

УДК 630*527

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ANALYSIS OF PIECE BY PIECE METHODS OF ROUND WOOD MEASUREMENTS

Based on literature review piece by piece methods of round wood measurements employed in different countries are briefly discussed. An analysis of round wood volume tables from GOST 2708–75 in comparison with the Lithuanian volume tables showed positive values of deviations that indicates larger values in “Lithuanian” volumes (up to 10% for butt and middle logs and 15% – for top logs, although for butt logs over 70 cm diameter the differences in their volumes are around 2% only). The main working method of upper diameter (STB 1667-2012, GOST 2708–75) was researched. 194 logs in 6 stacked batches were measured (diameters at both ends of a log (twice, rounding to 0.1 cm), and length (0.1 m)). The greatest deviations have been received when logs with increased taper coefficient (1–2 cm/m) are inventoried (–14.5% according to the formula of the “end cross-sections” (Smaliana) and – 13.1% – using formula of “truncated cone”). In our view, it is advisable to clarify the method of upper diameter based on the average value of taper coefficient in stacked batches of round wood (entering of amendments to the volumes from GOST 2708–75 on a log taper coefficient of real value).

Introduction. According to the Ministry of forestry of the Republic of Belarus in 2013 forestry enterprises sold around 6.5 mln cubic meters round wood at home market, including 3 mill. cubic meters industrial wood (46% of the total volume of sales). Belarusian forest products and services were exported in 25 country of the world (Poland (46% of export volume), Lithuania (11.2%), Germany (9.6%), Latvia (5.3%), Sweden (4.5%), Belgium (3%), Netherlands (2.9%) and other countries). Exports of forest products and services resulted in profit near 144.8 mill. USD, rate of growth – 129,8% [1]. It should be noted that round woods export of enterprises of the Ministry of forestry was carried out on the “leftover principle”: unclaimed at home market small commodity round wood was sold (pulpwood, technological raw material). It is planned that raw timber will not be exported anymore and only finished products with high value added will be sold. According to the Decree of President A. G. Lukashenko No. 504 “About making amendments and additions to the Presidential Decree of May 7, 2007 No. 214 and on September 9, 2009 No. 444” the norm for the gradual decrease in the sales of stem growing stock volumes at exchange trades was introduced: from 50% of volume proportionally by species group in 2013 (3.2 mill. cubic meters) to 25% in 2014 (1.7 mln cubic meters) for the transition to the sales of round wood only. In 2015 sales of stem volumes are offered only from softwood forests at inaccessible forest sites (0.8 mill. cubic meters) [2]. At the same time new edition of Forest Code provides that additional timber volumes can be involved for harvesting due to the transfer part of the first group forests to the second one: it is planned to decrease width of protective strips up to 500 m along rail-

ways and width up to 250 m along republican roads. In this case prescribed cut in the country will be increased by 437.9 thousand cubic meters, including coniferous by 233.5 thousand cubic meters [1]. According to the Ministry of forestry in 2015 it is planned to fell more than 30% timber or 13 mill. cubic meters (nowadays it is about 10 mill. cubic meters per year), including final felling in volume more than 9.6 mill. cubic meters. The volume of round wood sales at home market will be increased by 23%, up to 8 mill. cubic meters.

Therefore, researches of the methods of round wood measurements have practical importance.

Main part. Aim of the research: analysis of piece by piece methods of measurement and round wood volume calculation according to TCP 1667-2012 «Round wood. Methods of measurement and volume calculation» from the point of view of accuracy and practical application considering the experience of other forest countries. Also regulations and manuals of methods of round wood measurements and volume determination used in some European countries were analyzed. Experimental data is presented by the measurements of 194 logs.

According to the Belarusian standard TCP 1667-2012 some methods are proposed from the group of "piece by piece methods":

- a) method of upper diameter;
- b) mid-section method (round wood volume determination by Huber's formula);
- c) method of end cross-sections (Smalian's formula);
- d) sectional methods (automatic round wood measurements on longitudinal conveyors or measurement mechanisms of harvesters).

According to the introduction [p. II], the national standard coincides with the European one

(but with the change of the name) EN 1309-2:2006 "Round and sawn timber. Method of measurement of dimensions. – Part 2: Round timber. Requirements for measurement and volume calculation rules". The document has been developed by Technical Committee CEN/TC 175 European Committee for Standardization (CEN).

The piece by piece method of measurements by the log length and diameter (according to the method of upper diameter (TCP 1667-2012) implies in Norway – method of the upper diameter and normal taper coefficient (it means that it is admitted that all logs have the same taper coefficient – around 1 cm/m), in Finland – using special round wood volume tables by upper diameter and length (for pine and spruce tables compiled based on the average taper coefficient of logs for different parts of the country), in Sweden – method by the volume of the cylinder, and the cross-sectional area is equal to the area of the upper end of the log, in Poland – employing the upper diameter method and mean taper coefficients (log volume is determined by the upper diameter (without bark for the smallest diameter in centimeters (to 0.1 cm), result is rounded down to whole centimeter)) and length (to 0.01 m), in Ukraine – upper diameter method (volume is determined based on the data from international standard GOST 2708-75) as well as in Russia, although several attempts were undertaken to develop new standards (OST 13-303-92 "Round wood. Piece by piece methods of volume measurements" (1992), RD 13-2-3-97 "Exported round wood. Measurement methods of volumes and dimensions. Quality control. Acceptance" (1997). In 2008 new projects of national standards for round wood were developed. The federal law No. 415 of December 28, 2013 was amended to provide for mandatory accounting of harvested timber and establishment "State accounting wood system and deals with it") [3–6].

In Germany piece by piece method of round wood measurements and volume determination (under bark) is mid-diameter method (it implies two diameter measurements in the middle of the

log (at right angles to each other) with the calculation of the average diameter, result is rounded down to whole diameter) and log length (result is rounded down) [5].

According to the "Lithuanian rules of round wood measurement, growing timber and volume determination" (Apvaliosios medienos mata-vimo taisykles (1997, 1999, 2005) piece by piece method is used for measurements of middle logs (diameter under bark 23–24 cm), butt logs (≥ 35 cm); and for the top logs (10–22 cm) piece by piece or stack methods can be applied [6]. In any case, parties can choose piece by piece method instead of the less precise geometric method. Also, according to the rules random measurement error of 95% of all measurements should not exceed more than ± 1 cm, of 5% of all measurements – more than ± 1.5 cm. Measurement errors are determined during remeasurement and control measurements. If during the remeasurement the parties do not come to an agreement a control measurement is taken.

If round wood is measured employing piece by piece method, volume estimation error should not exceed $\pm 5\%$, when the amount of the measured timber does not exceed 10 solid cubic meters, $\pm 3\%$ – when the amount of the measured timber is 10 through 50 solid cubic meters, and $\pm 2\%$ – when the amount of measured timber exceeds 50 solid cubic meters.

If measurement is taken by automatic measurement lines or other wood volume measurement devices, volume estimation error should not exceed $\pm 3\%$, when the amount of the measured timber does not exceed 10 solid cubic meters, $\pm 2\%$ – when the amount of the measured timber is 10 through 50 solid cubic meters, and $\pm 1\%$ – when the amount of the measured timber exceeds 50 solid cubic meters [6].

For the calculation of round wood volume employing piece by piece method the national volume tables of logs are used ((«Lentele rastu turis») which in many respects are similar to the table GOST 2708-75 (Tables 1–3)

Table 1

Deviations of volumes of butt and middle logs according to the Lithuanian national volume tables in comparison with data of GOST 2708-75

Top end diameter under bark, cm	Difference of the volumes in accordance with GOST 2708-75 at length (m) of logs, %									
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
14	9.6	9.8	6.8	7.1	5.2	4.5	4.1	5.2	4.7	4.9
16	7.2	6.1	6.3	5.5	5.6	5.0	5.8	5.2	5.3	10.0
18	8.1	6.8	5.8	5.1	5.1	4.6	3.1	4.8	8.7	8.0
20	6.5	7.1	6.1	4.7	5.3	4.8	8.7	3.8	7.1	10.0
22	6.2	5.8	5.6	5.0	4.3	8.0	7.1	6.5	5.9	5.4
24	3.8	4.9	4.8	4.2	3.7	6.7	6.1	5.6	5.0	7.0

Table 2

**Deviations of volumes of top logs according to the Lithuanian national volume tables
in comparison with data of GOST 2708-75**

Top end diameter under bark, cm	Difference of the volumes in accordance with GOST 2708-75 at length (m) of logs, %									
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
7	14.0	15.4	15.0	12.0	9.7	10.8	9.1	10.0	10.5	10.9
8	11.1	10.0	12.0	9.7	10.5	8.9	9.4	8.2	8.7	9.0
9	12.4	8.3	10.0	10.8	8.9	7.4	7.9	8.3	7.3	7.6
10	9.5	10.7	8.3	9.1	9.4	7.9	8.2	7.1	6.2	6.5
11	8.0	9.1	7.1	5.8	8.2	8.3	7.1	6.2	6.4	7.4
12	6.9	5.1	8.3	6.8	5.6	7.3	6.2	6.4	5.6	5.7
13	6.1	6.8	5.5	7.6	7.6	6.5	5.6	5.6	5.0	5.1
14	5.3	6.1	4.8	6.8	5.6	5.8	5.8	5.8	5.2	5.2
15	4.7	5.5	4.3	6.0	4.0	5.2	5.3	4.6	4.7	3.6

Table 3

**Deviations of volumes of butt logs with diameter of more than 70 cm
according to the Lithuanian national volume tables in comparison with data of GOST 2708-75**

Top end diameter under bark, cm	Difference of the volumes in accordance with GOST 2708-75 at length (m) of logs, %									
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
72	2.2	1.7	1.4	0.6	0.5	0.9	1.7	2.3	2.4	1.3
74	2.0	1.6	1.3	0.6	0.5	0.9	1.2	2.2	2.3	0.9
76	1.9	0.8	1.3	0.5	0.5	0.4	0.7	2.1	2.2	0.6
78	1.8	0.7	0.6	0.0	0.0	0.4	0.4	1.9	1.8	0.5
80	0.9	0.0	0.6	0.0	0.0	0.0	0.3	1.9	1.1	0.0
82	0.8	0.0	0.5	0.0	0.0	-0.4	0.0	1.5	1.1	-0.2

Values in Lithuanian volumes are slightly larger (when the same input parameters are used) (deviations are up to 10% for butt and middle logs and up to 15% – top logs, but for butt logs with diameter more than 70 cm deviations are about 2%) (Tables 1–3). Lithuanian national tables contain the values of the volume of a) butt and middle logs with length from 1.0 to 9.5 m and diameter from 3 to 70 cm (Table 1), b) top logs with length from 2.0 to 7.0 m and diameter from 7 to 15 cm (Table 2), c) butt logs with length from 2.0 to 6.5 m and diameter from 71 to 100 cm (separate tables (unlike tables GOST 2708-75), Table 3), d) long logs with length from 10.0 to 13.5 m and diameter from 8 to 38 cm; e) one meter cylinders with length from 3.0 to 105.0 cm (increased by 0.5 cm).

For the purpose of analysis of the main piece by piece method that it's in use in Belarusian for-

estry (so called method of upper diameter) we carried out some extra measurements of logs. To determine the precise log volume its length (the shortest distance between the butt end and the top end of the log) and diameter were measured (in both ends of the log) (under bark) (twice, at right angles to each other in order to calculate the average value (to 0.01 cm)). Measurements were carried out using proven measuring tape. Assortment length was measured with an accuracy of at least 1 cm and expressed in meters rounded down to two places of decimal. To compare the results volume of each log was calculated using tables of GOST 2708-75 as well as by the formula of the “end cross-sections” (Smaliana, proposed in TCP 1667-2012) and formula of “truncated cone” («arbitration» formula) (Table 4).

Table 4

**Deviations of volumes of butt and middle logs according to the «arbitration» formula
in comparison with data of GOST 2708-75**

Number of logs in the stack	Difference of the volumes in comparison with tables of GOST 2708-75 according to the different formulas for volume calculations (with different log taper coefficient (cm/m)), %				
	end cross-sections (Smaliana)		truncated cone		
	up to 1.0	1.1–2.0	up to 1.0	1.1–2.0	
61	7.3	-10.3	7.6	-9.4	
30	4.6	-14.5	5.0	-13.1	
21	3.2	-7.9	2.5	-8.3	
20	5.6	-10.9	4.0	-9.8	
35	-0.3	-13.1	0.4	-11.7	
27	5.0	-12.0	6.5	-7.4	

It should be noted that measured assortments are not top logs (by criteria of GOST 2708-75 (p. 1) and table of standard (p. 30–34) which gives the log volumes with diameter 6–15 cm and log length 2.0–7.0 m). Formula of “truncated cone” provides more accurate results (also based on the experience of Lithuanian colleagues).

Conclusion. The measurement error of round wood volume calculation is usually from ± 3 to $\pm 12\%$ [3, 4]. Russian researchers identified that the systematic deviations of round wood volume estimation employing data from GOST 2708-75 in comparison with the data of the “end cross-sections” methods are from -9 to $+11\%$ [4]. According to our knowledge, the greatest deviations have been received when logs with increased taper coefficient are measured (up to 14.5% by formula of the “end cross-sections” (Smaliana) and 13.1% by formula of “truncated cone”) (table 4). Negative deviations indicate smaller values of log volumes that are given in tables GOST 27078-75 in comparison with the results from methods of the “end cross-sections” (volume calculation by «arbitration» formula). At the same time log volumes by GOST 2708-75 for logs with small taper coefficient are in the range of 5% in comparison with the volume determining by methods of the “two cross-sections” (Smaliana and truncated cone). The main table of GOST 2708-75 which is in use in the Belarusian forestry was developed by A. A. Krudener in 1913 for spruce butt logs. It is advisable to clarify the method of upper diameter based on the average value of taper coefficient in stacked batches of round wood (entering of amendments to the volumes from GOST 2708-75 on a log taper coefficient of real value). In our view, there is a sense of method classification based on their practical application: 1) methods of manual round wood measurement: a) piece by piece sectional methods (mechanical measurements by harvester, also on

automatic lines of piece by piece measurements); b) upper diameter method (TCP 1667-2012) (actually main “forest method”); 2) control measurement methods (control of the accuracy of manual measurements and (or) sampling calculation of the correction factor on the taper coefficient of logs for the volume estimation when working methods are employed): a) “arbitration” methods of the “end sections” (to calculate the volume of round wood by Smalian’s formula (TCP 1667-2012) or “truncated cone”); b) mid-sectional method.

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Received 19.02.2014