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EVALUATION OF MEASUREMENT UNCERTAINTY OF TEXTILES QUALITY

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In the article the features of applying of uncertainty types A and B, as well as the total expanded uncertainty to evaluate the accuracy of measurement results was analyzed. Applying of the method of uncertainty calculation on the example of evaluation of measurement accuracy of yarn linear density as a main parameter for evaluating the textiles quality was considered.

Keywords: *evaluation of accuracy, measurement uncertainty, textiles quality*

Accuracy ensuring of measurement of textiles parameters is a main thing in improving the quality and competitiveness of light industry.

The measurement process [1] is presentation of observed values by their values during experiment and calculations by using special equipment. The accuracy of measurement is the main characteristic of quality measurement which reflects the closeness of the result to the true observed value.

Nowadays in the world it is accepted evaluation of accuracy based on uncertainty. The main instrument of evaluation of uncertainty at the international level is [2], but in Ukraine is regulated by GOST-N RMG 43:2006 [3]. However, guidelines on the expression of measurement uncertainty is too broad and complex to use in practice, and regulatory documentation concerning test methods of textiles properties, for the most part, do not operate with evaluation of measurement uncertainty.

A lot of parameters regulated by normative documents should be defined to evaluate the quality of textiles [4]. All textiles parameters which are measured during the test can be considered as random value that can be detected through distributive law function. Estimates of parameters which characterise offense the veracity of the measurement result and have dimension of observed value is called the uncertainty of measurement [5].

Uncertainty of measurement expresses the fact that a given observed value for this result does not have single measure of value, and there is an infinite number of values scattered around the outcome that is consistent with all the observations and data.

Therefore, to evaluate the quality of the measurement result usually use not the error, but the probabilistic characteristic, based on the estimated variation of the measurement result.

Therefore, of the theoretical and experimental research methods to assess uncertainty measurement properties of textiles is an actual task of assurance of high quality products of light industry.

Formulation of the problem

Depend on calculation methods uncertainty can be standard, total and the expanded uncertainty [5, 6, 7].

The standard uncertainty divided into type A, which is estimated by statistical analysis of the results of repeated observations and type B, which is estimated non-statistic methods. Both types of uncertainties are evaluated based on probability distributions and quantitatively characterised by the square deviation.

The total uncertainty is the addition of the standard probabilistic uncertainties.

Expanded uncertainty is a value that specifies the interval around the measurement result which include most of distribution values that can be attributed to the observed value.

This article deals with measurement of linear density uncertainty like example for evaluation of measurement uncertainty of yarn properties.

The output data obtained by direct measurement are:

m – weight of yarn, 1.56 g,

l – length of yarn: 0.1 km.

Torsion fiber balance were used to determine the weight of the yarn and line to determine the length. A measuring sensitivity of torsion fiber balance is 0,001 g but line is 1 mm.

Objects and the methods of the investigation

The object of the investigation is to evaluate the accuracy of measurement of quality textiles based on the calculation of uncertainty.

Theoretical investigation based on the main provisions of metrology and standardization, including methods of accuracy evaluation, and the regulatory documentation concerning the selection of uncertainty. Processing of experimental research were carried out by using the software MS Excel.

Results and discussion

The value of the linear density of the yarn is obtained by indirect measurement.

$$T = \frac{m}{l} = \frac{1{,}56}{0{,}1} = 15{,}6 \text{ tex},$$

where m – weight of yarn, g: l – length of yarn km.

Array of data for the linear density parameter were obtained during repeated measurements (Table 1).

Table 1

Linear density parameter value

№ measurement	1	2	3	4	5	6	7	8	9	10
linear density, tex	15,60	15,62	15,54	15,69	15,58	15,62	15,64	15,55	15,58	15,51

The standard type A uncertainty of linear density parameter estimate as follows:

$$u_A^{л.г.} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n \cdot (n-1)}} = \sqrt{\frac{0,025}{10(10-1)}} = 0,0167 \text{ tex},$$

where x_i – the result of measurement, $\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ – the arithmetic average of measurement results, n – number of measurements.

The standard type B uncertainty of variables which included in the equation:

– the uncertainty of the yarn length is determined by the formula:

$$u_B(l) = \frac{q^l}{4\sqrt{3}} = \frac{1\times10^{-6}}{4\sqrt{3}} = 0,1443\times10^{-6}\,\text{km},$$

where q^l – measuring sensitivity. q^l = 1mm = 1×10^{-6} km.

– the uncertainty of the yarn weight is determined by the formula

$$u_B(m) = \frac{q^m}{4\sqrt{3}} = \frac{0,1}{4\sqrt{3}} = 0,01443 \text{ g},$$

where q^m – measuring sensitivity. q^m = 0,1 g

Additional influential factors are lacking or their influence can be neglected. The standard uncertainty of type B values not included in the equation are lacking as well.

Equation of functional connection (1) of total uncertainty of yarn linear density and uncertainties output values:

$$u_C(T) = \sqrt{\left(\frac{\partial T}{\partial m}\right)^2 \cdot u_B^2(m) + \left(\frac{\partial T}{\partial l}\right)^2 u_B^2(l)} \quad , \qquad (1)$$

However, considering that the value of the standard uncertainty have different dimension, they can not be summed, and they should be converted to nondimensional values - relative uncertainty:

$$\delta_B(l) = \frac{u_B(l)}{l} = \frac{0{,}1443 \times 10^{-6}}{0{,}1} = 1{,}443 \times 10^{-6};$$

$$\delta_B(m) = \frac{u_B(m)}{m} = \frac{0{,}01443}{1{,}56} = 0{,}0092\,,$$

Then, equation (2) to relative uncertainty evaluation of the total yarn linear density will look like:

$$\delta_C(T) = \sqrt{\left(\frac{\partial T}{\partial m}\right)^2 \cdot \delta_B^2(m) + \left(\frac{\partial T}{\partial l}\right)^2 \delta_B^2(l)}\,, \qquad (2)$$

Determining of weight coefficient as the first partial derivatives of the measurement for each of the input variables:

$$\frac{\partial T}{\partial m} = \frac{1}{l} = \frac{1}{0{,}1} = 10{,}0; \quad \frac{\partial T}{\partial l} = -\frac{l}{l^2} = \frac{1}{0{,}01} = 100{,}0$$

Thus, the relative uncertainty of the yarn linear density:

$$\delta_C(T) = \sqrt{10^2 \cdot 0{,}0092^2 + 100^2 \cdot 0{,}1443^2 \times 10^{-10}} = 0{,}092$$

Then, the total type B uncertainty of the yarn linear density:

$$u_C(T) = T \cdot \delta_C(T) = 15{,}6 \cdot 0{,}092 = 0{,}1472 = 0{,}15 \text{ tex}$$

Coverage factor of uniform distribution law and the trust level p = 0,95 is k = 1,65. Expanded uncertainty of yarn linear density:

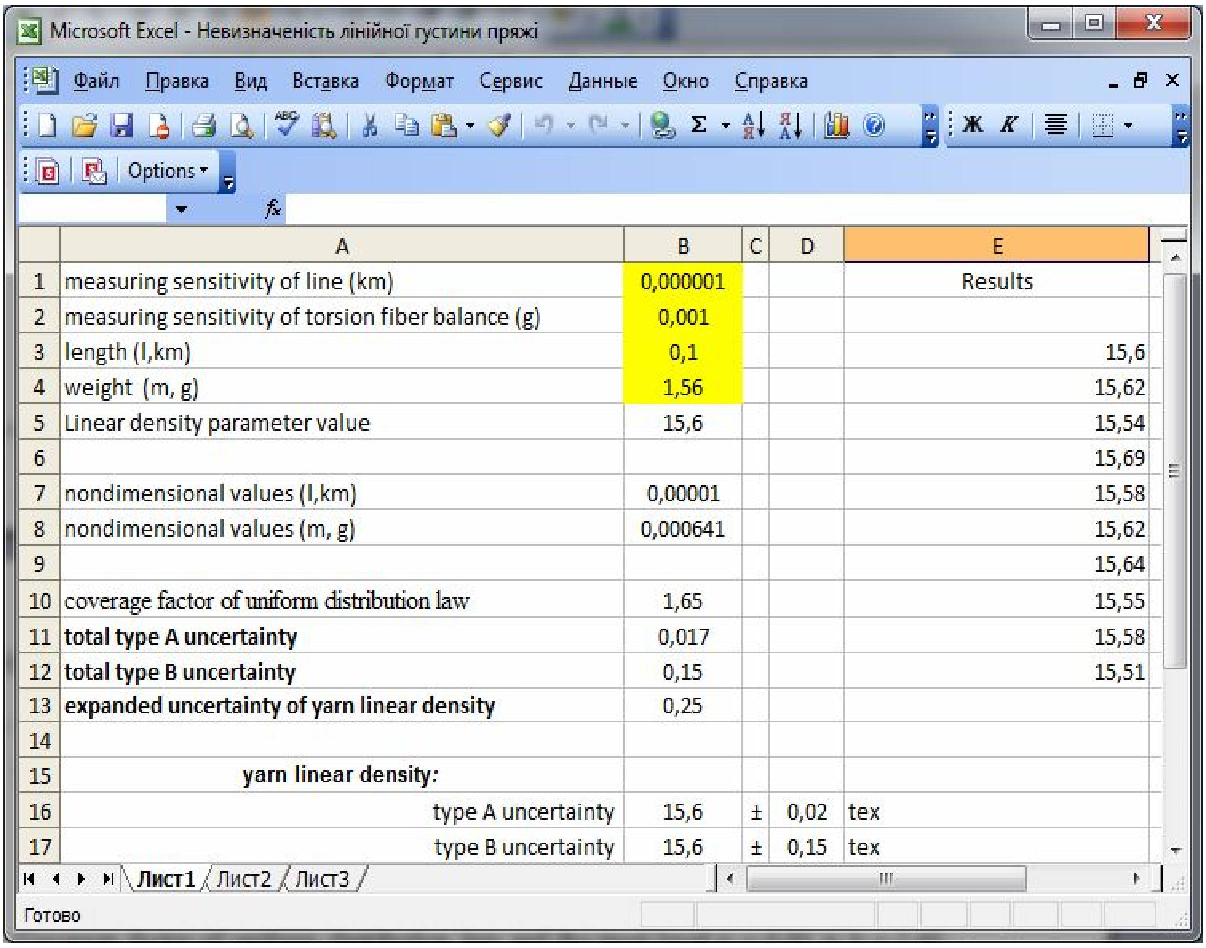
$$u(T) = k \cdot u_C(T) = 1{,}65 \cdot 0{,}15 = 0{,}25 \text{ tex}$$

According to rounding rules, the result of measurement of yarn linear density:

- for the type A uncertainty: T = 15,23 ÷ 15,97 tex , p = 0,95
- for the type B uncertainty: T = 15,36 ÷ 15,84 tex , p = 0,95

Calculation of uncertainty must be performed for each received a point each measured value, so the automation of calculations is necessary. For processing the results of evaluating the textiles quality and evaluation of uncertainty standard software will be enough.

Calculation example of measurement uncertainty of yarn linear density by using Microsoft Excel are presented (Figure 1).


Microsoft Excel - Невизначеність лінійної густини пряжі

	A	B	C	D	E
1	measuring sensitivity of line (km)	0,000001			Results
2	measuring sensitivity of torsion fiber balance (g)	0,001			
3	length (l,km)	0,1			15,6
4	weight (m, g)	1,56			15,62
5	Linear density parameter value	15,6			15,54
6					15,69
7	nondimensional values (l,km)	0,00001			15,58
8	nondimensional values (m, g)	0,000641			15,62
9					15,64
10	coverage factor of uniform distribution law	1,65			15,55
11	**total type A uncertainty**	0,017			15,58
12	**total type B uncertainty**	0,15			15,51
13	**expanded uncertainty of yarn linear density**	0,25			
14					
15	**yarn linear density:**				
16	type A uncertainty	15,6	±	0,02	tex
17	type B uncertainty	15,6	±	0,15	tex

Лист1 / Лист2 / Лист3

Готово

Figure 1. **Calculation of measurement uncertainty of yarn linear density by using Microsoft Excel**

Conclusions

The accuracy estimation of yarn linear density measurement based on the applying the methods of uncertainty calculation of measurement results were obtained. According to the calculation the type A uncertainty is 0,017 tex, type B is 0.15 tex, expanded uncertainty is 0.25 tex.

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Оцінка невизначеності вимірювання показників якості текстильних матеріалів

У статті проаналізовано особливості застосування невизначеностей типів А та В, а також сумарної та розширеної невизначеностей для оцінювання точності результатів вимірювання. Розглянуто застосування методики розрахунку невизначеностей на прикладі оцінки точності вимірювання лінійної густини пряжі, яка є ключовим параметром для оцінки якості текстильних матеріалів.

Ключові слова*: оцінка точності, невизначеність вимірювань, якість текстильних матеріалів*

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Оценка неопределенности измерений показателей качества текстильных материалов

В статье проанализированы особенности применения неопределенностей типов А и В, а также суммарной и расширенной неопределенностей для оценки точности результатов измерений. Рассмотрено применение методики расчета неопределенностей на примере оценки точности измерения линейной плотности, которая является ключевым параметром для оценки качества текстильных материалов.

Ключевые слова*: оценка точности, неопределенность измерений, качество текстильных материалов*