DETERMINATION CLASS OF THE COMPRESSES OF A COMPRESSION KNITTED GOODS AND EVALUATION OF THEIR UNCERTAINTY

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Abstract. This article discusses one of the issues of assessing the quality of a compression medical jerseys - this gives determining their compression class, as well as the accuracy characteristics (uncertainties) of the test results.
Keywords: class, compression, knitwear, elongation, working, breaking load, surface density, uncertainty.

Relevance of work

Despite the relevance and topicality of the issue, relating to the determination of the compression class of a compression medical jersey (further - product compression class) and estimation of the uncertainty of the research results, at this time there are practically no works devoted to the issue of uncertainty estimation.

Purpose of work

In this regard, we considered the development of a program for determining the compression class of a medical device and assessing the uncertainty of research results in accordance with international requirements.

Statement of the main material

The compression class of the product, as you know, is determined by such technical characteristics as: elongation, working elongation, breaking load and surface density [1].

Working elongation and breaking load are determined experimentally [1, p.6.6]. Elongation Lp and surface density P of the product are determined respectively by formulas (1) and (2). [1, p.6.5.5.1]

$$L_p = L_{p,mm} \cdot \text{C} \tag{1}$$

$$\Pi = 10^6 \cdot \frac{m}{l \cdot b} \tag{2}$$

Here,

L_p – elongation, %,

$L_{p,mm}$ – elongation, mm,

C – recount coefficient, equal 10^6,

Π – surface density, g/m^2

m, *l*, and *b* – weight, length and width of the strip.

Further, according to the experimentally obtained values of elongation, working elongation, breaking load, surface density and the requirements given in table 6 of the standard [1], determine the compression class of highly elastic medical and preventive hosiery and sleeves

It is advisable to determine the compression class of the product using a software product. The simplest implementation of this kind of programs is the program that we are developed in the Excel environment (Table 1).

Depending on the results of comparisons of values which obtained experimentally with the requirements of the standard [1], in one of the cells H32: L32 (Table 1) appears a Roman numeral, that corresponding to the compression class of the goods (with positive results of comparisons), otherwise in cells I33: L33 may appear information on non-compliance of the product with the requirements of standard [1] in the form of "<30%", "<49.0 N", "<120%", "<40 g / m^2".

The experimentally received results of the mass *m*, length *l*, and width *b* of the strips, working elongation X_1, breaking load X_2 and elongations X_3 (hereinafter - input values X_j (BxB)) of the tested product is introduced respectively by typing their values into cells C4: E8, J4: L8 Table 1.

Estimates (arithmetic mean values) of the input quantities, with the number of their observations $n_j > 1$, are determined by the well-known formula and are reflected in cells C9: E9, J9 and L9.

The program that we developed also allows to automate the process of evaluating accuracy characteristics, in particular, the uncertainty of the results of measuring mass *m*, length *l*, and width *b* of strips, original length L_0, extensibility, working extensibility $L_{p,\ mm}$ and breaking load, surface density and as a result, the uncertainty determining the compression class of the tested product.

Estimation of the uncertainty of results of test products, especially for medical destination, is a requirement of the international standard IS0/1EC 17025: 2005 [2] and identically to it state standard of the Republic of Uzbekistan O'z DSt ISO / IEC 17025 [3]

Tab. 1.

The program for determining the compression class of the product and their uncertainties

A	B	C	D	E	F
2	n_i	x_j			y_1, g/m^2
3		m_i, g	l_i, *mm*	b_i, mm	
4	1	3,5	101	101	343,1
5	2	3,6	101	102	349,4
6	3	3,4	101	100	336,6
7	4	3,6	100	99	363,6
8	5	3,7	102	101	359,2
9	x_{cp}	3,56	101	101	350
10	$u_A(x_j)$	0,05	0,3	0,5	5
14	$u_B(x_j)$	0,3	0,6	0,6	
15	$u(x_j)$	0,3	0,7	0,8	1,1
16	$c_j=\partial f/\partial x_j$	98,4	3,5	3,5	
17	$c_j \cdot u_A(x_j)$	5,0	1,1	1,8	
18	$c_j \cdot u_B(x_j)$	0,294	0,648	0,648	
19	$r(m, l)$	0,310			
20	$r(l, b)$		0,620		
21	$r(m, b)$	0,231			
22	$t_p(\upsilon_{eff})$	2,776	P=	0,95	
26	$u_{cA}(y_1)$				5
27	$u_{cB}(y_1)$				1,0
28	$u_c(y_1)$				6
29	υ_{eff}				4
30	U determination of surface density				15
31	Writing a measurement result, g/m^2				
32	350	±	15	P=	0,95
33					

H	I	J	K	L
2	Definition of Compression Class			
3	n_i	x_1, %	x_2, N	x_3, %
4	1	35	198	133
5	2	38,9	195	130
6	3	42	197	131
7	4	45	196	132
8	5	47,6	195	133
9	x_{cp}	41,7	196,2	131,8
10	$u_A(x_j)$	2,2	0,6	0,6
14	$u_B(x_j)$	0,8	0,8	0,8
15	$u(x_j)$	2,4	1,0	1,0
16	$c_j=\partial f/\partial x_j$	3,161	0,672	1,000
17	$c_j \cdot u_A(x_j)$	7,015	0,392	0,583
18	$c_j \cdot u_B(x_j)$	0,819	0,819	0,819
19	$r(x_1, x_2)$	-0,626		
20	$r(x_2, x_3)$		0,324	
21	$r(x_1, x_3)$	0,174		
22	$t_p(\upsilon_{eff})$	2,776	P=	0,95
26	$u_{cA}(y_1)$		0	9
27	$u_{cB}(y_1)$		0	1,7
28	$u_c(y_1)$		0	9
29	υ_{eff}			4
30	U definition of compression class			25
31	compression class			
			III	
33	<30	<49,0	<120	<40

The implementation of these requirements of the standards is carried out on the basis of the use of the "Guidelines for the expression of uncertainty of measurement" (GUM: 1993) [4]. As a rule, these requirements cause certain difficulties for laboratory personal.

Given these circumstances, the program we are considering, along with the definition of the compression class, includes questions of estimating the uncertainty of test results.

The program we are considering determines the **standard uncertainties (SU)** of the measurement results $\boldsymbol{m}_i$, $\boldsymbol{l}_i$, $\boldsymbol{b}_i$, working elongation x_1, breaking load x_2 and elongation x_3 by types A and B.

Type B uncertainties are estimated taking into account: weighing errors (±0.01 g), measurements (± 1%), calculations (± 0.1), rounding, and also the division error of the measuring instruments and setting the distance between the clamps [1] .

The program further calculates the sensitivity coefficients $\partial f / \partial x_j$, $\partial f / \partial x_L$ of the BxB estimates for the changes in the BxB estimates x_j and x_L, the contribution of the SU BxB on the total standard uncertainty (TSU) of type A and type B, correlation coefficients (CC) between BxB and evaluates their significance using criteria of coefficient student.

After determining all the components of the measurement uncertainty are estimated their *total standard uncertainty* $u_c(y)$ in accordance with the law of propagation of the uncertainty [4].

Next, the expanded uncertainties of the measurement results (cells F30 and L30) are calculated as

$$U = k \cdot u_c(y)$$

Here,

k - is the coverage coefficient, defined as the student coefficient for the effective number of degrees of freedom υ_{eff}, calculated by the formula of Velch-Sutterswaite.

$$\nu_{eff} = (n-1)\left(1 + \frac{u_B^2(y)}{u_A^2(y)}\right)^2$$

Compilation of the budget of uncertainty. To analyze the results obtained, they are presented in the form of an uncertainty budget (Table 2), which includes a list of all the inputs and their estimates along with the standard measurement uncertainties, sensitivity coefficients and degrees of freedom, the measurement result, the total standard uncertainty, and the effective number degrees of freedom, coverage of coefficient and expanded uncertainty.

Table 2.

Uncertainty Budget

Value and her unit Xi	Rating, x_i	A type uncertainties	Distribution probabilities	Standard and ∑ uncertainty $u(x_i)$	the degree of freedom υ	Coefficient sensitivity c_i	Contribution uncertainties	Share in percents, %
Input values, X_i								
m, g	3,56	Type A	normal	0,3			5,027	**83**
l, mm	101	Type A	normal	0,7			1,274	**5**
***b*, mm**	101	Type A	normal	0,8			1,891	**12**
x_1, %	42	Type A	normal	2,4			7,063	**61**
x_2, N	196,2	Type A	normal	1,0			1,059	**1**
x_3, %	131,8	Type A	normal	1,0			1,005	**1**
Output Values, Y_i								
y_1, g/m^2	350,4	Type A	normal	6	4	1	2,776	**9**
КК	III	Type A	normal	9	4		Coverage rate 2,776	expanded uncertainty **25**

From the analysis of the uncertainty budget, it follows that the total standard uncertainty in estimating the compression class and surface density of the product is mainly due to the (83%) standard uncertainty in measuring the mass of the test strip.

Conclusion

1. We offer testing laboratories to use a program that allows you to automate the process of assessing the quality of compression medical jerseys - this gives determining their compression class and the uncertainty of test results.
2. To improve the quality of determining the compression class and reduce the uncertainty of test results, first of all, increase the accuracy of measuring the mass of the test strip.
3. In accordance with the requirements of standards [2, 3] and GUM Guidelines [4], test uncertainty ratings must be indicated in test certificates.

List of references

[1] GOST 31509:2012 Medical elastic manufactured articles for the fixation and compression. General technical requirements. Test methods.
[2] ISO/IEC 17025:2005 General requirement for the competence of testing and calibrating laboratories.
[3] O'z DSt ISO/IEC 17025: 2007 General requirements for the competence of testing and calibration laboratories. (ISO/IEC 17025:2005, IDT)
[4] Guide to the Expression of Uncertainty in Measurement. ISO, Geneva, First Edition. - 1995 -101 p.