INFLUENCE OF LAUNDERING ON VISCO-ELASTIC PROPERTIES OF CLEANROOM POLYESTER FABRICS

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Abstract
In paper results of investigation of influence of repeated processing "washing-sterilization" on viscoelastic properties of cleanroom fabrics presented. The method of longitudinal resonances vibrations has been used for an estimation of the dynamic module of elasticity, dynamic rigidity and logarithmic decrement of attenuation. It has been established, that the dynamic module of elasticity decreases after the first 10 processing cycles; the subsequent 50 cycles practically do not influence elasticity and rigidity of fabrics. Influence of processing on logarithmic decrement of attenuation has not been revealed. Conclusion has been done that the longitudinal resonance vibrations method is sensible and applicable for estimation of the anisotropy of the visco-elastic properties of textile materials.

Key words: cleanroom fabric, visco-elastic properties, dynamic module of elasticity, logarithmic decrement of attenuation, rigidity, stability, laundering.

1. Interdiction

The cleanroom garment and accessories while in service are exposed to mechanical, thermal and chemical loadings. As a rule, the cleanroom garment should be processed (laundered and sterilised) after each use. One of requirements to cleanroom garment is a saving of physical properties of textile materials. On the average, the cleanroom garment should keep the properties during 50 cycles of processing.

The purpose of work was to study influence of repeated cycles “laundering-sterilization” on visco-elastic properties of cleanroom polyester fabrics with using of longitudinal resonance vibration method.

The structure stability may be characterized by dynamic module of elasticity, dynamic rigidity and logarithmic decrement of attenuation [1, 2]. The visco-elastic characteristics of textiles under dynamic conditions are the fundamental properties in determining the complex parameter of fibre or fabric handle.

2. Materials and method of investigation

For the researches four samples of the polyester fabrics containing in their structure conductive carbon fibres, intended for outer cleanroom garment and one sample of a polyester fabric for underwear have been investigated (Table 1).

Conditions of processing.

Washing was provided in a washing machine at the module of a bath 1:5; it was used non-ionogen surfactant; temperature of washing 60 ºC; time of one washing cycle – 1 hour.

Sterilization was provided in an autoclave at 132ºC; duration of one sterilization cycle – 30 minutes.

The visco-elastic characteristics of textiles under dynamic conditions were investigated by not destroying method of longitudinal resonance vibrations with using of device UDM-1 (elaborated in KNUTD) [3]. There are determined: the complex module of elasticity by measured values of own frequencies; decrement of attenuation and was calculated dynamic rigidity [3].

The method for the determination of dynamic modulus of elasticity, E_d is based on the theory that elasto-plastic bodies such as textiles when are subjected to cyclic sinusoidal forces assume a state of equilibrium after a number of cycles, which is a function of the dynamic properties of structure.

A device operates on the basis of developing the resonance of longitudinal vibration in sample and measurement of vibration frequency at the moment of equilibrium and allows one to determine the modulus of elasticity. A scheme of the device is shown in Figure 1.

Dynamic modulus of elasticity is determined on the basis of the read-out of vibration period and sample parameters (dimension, weight).

Table 1. Structural characteristics of textile for cleanroom garment

Sample symbol	Type of textile, weaving	Raw composition, %	Diameter of fibers, μm, elementary/ complex		Linear density, *tex* / filaments		Surface density, g/m^2	Thickness, *mm*	Sett /10cm		Shrinkage, % (in boiling water)	
			warp	weft	warp	weft			warp	weft	warp	weft
Vectron	woven fabric, plain	PES–99 Carbone fiber–1	10,2/ 168	10,2/ 178	8,3/ 72	8,3/ 72	98	0,12	645	385	1,0	1,0
ALK-LV-102	woven fabric, twill 3/2	PES–99 Carbone fiber–1	14,5	14,4	8,3	10,8	117	0,14	750	500	1,0	1,0
TD-2	woven fabric, plain	PES–99 Carbone fiber–1	10,4	10,0	8,3	20,1	120	0,16	550	330	2,1	0,4
OST-321	knitting fabric, combine	PES–98 Carbone fiber–2	17,0	17,0	–	–	137	0,33	160	130	1,5	3,2
Luna ton	woven fabric, twill 2/1	PES – 100	12,4/ 168	7,9/ 238	8,4/ 72	7,6/ 144	95	0,13	630	335	12,4	+1,4

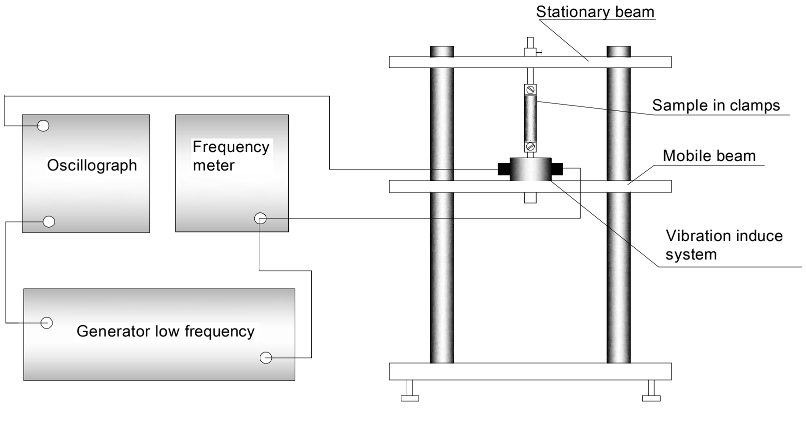


Figure. 1 Operating principle of UDM-1 device [3]

This modulus is calculated from the following formula [N/m^2] [3]:

$$E_d = \frac{4\pi^2 l_o M}{F T_p^2}, \tag{1}$$

where: $\pi = 3{,}14$;

l_0 – operating sample length (m);

M – load weight (kg);

F – surface of sample cross-section (m^2);

T_p – vibration period corresponding to resonance moment (s).

Dynamic rigidity, G [μN·m^2], is measured by the product of modulus E and the moment of inertia, I, of the cross-section in relation to the neutral axis passing through the middle of cross-section according to the following formula:

$$I = \frac{bh^3}{12} \qquad (2)$$

$$G = E_d \cdot I \qquad (3)$$

where: b – sample width (m);
h – sample thickness (m).

The value of logarithmic decrement of attenuation, δ (a phase angle of delay of deformation relatively stress at constant harmonious fluctuations in the visco-elastic environment) is defined with using formula:

$$\delta = \frac{\pi (T_1 - T_2) T_p}{T_1 T_2 \sqrt{N^2 - 1}}, \qquad (4)$$

where T_1 and T_2 – value of the period of fluctuations at which the amplitude of fluctuations is equal to its equilibrium value ($T_1 > T_2$) (s);
T_p – value of the period of fluctuations, by moment of resonance (s);
N – coefficient of increase of excitation force.

Measurements are taken on rectangular samples cut out in longitudinal and crosswise direction and at an angle of 45^0. The developed program of mathematical processing, co-operating with the device, allows one to analyse multi-directionally modulus of elasticity with the angle range from 0 to 360^o by interpolation.

3. Results of investigation

Data of the dynamic module of elasticity, dynamic rigidity and decrement of attenuation before and after 10, 20, 60 cycles of washing are submitted in table 2 and fig.3. Graphics representation of polar diagrams of dynamic characteristics of textiles before washing there are on fig.2.

Table 2. Dynamic characteristics of textiles before and after washing

Sample symbol	Measurement direction	Dynamic module of elasticity, E_d, MPa				Dynamic rigidity, G, μN·m^2				Logarithmic decrement of attenuation, δ			
		Processing cycle, cycle											
		0	10	20	60	0	10	20	60	0	10	20	60
Vectron	warp	182	98	94	120	0,61	0,33	0,31	0,40	0,30	0,21	0,21	0,25
	45 angle	71	48	55	62	0,24	0,16	0,18	0,21	0,25	0,23	0,24	0,21
	weft	241	111	156	148	0,80	0,37	0,52	0,49	0,22	0,36	0,25	0,27
ALK-LV-102	warp	193	132	115	132	0,83	0,57	0,50	0,57	0,26	0,34	0,35	0,29
	45 angle	83	70	55	61	0,36	0,30	0,24	0,26	0,39	0,25	0,29	0,26
	weft	240	153	102	114	1,04	0,66	0,44	0,49	0,22	0,31	0,26	0,22
TD-2	warp	116	97	77	77	1,99	1,66	1,32	1,32	0,26	0,19	0,20	0,17
	45 angle	35	44	40	38	0,60	0,75	0,69	0,65	0,22	0,17	0,23	0,17
	weft	49	74	51	74	0,84	1,27	0,87	1,27	0,22	0,20	0,23	0,17
OST 321	warp	9	9	9	8	1,44	1,44	1,44	1,28	0,18	0,24	0,21	0,19
	45 angle	5	4	4	4	0,80	0,64	0,64	0,64	0,26	0,27	0,26	0,26
	weft	7	7	7	7	1,12	1,12	1,12	1,12	0,24	0,26	0,26	0,24
Luna ton	warp	157	44	13	17	0,68	0,19	0,06	0,07	0,25	0,32	0,37	0,44
	45 angle	42	20	9	14	0,18	0,09	0,04	0,06	0,41	0,28	0,30	0,30
	weft	28	20	13	14	0,12	0,09	0,06	0,06	0,20	0,23	0,36	0,45

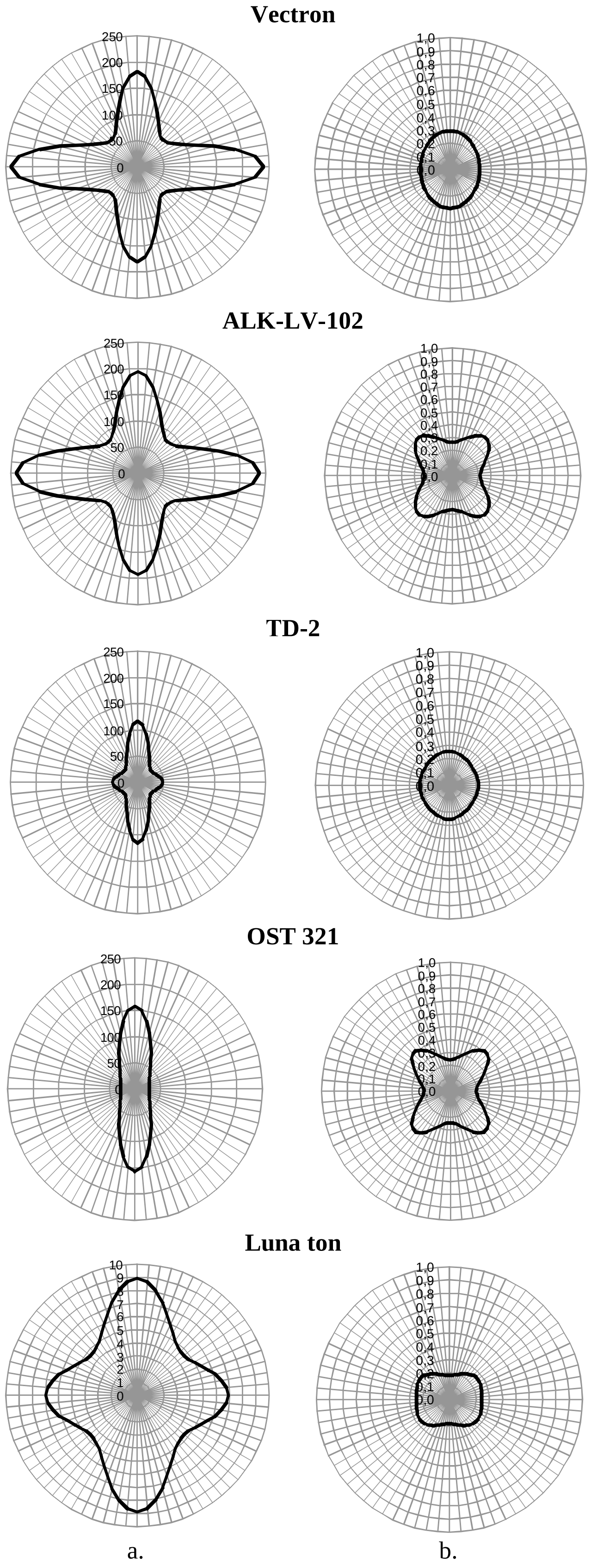


Figure 2. Dynamic characteristics of textiles before washing :
a – Dynamic module of elasticity, E_d, MPa
b – Logarithmic decrement of attenuation, δ.

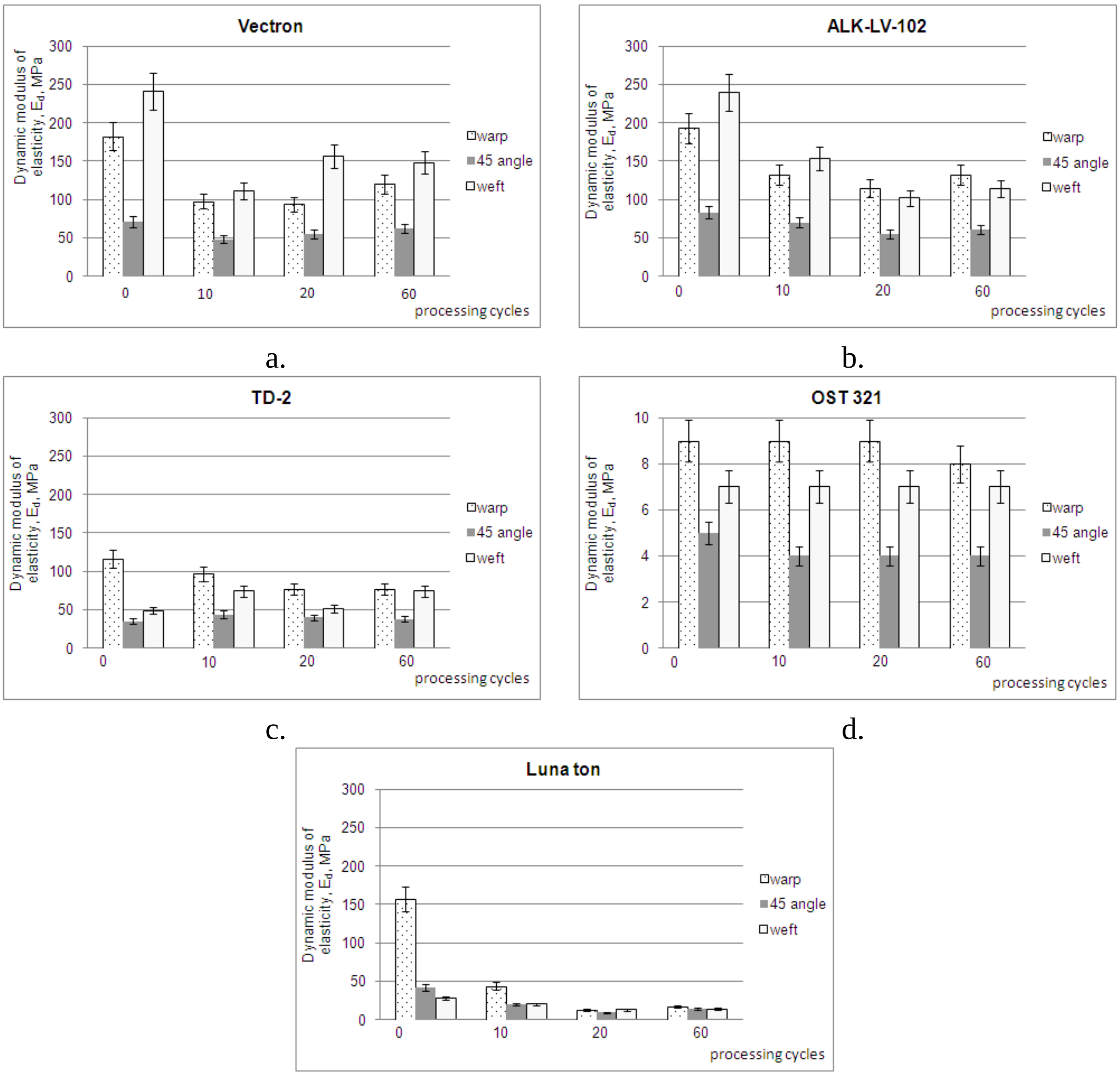
One can see that the first 10 cycles of washing-sterilization cause in changes of dynamic characteristics in all measuring directions (except results for knitting fabric OST 321).

After subsequent 50 cycles of processing these characteristics are not changed practically.

The dynamic module of elasticity characterizes a macrostructure of an investigated material, evolutionary changes during its deformation. The dynamic module is more, the material is more rigid, and its structure is less mobile.

Concerning logarithmic decrement of attenuation: number of washings do not influence its value. Probably it may be explained by stability the structure of polyester fabrics to high-temperature processing.

Significant changes of dynamic characteristics under influence of high-temperature processing in water solutions of a non-ionogen surfactant during the first 10 processing cycles may be explained first of all their significant shrinkage (table 1). The data received by us show that the fabric structure becomes more stable after some first processing cycles.



a. b.

c. d.

f.

Figure 3. Dynamic module of elasticity (E_d, MPa) of textiles before and after washing

4. Conclusion

It has been established, that the structure of fabrics for cleanroom garment is changed considerably after the first 10 processing cycles of “washing-sterilization”. The subsequent 50 cycles practically do not influence stability of fabric structure. The assumption is made, that stability of visco-elastic properties of fabrics is defined by their shrinkage.

The results of the investigations show that the longitudinal resonance vibrations method is rather sensible and its application allows the estimation and control of the anisotropy and stability of textile materials.

5. References

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