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STATISTICAL JUSTIFICATION OF THE REQUIRED SAMPLES' SIZE OAK SAWN TIMBER BATCH

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Abstract

The task of the study is to establish and justify the required amount of sawn timber, which must be measured to determine the conformity of the entire batch of sawn wood to the specified size on the basis of statistical processing of a sample of sawn timber from the total batch. It is established that the batch is homogeneous in width and thickness, and differs in length of a sawn timber. The values of variation coefficients for length of a sawn timber are much lower than similar values for thickness and width. Given the nature of the grouping of sawn timber particles around the central stage in terms of thickness, width and length, it can be argued that the samples are similar. Student's *t*-test was used at the *p*-level to check the difference between the mean values of individual samples. Measurement error (ME) for almost all indicators of the studied sawn timber is in the range of 0.1–5.0 %, which indicates that the experiment was performed with sufficient accuracy. In fact, 144 units of lumber were selected from 5 packages, which is more than 125 of the minimum required to establish the batch conformity of size and quality characteristics. Using the values of SE, ME and SD, calculated for individual samples, it was found that to correctly determine the deviations, including measurement accuracy and appropriate moisture content errors, it is sufficient to use from each individual sample no more 24 pieces of the appropriate sawn timber types. Using the recommendations for checking the conformity of sample to acceptable quality level for the total batch of a sawn timber, which was 2207 pcs in 5 packages, was confirmed the sufficiency of usage of the sample of 125 pieces from 5 packages.

Key words: oak sawn timber, regulatory documents, statistical indicators, wood moisture content.

Introduction

According to the implementation of the Program of Activities of the Cabinet of Ministers of Ukraine, approved by Resolution No. 695/09.12.2014, the State Enterprise 'Ukrainian Research and Training Center of Standardization, Certification and Quality' (State Enterprise 'UkrNDNC') have cancelled, with certain dates of cancel-

lation (from 2016, 2017, 2018 and 2019) all the valid interstate standards (GOST) in Ukraine, which were developed up to 1992 – order number 184/14.12.2015. This is due to the fact that in the national legislation of Ukraine as a member state of the World Trade Organization (WTO) were implemented the provisions of WTO Agreement on technical barriers to trade, in particular the Code of devout practice on the development, adoption and appliance of standards, and have been implemented international and European standards of standardization (Welling 2010). First of all, this relates to the principle of the voluntary application of national standards, except of cases where the obligatory application of them is established by regulatory acts. National standards are used directly or by reference to them in other documents.

Almost all regulatory documents on determining the dimensional and qualitative characteristics of sawn wood, which in practice are widely used in the forestry complex enterprises got under the action of the State Enterprise 'UkrNDNC' order No. 184. About 14 interstate standards only in the area of measurement, classification, sorting, acceptance and storage of sawn wood were cancelled from January 1, 2019. Therefore, it is expedient to use international experience during the selection process of sampling of sawn timber batch to assess compliance with the dimensions, moisture and quality of the researched sawn timber.

Evaluation of sawn timber batches, including statistical methods, is used mainly during wood processing: to the size control of sawn timber, their quality and size determining (Cochran 1963; Brown 1979, 1982, 1986, 2000; Buchanan 2000) or control of size changing in the course of drying (Pinchevska et al. 2016), or drying quality (Guzenda et al. 2002). In addition, in determining the quality or quantitative parameters are mainly used homogeneous sawn timber batches (Buchanan 2000, Pinchevska et al. 2016). At the same time, when exporting sawn timber, they are often of different sizes in one batch. In this case, a justification for the choice of the minimum required number of sample measurements is required. Such studies, especially if they relate to export-import operations with sawn timber with reference to the updated standards, are currently non-existent. Therefore, the relevance of our research is caused both by theoretical foundations of the use of statistical evaluation of homogeneous samples, and application of the obtained justification.

Aim of the study

The wood is exploited to the appropriate moisture content, which is achieved by drying. For the possibility of unification and technical acceptance of the batch, the dimensions of sawn timber are indicated by moisture content of 20 %. Under influence of external factors moisture content may change. On this cause, appropriate corrections are used. Corrections are defined, calculated and accepted for different moisture content and for different types of wood by normative tables. Often, there are conflicts regarding the acceptance of sawn timber batch associated with the moisture content changes and, consequently, with change of its size. In this case, there is often an increase or, conversely, a decrease in the nominal dimensions of wood that corresponds to the volume of sawn timber.

Different sizes of lumber in individual packs and in the general batch may cause difficulties in establishing the selection of

the required minimum number of samples for analysis. To do this, it is necessary to statistically confirm the possibility of selecting a certain amount of lumber from appropriate packages, in which collected materials of the same size, and in general for the whole party. An additional difficulty in carrying out this analysis is the change in moisture content of the lumber. During their manufacture, according to technological operations, the moisture content may have the same values, but during transportation and storage they may change. To be able to establish compliance with the lumber to the specified dimensions, it is also necessary to establish permissible changes in these dimensions to accepted limits with changes in humidity by the climatic characteristics of the region.

The research objective is to establish and justify the required amount of sawn timber that needs to be measured to determine the accordance of the whole batch of sawn wood to the indicated sizes based on the statistical processing of a sampling from the total. For this purpose in the case of export operations, valid international and Ukrainian normative documents must be used to appropriateness on the size and volume of sawn timber.

To solve the study purpose it is necessary to solve the following tasks:

- to establish the criterion of parameters compliance of lumber batch with the accompanying technical documentation;
- to establish grouping features of the shares of number lumber around the central stage of the relevant indicator and the decisiveness of this indicator to establish the similarity of lumber of different packages to the whole party;
- to investigate the influence of statistical indicators on the homogeneity characteristics of the lumber in different packages to the total volume of the party;
- to establish the minimum number of selected samples of lumber from packages within the party based on the analysis of statistical indicators of their sizes and humidity.

Materials and Methods

Quality control and sawn timber batches size involves determining indicators of the units selected in the sample. The selection of pieces in the package for control was carried out randomly (for example, throwing cubes e.g. by throwing a dice), while from the outer layers of lumber were not selected. Random selection means that at each step of the sample, the elements that remain in the party are equally likely to be selected (Montgomery and Runger 2003).

The research used the results of processing the actual batch of sawn timber. The declared dimensions and technical parameters are: oak sawn timber, moisture content 8–10 %, grade Q-F 3-4 (according EN 975-1:2009), size: 27×190×2030 mm – 943 pcs (7 packages) (code 06-2030), 27×190×2230 mm – 615 pcs (5 packages) (code 08-2030; 09-2230), 27×190×2780 mm – 309 pcs (2 packages) (code 13-2780), 27×190×3000 mm – 340 pcs (3 packages) (code 17-3000); in total 2207 pcs in 17 packages.

In grade the first character represents the initial of the Latin name ‘Q’ for Quercus = oak. The second character indicates the type of product. ‘F’ means strips and square-edged timber. The quality of every sawn piece is assessed by the appearance of its faces and, if applicable, its edges, while taking account of the presence, extent, position and distribution of any features, specific sawing and deteriorations resulting from it. In case of failure to

meet any one of the specified conditions, the piece in question will be downgraded. Size defects due to sawing (irregular thicknesses and widths) are disregarded when appearance grading pieces (standard EN 1313-2). Such products may not be subjected to width and/or length reduction. The third character refers to the quality grade. A means exceptional quality, 1-2-3-4: in decreasing order of quality.

For all lumber samples were taken measurements of the actual dimensions of thickness and width, using an electronic caliper with accuracy of 0.01 mm, length – a metal measuring tape with accuracy of 0.01 m according to EN 1309-1: 2001. The smallest value of the three thickness and width values was recorded. These values were measured in the direction perpendicular where there is no wane. Of these, two dimensions are as close as possible to the ends, but not closer than 150 mm from the end, the third – at a random point between them. The length of the most possible rectangular parallelepiped inscribed in the lumber was taken as lumber length.

Actual moisture content of lumber was determined using an electric moisture meter Logica LG-43 according to DSTU EN 13183-2:2004 (2004). To reduce the effect of the way the meter is used, standard SS-EN 13183-2 describes how the insulated hammer electrodes should be inserted into the piece of wood. The average moisture content of wood is measured as follows: measure 300 mm from the end. Insert the insulated hammer electrodes into the face of the wood, in the direction of the grain, and along an imaginary line running 0.3 times the width of the wood from the edge. The measurement depth should be 0.3 times the thickness of wood.

Measurements of the visual characteristics parameters of wood were carried out according to DSTU EN 1310:2005 (2005). Biological damage (by insects, fungi, etc.) – according to DSTU EN 1311-2001 (2001). The value of lumber drying for nominal dimensions was set by taking into account its moisture content according to DSTU 4920:2008 (2008). The permissible deviations from the nominal dimensions according to DSTU EN 1313-2:2018 (2018).

To test the difference between the mean values of individual samples, at *p*-level Student's *t*-test was used. To do this, we compared the arithmetic mean x_1 and x_2 of samples taken from different types of samples. In the case when $n_1 \neq n_2$, the standard error (s_d) between standard deviation (SD) is determined by the formula (1) (Lakin 1980).

$$s_d = \sqrt{\frac{s_1^2 + s_2^2}{n_1 + n_2 - 2} \cdot \left(\frac{n_1 + n_2}{n_1 n_2} \right)} \qquad (1)$$

Having accepting that $s_1^2 = \sum (x_i - \overline{x}_1)^2$ and $s_2^2 = \sum (x_i - \overline{x}_2)^2$. The value of Student's *t*-test (t_f) for such case is determined by the formula (2).

$$t_f = \frac{\overline{x}_1 - \overline{x}_2}{s_d} \qquad (2)$$

Zero hypothesis is refuted if $t_f \geq t_{st}$, where: t_{st} – tabular value of Student's *t*-test (Lakin 1980).

We calculated the amount of required number of samples by the formula (3) (Lakin 1980).

$$n = \frac{t^2 s_x^2}{\Delta^2}, \qquad (3)$$

where: n – number of samples; $\Delta = t s_{\overline{x}}$; s_x – standard deviation (SD); t – normalized deviation of Student's *t*-test, with which is probability volume (p).

Results and Discussion

The results of statistical processing of experimental data of sawn timber of investigated packets are given in tables 1–5. For the ability to set the average index of quality, the following encoding of this indicator is used in numerical values: Q-F-1a – 1; Q-F-1b – 2; Q-F 2 – 3; Q-F 3 – 4, Q-F 4 – 5.

Table 1. Statistical characteristics of testing material for sampling from the package 06-2030.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Arithmetic mean (AM)	29.6	193.1	2030.6	3.0	12.21
Standard deviation (SD)	1.33	3.77	1.01	0.65	0.84
Coefficient of variation (CV)	4.51	1.95	0.05	21.92	6.90
Min	26.9	187.0	2030.0	1.0	11.1
Max	32.3	203.0	2034.0	4.0	14.9
Skewness (Sk)	-0.07	1.13	1.82	-0.88	1.48
Kurtosis (Ku)	-0.55	1.20	3.53	2.63	3.02
Standard error (SE)	0.26	0.72	0.19	0.12	0.16
Measurement error (ME)	0.87	0.38	0.01	4.22	1.33
Total number (N)	27	27	27	27	27

Table 2. Statistical characteristics of testing material for sampling from the package 08-2230.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Arithmetic mean (AM)	29.05	194.13	2230.80	2.90	11.97
Standard deviation (SD)	1.36	3.13	1.37	0.61	0.52
Coefficient of variation (CV)	4.67	1.61	0.06	20.95	4.33
Min	26.1	190.0	2230.0	1.0	11.0
Max	33.1	205.0	2235.0	4.0	12.8
Skewness (Sk)	0.30	1.27	1.92	-0.95	-0.07
Kurtosis (Ku)	1.81	3.64	3.02	2.91	-1.11
Standard error (SE)	0.25	0.57	0.25	0.11	0.09
Measurement error (ME)	0.85	0.29	0.01	3.82	0.79
Total number (N)	30	30	30	30	30

Table 3. Statistical characteristics of testing material for sampling from the package 09-2230.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Arithmetic mean (AM)	29.17	193.26	2230.93	2.85	11.94
Standard deviation (SD)	1.05	5.36	1.52	0.60	0.45
Coefficient of variation (CV)	3.60	2.77	0.07	21.09	3.75
Min	26.6	186.0	2230.0	2.0	11.2
Max	31.3	205.0	2235.0	4.0	12.8

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Skewness (Sk)	-0.25	0.63	1.70	0.05	0.24
Kurtosis (Ku)	0.46	-0.23	1.71	-0.08	-0.71
Standard error (SE)	0.20	1.03	0.29	0.12	0.09
Measurement error (ME)	0.69	0.53	0.01	4.06	0.72
Total number (N)	27	27	27	27	27

Table 4. Statistical characteristics of testing material for sampling from the package 13-2780.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Arithmetic mean (AM)	28.59	191.77	2780.67	2.80	12.19
Standard deviation (SD)	1.06	3.71	0.96	0.48	0.54
Coefficient of variation (CV)	3.70	1.94	0.03	17.29	4.42
Min	26.1	185.0	2780.0	2.0	11.3
Max	30.1	200.0	2784.0	4.0	13.5
Skewness (Sk)	-0.62	0.53	1.75	-0.55	0.44
Kurtosis (Ku)	0.16	0.31	3.66	0.50	-0.37
Standard error (SE)	0.19	0.68	0.18	0.09	0.10
Measurement error (ME)	0.67	0.35	0.01	3.16	0.81
Total number (N)	30	30	30	30	30

Table 5. Statistical characteristics of testing material for sampling from the package 17-3000.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
Arithmetic mean (AM)	28.23	192.47	3000.53	3.10	12.34
Standard deviation (SD)	2.33	2.76	0.82	0.31	0.80
Coefficient of variation (CV)	8.25	1.44	0.03	9.84	6.50
Min	18.2	187.0	3000.0	3.0	11.2
Max	31.7	200.0	3003.0	4.0	14.7
Skewness (Sk)	-2.77	0.46	1.50	2.81	1.19
Kurtosis (Ku)	11.80	0.64	1.63	6.31	1.60
Standard error (SE)	0.42	0.50	0.15	0.06	0.15
Measurement error (ME)	1.51	0.26	0.00	1.80	1.19
Total number (N)	30	30	30	30	30

It was found that the average value varies from 28.2 to 29.6 mm by analyzing statistical indicators of sawn timber thickness. The highest value was determined for the package 06-2030, and the lowest – for 17-3000. The coefficient of variation of this indicator is in the range from 3.60 to 8.3 %. The lowest value was found for the package 09-2230, and the highest – for 17-3000.

The value of width of the sawn timber varies from 191.8 to 193.3 mm. The lowest average was found for the package 17-3000, and the highest – for 09-2230.

The coefficient of variation for width is lower, in comparison to the same indicator for thickness, which indicates lover variability of width. The lowest value of this indicator was found for package 17-3000 and is 1.44 %, and the highest – for 09-2230 and is 2.77 %.

The value of the length of sawn wood in the packages of this batch is different: in 06-2030 the average is 2030.6 mm, for 08-2230 – 2230.8 mm, for 09-2230 – 2230.9 mm, for 13-2780 – 2780.7 mm, and for 17-3000 – 3000.5 mm. It is thus established that the batch is homogeneous in width and thickness, but differs by length of the sawn timber. The values of variation coefficients for length are significantly lower than the similar values of the indicator for thickness and width of the sawn timber. The lowest value of the coefficient of variation is 0.03 % for the package 17-3000, and the highest – 0.07 % for 09-2230. The value of moisture content of sawn timber is not significantly different. The lowest value was found in the package 09-2230 and is 11.9 %, and the highest – in 17-3000 and is 12.3 %. The lowest value of the variation coefficient was found for package 09-2230 and is 3.75 %, and the highest is 6.90 % for 06-2030.

The quality assessment is carried out by replacement of indicator value on its digital counterpart and graded in the reverse order – the best quality class is assigned 1, and the worst one is 5. Thus, with a decrease in the average value, the average quality class for sawn timber in the corresponding package increases. The highest value of quality is 2.80 for the package 13-2780, and the lowest is 3.10 for 17-3000. The value of the coefficient of variation is the lowest for 17-3000 and is 9.84 %, and the highest for 06-2030 and is 21.92 %. The variability of this indicator is the highest among all the indicators of researched sawn timber.

For the graphical representation of the research material, relative degrees of relevant indicators of the sawn timber were used: that is, separately, for the samples taken from different packs, the share grouping (in %), which were obtained by dividing the actual values by its average, was made according the relative degrees of the corresponding index. The results are shown in figures 1–4. Graphical representation of distributions by relative degrees of length is not given, since for all packages there is one hundred percent grouping at relative level of 1.0.

Given the nature of the share grouping of sawn timber pieces around the central degree by thickness, width and length, it can be argued that the samples are similar to each other. Generally, similarity is also observed in the distribution for the average value of wood moisture content – the difference is only in the percentage grouped around the central degree. The

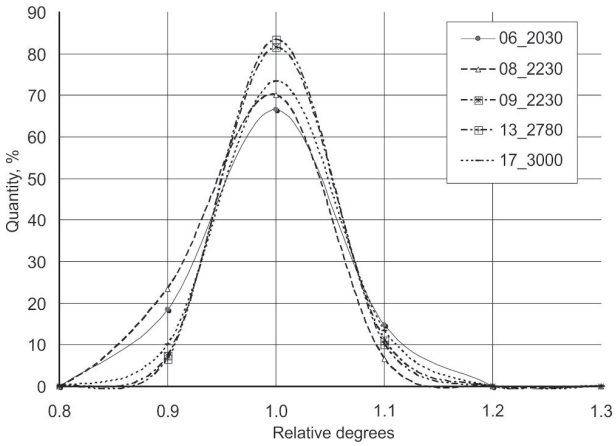

Fig. 1. Share distribution of sawn timber pieces by relative degrees of thickness.

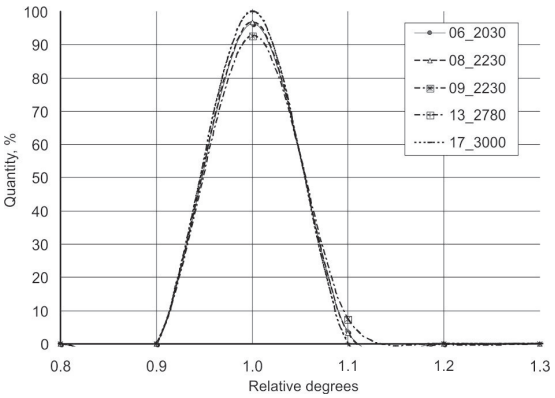

Fig. 2. Share distribution of sawn timber pieces by relative degrees of width.

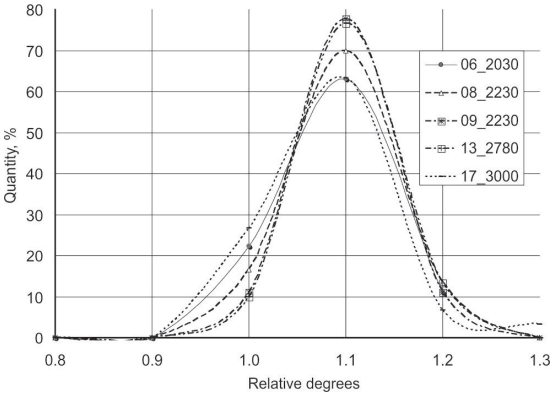

Fig. 3. Share distribution of sawn timber pieces by relative degrees of moisture content.

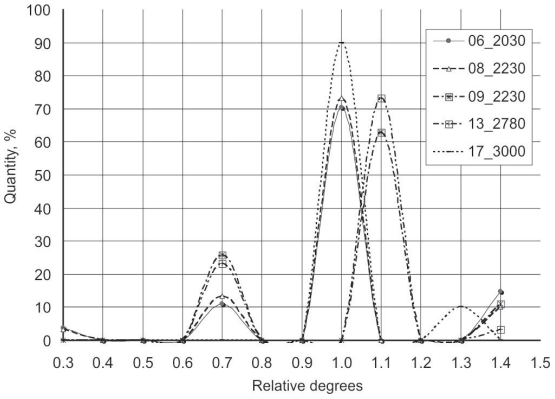

Fig. 4. Share distribution of sawn timber pieces by relative degrees of quality.

difference in distributions by relative degrees of quality classes is explained by different values of the minimum and maximum values of this indicator in different samples, selected from packages: 06-2030 and 17-3000 had an average quality lower and it was 3.0 and 3.10 accordingly, and 08-2230, 09-2230 and 13-2780 had an average value of less than 3.0, 2.90, 2.85 and 2.80, accordingly. Therefore, for 06-2030 and 17-3000, the formation of peak distributions is observed at a relative degree of 1.1, and for the rest of the samples – by 1.0.

The results of measurement error calculating between comparisons of the arithmetic mean of experimental data, determined by formulas 1 and 2, are shown in Table. 6.

Since the obtained indexes of the measurement error of arithmetic mean values of experimental data between the corresponding samples for all, without exception, the sample pairs are less than the table data's, one can assert the homogeneity of the selected research material.

Measurement error (ME) is practically for all indicators of researched sawn timber in the range of 0.1–5.0 %, which suggests that the experiment has been conducted with sufficient accuracy. It should be noted that the measurement error of dimensional indicators is actually the lowest, comparing them with the quality and moisture content. The highest measurement error values were found to evaluate the quality of timber, which is quite logical, given the high value of the coefficient of variation. At the same time, the value of the measurement error indicator for quality is quite high and does not exceed 5 %.

Table 6. Calculation of ME comparing AM of experimental data between the corresponding samples.

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
$s^2_{06-2030}$	46.2	368.7	26.3	11.0	18.4
$s^2_{08-2230}$	53.5	283.5	54.8	10.7	7.8
k_1	57	57	57	57	57
t_1 value	**0.36**	**0.91**	**0.32**	**0.17**	**0.18**
$s^2_{06-2030}$	46.2	368.7	26.3	11.0	18.4
$s^2_{09-2230}$	28.7	747.2	59.9	9.4	5.2
k_2	54	54	54	54	54
t_2 value	**0.33**	**1.26**	**0.35**	**0.17**	**0.18**
$s^2_{06-2030}$	46.2	368.7	26.3	11.0	18.4
$s^2_{13-2780}$	32.4	399.4	26.7	6.8	8.4
k_3	57	57	57	57	57
t_3 value	**0.32**	**0.99**	**0.26**	**0.15**	**0.19**
$s^2_{06-2030}$	46.2	368.7	26.3	11.0	18.4
$s^2_{17-3000}$	157.1	221.5	19.5	2.7	18.6
k_4	57	57	57	57	57
t_4 value	**0.51**	**0.87**	**0.24**	**0.13**	**0.22**
$s^2_{08-2230}$	53.5	283.5	54.8	10.7	7.8
$s^2_{09-2230}$	28.7	747.2	59.9	9.4	5.2
k_5	57	57	57	57	57
t_5 value	**0.32**	**1.15**	**0.38**	**0.16**	**0.13**
$s^2_{08-2230}$	53.5	283.5	54.8	10.7	7.8
$s^2_{13-2780}$	32.4	399.4	26.7	6.8	8.4
k_6	60	60	60	60	60
t_6 value	**0.31**	**0.89**	**0.31**	**0.14**	**0.14**
$s^2_{08-2230}$	53.5	283.5	54.8	10.7	7.8
$s^2_{17-3000}$	157.1	221.5	19.5	2.7	18.6
k_7	60	60	60	60	60
t_7 value	**0.49**	**0.76**	**0.29**	**0.12**	**0.17**

Index	Thickness, mm	Width, mm	Length, mm	Quality	Moisture content, %
$s^2_{09-2230}$	28.7	747.2	59.9	9.4	5.2
$s^2_{13-2780}$	32.4	399.4	26.7	6.8	8.4
k_8	57	57	57	57	57
t_8 value	**0.28**	**1.21**	**0.33**	**0.14**	**0.13**
$s^2_{09-2230}$	28.7	747.2	59.9	9.4	5.2
$s^2_{17-3000}$	157.1	221.5	19.5	2.7	18.6
k_9	57	57	57	57	57
t_9 value	**0.49**	**1.11**	**0.32**	**0.12**	**0.17**
$s^2_{13-2780}$	32.4	399.4	26.7	6.8	8.4
$s^2_{17-3000}$	157.1	221.5	19.5	2.7	18.6
k_{10}	60	60	60	60	60
t_{10} value	**0.47**	**0.84**	**0.23**	**0.10**	**0.18**
t_{st} (P 0.05)	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Note: Comparison code between samples: 1 – 06-2030 i 08-2230; 2 – 06-2030 i 09-2230; 3 – 06-2030 i 13-2780; 4 – 06-2030 i 17-3000; 5 – 08-2230 i 09-2230; 6 – 08-2230 i 13-2780; 7 – 08-2230 i 17-3000; 8 – 09-2230 i 13-2780; 9 – 09-2230 i 17-3000; 10 – 13-2780 i 17-3000; k_n – total number of options for pairs of samples.

In fact, 144 pieces of sawn timber from 5 packages were selected, which is more than the minimum 125 required to determine batch consistency with dimensional and qualitative characteristics (Welling 2010).

The amount of required number of samples was calculated by the formula (3). Using the values of SE, ME, and SD, calculated for individual samples, it was found that to correctly determine the deviations, including measurement accuracy and errors at the appropriate humidity, it is sufficient to use no more than 24 pcs. from each sample of the appropriate type of lumber. To receive an odd number from each package from the randomly selected package it is expedient to use for the general account one additional piece of a sawn timber (Lakin 1980).

So, it is proved that in general for the selected batch of sawn timber it is enough to use a sample of 125 samples – 25 samples from 5 packages.

The next stage of the study was to determine the size indicators and their changes by fact moisture content. These data are compared with the declared moisture content.

According to DSTU EN 1313-2:2018 (2018) the permitted deviations at moisture content of 20 %, are as follows:

- thickness (t_{nom}) at $t \leq 32$ mm: – 1 mm, + 3 mm; at $t_{nom} > 32$ mm: – 2 mm, + 4 mm;
- width (b) at $b \leq 100$ mm: – 2 mm, + 6 mm; at b 100 mm < b < 200 mm: – 3 mm, + 9 mm; $b > 200$ mm: – 4 mm, + 12 mm;
- length (l) – 0, + 3 % of nominal length, but not more than 90 mm.

DSTU EN 1313-2:2018 (2018) also contains a list of the most common nomi-

nal sizes of hardwood sawn timber (20 % moisture content): 20, 27, 32, 40, 50, 60, 65, 70, 80, 100 mm by thickness; by width – from 50 to 90 mm in steps of 10 mm and from 100 mm with a step of 20 mm.

The actual moisture content of wood was within 11–16 %. Permitted thickness and width of sawn timber for this moisture content are given in Table 7.

Table 7. Permitted thickness and width of sawn timber by fact moisture content (DSTU EN 1313-2:2018 2018).

Nominal size of thickness and width, mm	Moisture content of sawn timber, %			
	11–13		14–16	
	Permitted thickness and width, mm			
	min	max	min	max
27	25.4	29.4	25.6	29.6
32	30.3	34.3	30.4	34.4
190	184.3	192.3	185.7	193.7
200	193.1	205.1	194.5	206.5

Definition of the volume of sawn timber was carried out at nominal dimensions in accordance to EN 1312:1997 (1997) – formula (4).

$$V = t_{nom} \cdot b_{nom} \cdot l_{nom}, \quad (4)$$

where: V – volume of sawn timber, m^3; t_{nom} – nominal thickness of sawn timber, mm; b_{nom} – nominal width of edged timber, mm; l_{nom} – nominal length of sawn timber, m.

Due to the proof of a sufficient number of samples (125), it was from this number that samples were taken at random by analysis.

The results of the control show that the number of sawn timber, which by size does not correspond to the declared in the shipping documents, is 57 pcs of the 125 selected in the sample. Since it is larger than the acceptance number 21, such a batch is considered to be ineligible for technical characteristics stated in the shipping documents (ENV 12169:2008 2008). Exceeding the dimensional characteristics is +4.0–8.7 mm in thickness and +9.0–18.7 mm in width at 58.4 % of the sawn timber from the total in the batch. Of these, 44.8 % of boards have nominal dimensions of 32 mm in thickness and 200 mm in width. The length does not exceed the permitted deviation of +0–90 mm. The results of selective control expressed in volumetric units (4.22 % over by volume) were distributed to the entire lot of sawn timber. Thus, the fact volume of the lot of sawn timber will amount to 28.255 m^3, which is 1.759 m^3 (4.22 %) higher than the volume declared in the shipping documents. According to the qualitative characteristics, the results of the control show that the higher grade Q-F 3-4 according to EN 975-1:2009 (2009) – there are 7 pcs sawn timber from 125 pcs, which is below acceptance number 21. In this case, the batch of sawn timber corresponds to the information in shipping documents by quality.

Conclusions

It was confirmed the sufficiency of usage of the sample of 125 pieces from 5 packages by using the recommendations for checking the conformity of the sample to the acceptable quality level for the total batch of a sawn timber, which was 2207 pcs in 5 packages.

The criterion for determining the batch conformity of accompanying technical documentation is the corresponding value of acceptance number, which depends on the acceptable quality level (AQL) for the appropriate batch size: this is usually defined as the worst quality level, the percentage of non-compliant parts still acceptable. In this study, we considered a partial case for a total batch of 1201 to

3200 pcs (total number of pieces in the batch).

According to the results, it is established that the features of grouping the number of sawn timber particles around the central stage by degrees of thickness, width and length are crucial for establishing similarity. The distribution of particles by degree of wood moisture content also confirms the established patterns and differs only in the values of the particles of sawn timber grouped around the central stage of the index.

For the characteristics of homogeneity of the material, it is advisable to use indexes of the significance of difference in the comparison of average values of experimental data between the appropriate samples. In the case of our study, ME for almost all indexes of the studied sawn timber is in the range of 0.1–5.0 %, which indicates that the number of samples taken for measurement is sufficient, and the experiment was conducted with sufficient accuracy. It was also found that MEs of dimensional indicators (width, length and thickness of the wood blanks) are actually the lowest, compared with the quality and moisture content of sawn timber. The highest values of measurement error were found to assess its quality, which is quite logical, given the high value of variation coefficient. However, the value of measurement error for quality is quite high and does not exceed 5 %.

In fact, by analyzing the distributions by relative degrees and statistical indicators of the experimental material by dimensional indexes, less sawn timber could be used in the sample. But due to the fact that the moisture content is uneven even within one package, and the quality is more variable than the rest indexes, we will stop on the confirmed choice of the set quantity of pieces for measurement.

References

Brown T.D. 1979. Determining Lumber Target Sizes and Monitoring Sawing Accuracy. Forest Products Journal 29(4): 48–54.

Brown T.D. 1982. Quality Control in Lumber Manufacturing. Miller-Freeman Publications, USA. 288 p.

Brown T.D. 1986. Lumber Size Control. Forest Research Laboratory, Oregon State University, USA, Special Publication 14. 16 p.

Brown T.D. 2000. Performance excellence in the wood products industry, Lumber size control, Part 1: Measurement methods. Oregon State University, USA, Publication EM 8730. 11 p.

Buchanan T. 2000. Costly wood, product quality drive push for size control. Wood Technology 127(2): 56–57.

Cochran W.G. 1963. Sampling Techniques. John Wiley & Sons, Inc., USA. 413 p.

DSTU 4920:2008 2008. Sawn wood. Assessment of radial and tangential shrinkage. (in Ukrainian).

DSTU EN 1309-1:2001 2001. Round and sawn timber – Method of measurement of dimensions – Part 1: Sawn timber. (in Ukrainian).

DSTU EN 1310:2005 2005. Round and sawn timber – Method of measurement of features. (in Ukrainian).

DSTU EN 1311-2001 2001. Round and sawn timber. Method of measurement of biological degrad. (in Ukrainian).

DSTU EN 1313-2:2018 2018. Permitted deviations and preferred sizes – Part 2: Hardwood sawn timber (EN 1313-2:1998/AC:1999, IDT). (in Ukrainian).

DSTU EN 13183-2:2004 2004. DIN EN 13183-2. Moisture content of a piece of sawn timber – Part 2: Estimation by electrical resistance method. (in Ukrainian).

EN 975-1:2009 2009. Sawn timber – Appearance grading of hardwoods – Part 1: Oak and beech.

EN 1312:1997 1997. Round and sawn timber. Determination of the batch volume of sawn timber.

ENV 12169:2008 2008. Criteria for the assessment of conformity of a lot of sawn timber.

Guzenda R., Majka J., Olek W., Dudzinski J.

2002. Moisture content of timber after drying – estimation of drying quality. Electronic Journal of Polish Agricultural Universities. Wood Technology 5(2), #01. Available at: http://www.ejpau.media.pl/volume5/issue2/wood/art-01.html

Lakin G.F. 1980. Biometrics. Moscow: Vysshaya shkola. 293 p. (in Russian).

Montgomery D.C., Runger G.C. 2003. Applied Statistics and Probability for Engineers. 3rd edition, John iley & Son, Inc., Hoboken. 976 p. Available at: http://www.um.edu.ar/math/montgomery.pdf

Pinchevska O., Spirochkin A., Sedliačik J., Oliynyk R. 2016. Quality assessment of lumber after low temperature drying from the view of stochastic process characteristics. Wood Research 61(6): 871–884.

Welling J. 2010. Dried Timber – how to specify correctly. Hamburg. 38 p.