuring") and in log yards of sawmills ("electronic measuring") give different results – volume of logs. The subject of this paper is the quantification of differences caused by the number and direction of scanning, by rounding and by volume calculation. The main results of measuring carried out under the actual sawmill conditions are as follows: single direction scanning is used for orientation or rough measuring, and not for exact measuring of round timber (at least two perpendicular directions are necessary), rounding (no cutting) has a very low influence (generally, not by single pieces), calculation of volume by sections results in a higher volume level when compared to the standard Huber's method of calculation based on mid diameter.*

Keywords: *round timber, dimension measurement, log volume*

SAŽETAK • *Različite metode mjerenja i izračunavanja obujma trupaca u šumi nakon rušenja ("ručno mjerenje") i na stovarištima pilana ("elektroničko mjerenje") daju različite vrijednosti. Tema ovog rada jest kvantifikacija razlika prouzročena brojem i smjerom skeniranja, zaokruživanjem dobivenih vrijednosti i izračunavanjem obujma. Glavni rezultati mjerenja dobiveni u stvarnim pilanskim uvjetima jesu: skeniranje u jednom smjeru može se provoditi za orijentaciju ili grubo mjerenje, a ne za točno mjerenje oblovine (nužna su najmanje dva unakrsna smjera skeniranja); zaokruživanje (ne odsijecanje) općenito vrlo malo utječe na razlike u vrijednostima obujma; izračunavanje obujma po sekcijama rezultira većom vrijednošću obujma u usporedbi sa standardnom Huberovom metodom izračunavanja prema srednjem promjeru trupca.*

Ključne riječi: *oblovina, mjerenje dimenzija, obujam trupca*

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1 INTRODUCTION
1. UVOD

At present, an electronic apparatus for scanning the diameter and length of round timber is the standard equipment of cross-cutting sorting lines of sawmills and a considerable part of sorting carriages is equipped with this device. The measurement is necessary in cross-cutting long round timber to logs and for sorting logs in particular groups according to the production requirements. Values obtained by these devices make possible to determine dimensions and volume of particular logs with high accuracy. Consequently, they are also increasingly used as a basis for the payment of round timber to its suppliers – thus becoming part of business relations.

However, in the course of logging operations (with the exception of felling carried out by harvesters) the comparable accuracy and density of measurements are not feasible. So, the traditional method of measurement by means of a tape-measure and calliper still largely predominates as well as the determination of round timber volume by the Huber's method.

Different methods of measurements and calculations result in differences in the values of the obtained log volume. The origin of a dubious relationship between the supplied round timber volume and money paid for it can often be found in the relationship between the supplier and processor of the raw material. In the Czech Republic, the absence of a legal standard determining technical parameters of scanning devices, method of processing the measured values and methods of calculation of the log volume largely account for this situation. The currently applied procedures of data processing try to get closer to the results of measurements obtained by a classical method, which gives a slight advantage to the raw material supplier or favours technological requirements of the raw material processor and urges the supplier to adapt to the requirements.

Conditions for the establishment of repeatability of results of both types of measurement imply precise knowledge of the measurement method, the way of processing the measured data, determination of the raw material volume and potential differences arising between results determined by the classical and electronic method. This paper deals with the analysis of selected effects and quantification of differences in the volume of raw material caused by different methods of its determination. The objective and wish of the author will be fulfilled if this paper contributes to the explanation of the origin of these differences.

2 ANALYSIS OF CURRENT CONDITIONS
2. ANALIZA TRENUTAČNIH UVJETA

The volume of round timber determined by electronic scanning of dimensions differs from the volume determined by manually measured dimensions. Differences occur in the actual values of dimensions during their scanning, during processing and during the actual calculation. The main causes are as follows:

Figure 1 The entry of a cross-cut and sorting line in the Bylnice sawmill in the period of measurements (the scanning device is placed in a wooden shelter)
Slika 1. Ulaz na liniju za poprečno krojenje i sortiranje u pilani u Bylnicama za trajanja mjerenja (uređaj za skeniranje smješten je u drvenoj kućici)

- *mechanical implementation of a transport line* – affects the stability of logs during scanning which particularly influences scanning the log length and evaluation of the stem curvature (if carried out);
- *the raw material shape* – mainly curvature, root swelling. In processing crooked raw material demands on the mechanical implementation of transport lines are markedly higher;
- *parameters of a scanning device* - mainly accuracy (usually ±1 mm), frequency of measurements (usually 50 - 200 Hz) and directions of scanning. Under conditions of our country, two directions of scanning perpendicular to each other are usual, less frequently one direction only. 3D measurement (scanning the whole peripheral curve) is still not much used;
- *filtration of values* - selection and equalization of the original data extremely different from other values. The origin of different data usually lies in frayed parts of bark, rests of branches etc. which can shade input parts of the scanning device. During filtration, comparison is made of values scanned in close vicinity. Markedly different value (if not repeated) is considered to be erroneous and it is replaced by an average value obtained from neighbouring measurements. The way of defining the wrong value as well the way of its replacement is given by the type of filtration. In the next step, the values are only selected from all scanned values, which correspond to specified length steps, usually 10 cm. The filtration is usually carried out by the control unit of the actual scanning device. Thus, after the correction, the selected values proceed to the control computer;
- *the way of rounding* – mathematical rounding is used, rounding to even values (in electronic devices very rarely), processing to the nearest 1 cm (mm are not taken into account) or processing values in mm (without rounding);
- *the way of the determination of a diameter decisive for the volume calculation* – it is possible to use the only value scanned in the middle of a length (rarely),

the mean value of a diameter in a section (usually ±10 cm from the length centre – used frequently), the value of the smallest diameter found in the same section (only in 3D scanning) or the average value of all measurements carried out throughout the length (less frequently);

- *the order of operations* – mainly the moment of rounding the values - before the diameter calculation, after the calculation or after both steps;
- *the way of bark deduction* – for a given species the constant value of bark is deducted (rarely) or a value derived from the raw material diameter for the given species (most frequently) (Doporučená pravidla, 2002) or the value of diameter o.b. is left (without deduction) and the volume of logs i.b. is determined in the next step according to tables (ČSN 49 0009, 1975);
- *the way of volume determination* – the Huber's method is used most frequently.

In order to achieve the uniformity of raw material volumes determined on the basis of manually and electronically obtained values of diameters, the calculation of the volume determination is not used at all and values of volume are obtained from a table adapted from (ČSN 48 0007, 1959) or (Černý and Pařez, 1995).

In order to achieve the highest accuracy of the volume of a given log, its volume is calculated as the sum of volumes of particular sections.

The section length corresponds to the length step of measuring the diameter (usually 10 cm) and its volume is defined as the volume of a cylinder of a diameter amounting to the section mid diameter. However, this calculation of volume is almost never used in practice because of the differences of its results as compared to the values obtained by traditional measurement.

Figure 2 A measuring device identical with the device installed in the Stará Ves sawmill where a substantial part of measurements was carried out (a scanning frame with a vertical and horizontal system placed in front of the log sorter)
Slika 2. Mjerni uređaj jednak uređaju instaliranom u pilani u Staroj Vesi, gdje je obavljen znatan dio mjerenja (ekran za skeniranje s vertikalnim i horizontalnim sustavom smješten je ispred sortera trupaca)

The Huber's method calculates the volume of round timber (logs) in the same way as the volume of a cylinder. The length of the cylinder corresponds to the length of the log, the diameter of the cylinder corresponds to the middle diameter of the log., measured to the nearest 1 cm. The Huber's method was taken as the comparison method, because a lot of national standards for calculating the volume of round timber (including the Czech ones) are based on it.

The overview of parameters included into the comparison is shown in the Table of results obtained.

3 MATERIAL AND METHODS
3. MATERIJAL I METODE

The aim of this paper is to quantify the effects of various methods used for the determination of the raw material volume. The study was carried out under the following conditions:

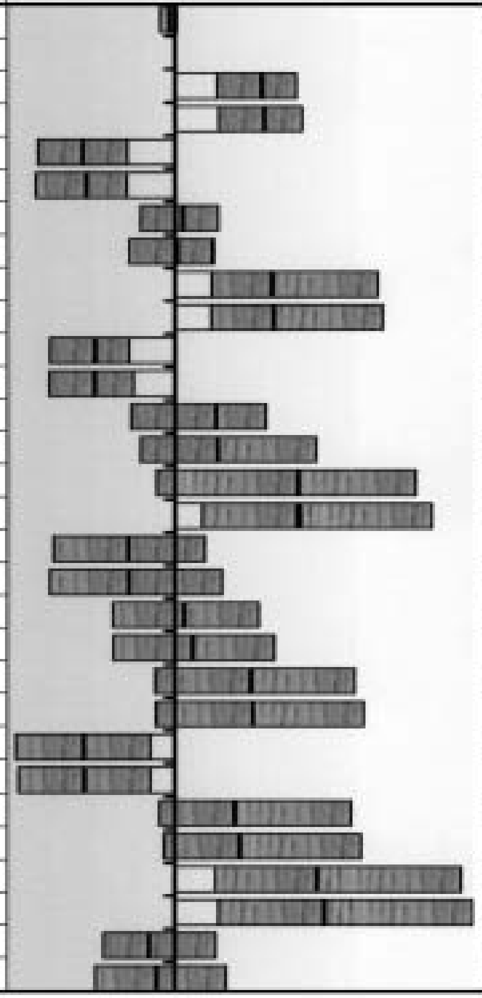
- input data (diameters and lengths) result from the actual measurement of logs (inside bark) in a sawmill – maintaining conditions of practice, elimination of the effect of bark deduction;
- Norway spruce, the raw material includes both final logs and combined lengths;
- all methods of the calculation start from identical input data - elimination of the effect of instability of a log, location and filtration of data, etc.;
- methods of determination of the raw material volume include effects of the mid diameter determination, ways of scanning, rounding and calculations by the Huber's method and a method by sections;
- evaluation consists in the volume deviation in [%] obtained by the given method as compared with the Huber's method – determination of the volume of logs i.b. in measuring the mid diameter i.b.

4 RESULTS AND DISCUSSION
4. REZULTATI I DISKUSIJA

The measurement was carried out in a sawmill of the South-Moravian Woodworking Plants Co in Bylnice and in a sawmill Katr Nová Ves Ltd. near Rýmařov. The program equipment of the sawmill Katr Nová Ves was adapted in such a way to make possible the independent storage of data from a scanning device before their processing. For the following analysis, values were used of the log diameter (in mm) scanned after barking and given separately in the horizontal and vertical direction after each 10 cm of length plus the total length in cm. Data of each of the logs made a separate file. On the basis of parameters determined by the methods whose effects were analysed, some 30 combinations were compiled - methods for the evaluation of the raw material volume. The results were processed using tables and diagrams separately for groups of logs of identical lengths and diameters. A total survey and comparison is given in the following table. The table was compiled on the basis of data on 1 793 logs. Further details can be found in (Janák and Peter, 2004).

Based on the above relationships, it can be concluded that there are almost no differences between va-

Table 1 An overview of methods of evaluation of the raw material volume and corresponding deviations
Tablica 1. Pregled metoda određivanja obujma trupaca i prikaz razlika koje iz njih proizlaze

Method of volume calculation *Metoda izračuna obujma*	Method of mid diameter determination *Metoda određivanja srednjeg promjera*	Direction of diameter scanning *Smjer skeniranja promjera*	Rounding (the unit of mid Ø) *Zaokruživanje (jedinica promjera)*	Deviation of the volume from the comparative method in % *Razlika vrijednosti obujma, %* — Range - *Raspon*: graphically - *grafički*	Range - *Raspon*: numerically *numerički*	Mean *Srednja vrijednost*
According to the mid diameter *prema srednjem promjeru*	One value of measurement in the log mid length *jedna vrijednost mjerenja na sredini trupca*	crosswise *unakrsno*	mm		-0,26 ÷ +0,03	-0,09
			cm		0	0
		horizontal only *samo horizontalno*	mm		+0,71 ÷ +2,05	+1,46
			cm		+0,74 ÷ +2,13	+1,48
		vertical only *samo vertikalno*	mm		-2,31 ÷ -0,81	-1,56
			cm		-2,34 ÷ -0,82	-1,50
	The mean of values measured in the section ±20 cm from the middle of the length *srednja vrijednost nekoliko mjerenja u razmaku ±20 cm*	crosswise *unakrsno*	mm		-0,58 ÷ +0,81	+0,13
			cm		-0,78 ÷ +0,70	+0,06
		horizontal only *samo horizontalno*	mm		+0,62 ÷ +3,41	+1,63
			cm		+0,61 ÷ +3,49	+1,66
		vertical only *samo vertikalno*	mm		-2,11 ÷ -0,78	- 1,35
			cm		-2,12 ÷ -0,71	-1,36
	The mean of values of all measurements within the whole length *srednja vrijednost mjerenja na cijeloj duljini trupca*	crosswise *unakrsno*	mm		-0,74 ÷ +1,53	+0,69
			cm		-0,58 ÷ +2,37	+0,72
		horizontal only *samo horizontalno*	mm		-0,31 ÷ +4,05	+2,07
			cm		+0,46 ÷ +4,28	+2,06
		vertical only *samo vertikalno*	mm		-2,05 ÷ +0,50	-0,79
			cm		-2,11 ÷ +0,79	-0,78
According to 10 cm sections *prema promjeru odsječaka duljine 10 cm*	The value of a smaller diameter in the section *vrijednost manjeg promjera na odsječku trupca*	crosswise *unakrsno*	mm		-1,05 ÷ +1,41	+0,16
			cm		-1,04 ÷ +1,67	+0,30
		horizontal only *samo horizontalno*	mm		-0,34 ÷ +3,03	+1,28
			cm		-0,32 ÷ +3,18	+1,31
		vertical only *samo vertikalno*	mm		-2,67 ÷ -0,42	-1,54
			cm		-2,63 ÷ -0,42	-1,53
	The mean value from both ends of a section *srednja vrijednost promjera obaju krajeva odsječka trupca*	crosswise *unakrsno*	mm		-0,26 ÷ +2,96	+1,01
			cm		-0,18 ÷ +3,14	+1,09
		horizontal only *samo horizontalno*	mm		+0,68 ÷ +4,81	+2,39
			cm		+0,74 ÷ +5,01	+2,51
		vertical only *samo vertikalno*	mm		-1,20 ÷ +0,69	-0,44
			cm		-1,35 ÷ +0,86	-0,31

lues calculated by the same methods in mm and cm. A maximum deviation amounts to 0.15 %. The values in cm were obtained by mathematical rounding and not by cutting off mm.

Methods based on horizontal measurement give 2.5 – 3 % higher values of the log volume than methods based on vertical measurement. This is the result of the position of the log on a longitudinal conveyor during measurements. The log cross-section is not ideally circular but oval. During rolling the log on a conveyor the timber is stabilized by its "larger area" on drive dogs. In this case, the value of a horizontally scanned diameter is higher than that the value of a vertically scanned diameter. Deviations from this condition are caused by the curvature of logs. A crooked log is stabilized in such a way that the plain of its curvature has to be horizontal regardless of flattening. The lowest deviation (0.06 %) is obtained by a method which takes into account the mean value of diameters scanned in the zone of ± 20 cm from the log centre in both directions and rounded to the nearest 1cm. It corresponds to the generally accepted assumption because the method is the nearest to the Huber's method. On the other hand, the method calculating the mid diameter shows a relatively high value of positive deviations (0.69 and 0.72 %) from all measurements in both directions along the whole length - the most objective value with respect to the actual dimensions of a log.

The results of methods calculating the raw material volume based on the volume of sections, taking the section diameter as the mean value of the vertical and horizontal measurement at both ends of the section (positive deviations 1.0 and 1.1 %) are close to the determined values. If a smaller value is considered as the section diameter and not the mean value (i.e. mean diameter at the smaller end of the section) the results are very similar to the results of the Huber's method (positive deviations 0.16 and 0.30 %). Consequently it can be concluded that the method for determining the log volume that uses mean values of the whole log length is more accurate than the Huber's method and that the Huber's method gives slightly lower values as compared with the actual conditions.

In most relationships, it is possible to notice higher deviations with the increasing diameter and length of a log. It is known and it can be mathematically proved that the Huber's method slightly under-measures long logs and over-measures short logs. The results achieved show the same tendency. However, it is not possible to use them as the virtually measured evidence of this dependence with respect to the markedly lower number of long and large-diameter logs (insufficiently large population from the aspect of statistics).

Generally, large differences can be noticed in the resulting values between particular methods (ranging about ±2 %). However, if we exclude methods only taking into account values of the vertical or horizontal measurement, we can determine the difference between particular methods amounting to about ±0.5 %. If we also exclude methods taking into account mean values of diameters obtained by measurements carried out throughout the log length, a difference of ±0.2 % is recorded between the remaining methods.

5 CONCLUSION
5. ZAKLJUČAK

Based on the analysis and comparison of results obtained by particular methods, it can be concluded as follows.

- Methods determining the mid diameter of raw material as the mean value of two measurements perpendicular to each other in the log centre or of more couples perpendicular to each other within a section of ±20 cm from the log centre are close to the Huber's method both from the viewpoint of scanning and assessing the volume and values of the obtained raw material (up to ±0.15 %).
- Therefore, these methods can be recommended for the electronic receipt of raw material as an "electronic equivalent" of the Huber's method.
- Methods determining the mid diameter of the raw material based on values obtained by one-direction measurement show high deviations (±2%) and, hence, they are virtually unusable for the requirements of the electronic receipt of raw material.
- Methods determining the raw material volume as the sum of volumes of particular sections and using crosswise scanning are methodically more accurate than the Huber's method. Their use appears to be prospective, however, not in combination with the Huber's method. According to the results obtained, the method determining the mid diameter as the mean value of all measurements (crosswise) carried out throughout the log length is close to the above methods.
- Rounding the values to the nearest 1 cm (no cutting off of mm!) does not show any substantial effect on the calculation of the raw material volume (differences ≤ 0.03%, in two cases ≤ 0.13%).

In further operations, it appears that it would be useful to:

- verify the effect of neglecting the value of incomplete cm (i.e. cutting off of tenths, not mathematical rounding to the nearest 1cm) which is currently carried out more frequently in practice;
- verify the effect of narrowing a section used for the diameter calculation of ±20 cm from the length centre (used in the paper) to ±10 cm (currently more common in practice);
- verify the effect of sorting at 0.5 cm (and thus also using the diameter with a gradient of 0.5 cm) which appears to be prospective in large plants (both cutting off and rounding);
- include whole peripheral curves of logs into scanning methods - 3D measurement (prospective in large plants);
- compare deviations obtained during "manual" measurements with deviations obtained during measurements carried out by electronic devices (obtained by repeated measurements of the same group of logs).

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