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INFLUENCE OF MOISTURE WITH DIFFERENT FORMS OF BONDING IN VISCOSE THREADS ON THE KINETICS OF THREAD DEFORMATION DURING DRYING

M. F. Kazanskii, V. R. Borovskii,
R. V. Lutsyk, A. F. Mel'nikova,
M. D. Korostash, V. A. Shelimanov,
and A. K. Stavtsov

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Shrinkage effects in viscose threads during drying are shown to be governed principally by the form of bonding in the water being eliminated, and the stabilization of the pore structure of the threads is shown to be governed principally by the number of times they are repeatedly wetted and dried.

Drying is one of the most important operations in the process of viscose-thread production. A swollen viscose thread being dried from a moisture content of almost 200% of its absolute dry weight shrinks by more than 10% of its initial volume during drying, causing marked changes in the thread structure and affecting its physicomechanical indices, capacity for dye absorption, capacity for deformation, etc. In this connection, investigations into the influence of the form of moisture bonding in viscose threads on the kinetics of their deformation during drying can be used to provide a sound basis for selecting drying conditions to produce a high-quality material.

The investigations are made on No. 60 viscose textile threads produced in the Kiev Artificial Fiber Combine by the centrifugal method of spinning.

Thermographic [1] and sorption [2] measurements of the aqueous properties of the threads under investigation, which characterize the state of moisture in them according to the form of bonding, are shown in Table 1.

The viscose threads under investigation belong to the group of colloidal capillary-porous bodies [3], and, as can be seen from Table 1, they possess a fairly well-developed macroporous (with pores more than 10^{-7} m in radius) and microporous (with pores less than 10^{-7} m in radius) structure.

The influence of moisture on the deformation of viscose threads during drying is investigated on an apparatus providing for the automatic tracing of the curve of thread weight loss, the curve of linear thread deformation, and the curves of ambient temperature and moisture during experiments onto the tape of a recording potentiometer.

A bunch of 50 threads with an initial length of $(110\text{-}115) \cdot 10^{-3}$ m is used in all the drying experiments. The threads for the bunch are unrolled from a wet coil which has not been dried. Before the experiment the bunch is wetted as much as possible with distilled water. The drying experiments are made with the following parameters for heat-transfer agents: relative moisture content of the air 30% and temperatures of 313, 353, and 393°K. Curves of the dependence of the relative deformation of the threads ε on the moisture content W of the bunch and curves of the rate of drying and rate of deformation are plotted from the experimental results.

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TABLE 1. Differential Water-Retaining Properties of Viscose Threads

Drying temperature, °K	Physicomechanical form of bonding			Physicochemical form of bonding				Amount of moisture in macropores, %	Amount of moisture in micropores, %
	overall moisture content, %	maximum amount of moisture in hygroscopic state, %		adsorbed moisture					
				polylayer		monolayer			
		according to thermograph traces	according to isotherms, $\varphi \to 1.0$	according to thermograph traces	according to sorption isotherms $\varphi \to 0.3$	according to thermograph traces	according to sorption isotherms $\varphi \to 0.1$		
298	179,0	32,0	40,0—50,0	7,0	8,0—10,0	3,3	3,0—4,0	147,0	25,0
353	179,0	32,8	—	6,9	—	3,0	—	146,2	21,8
393	167,0	30,6	—	6,8	—	1,6	—	136,6	23,8

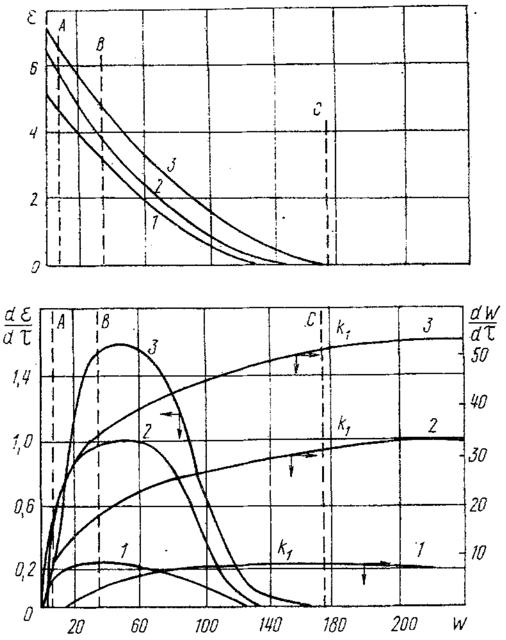

Fig. 1. Dependence of the relative deformation of the bunch of threads ε (%), rate of deformation dε/dτ (%), and rate of drying dw/dτ (kg/sec) on the moisture content W (%) with the following drying temperatures: 1) 313; 2) 353; and 3) 393°K. The dashed lines indicate the regions of various different forms of bonding between the moisture and the threads: A) maximum of amount adsorbed moisture; B) maximum by hygroscopic content; C) overall moisture content.

These curves are given in Fig. 1, in which the vertical lines indicate regions corresponding to the boundaries of the various different forms of bonding between the moisture and the viscose threads.

Table 2 shows values for the moisture content, relative deformation, and rate of deformation corresponding to the most characteristic points on the curves in Fig. 1. This table also shows the magnitudes of the relative thread deformation corresponding to the elimination of moisture from the macropores and micropores and of the adsorbed moisture.

It is clear from a comparison between the curves of Fig. 1 and the data in Table 2 that thread shrinkage begins after the material has reached the first critical point k_1, corresponding to the beginning of the fall in the drying rate. The most intensive thread deformation is observed as the moisture corresponding to the maximum hygroscopic state is eliminated. The rate of deformation falls sharply when the adsorbed moisture is eliminated and thread shrinkage ends virtually simultaneously with the end of the drying process. As the temperature of the heat-transfer agent rises (within the range of variation under investigation), a growth is observed in the maximum relative thread deformation. As can be seen from the figure, a large proportion of the

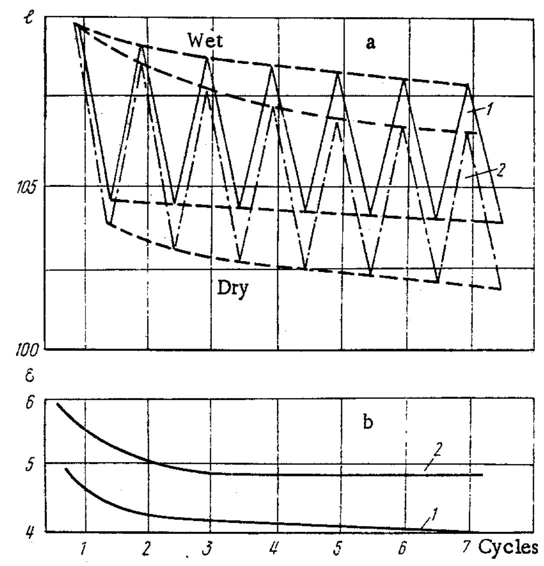

Fig. 2

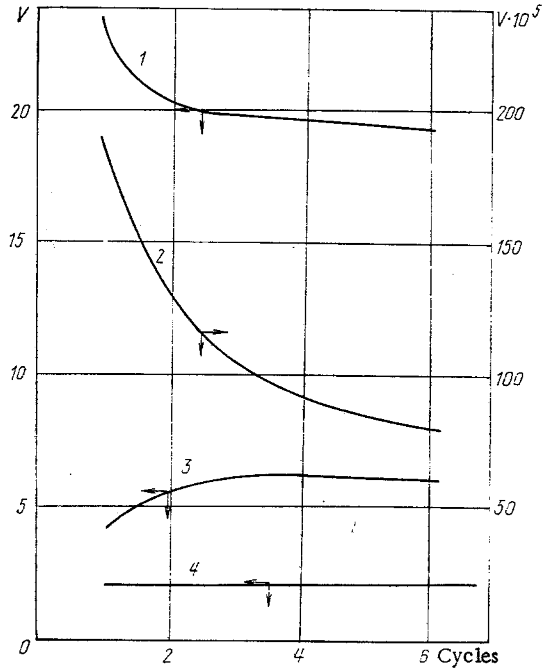

Fig. 3

Fig. 2. Wetting–drying cyclograms for a bunch of threads (a) and dependence of maximum relative deformation ε_{max} (%) on the number of drying–wetting cycles (b) at drying temperatures of 313°K (1) and 373°K (2).

Fig. 3. Dependence of volume V (m^3/kg) of the thread macropores (1), micropores (2), polymolecular adsorption pores (3), and monomolecular adsorption pores (4) on the number of wetting–drying cycles.

thread deformation occurs over the period of macrocapillary moisture elimination (60%). The rest of the deformation takes place during the elimination of microcapillary moisture (30%) and of adsorbed moisture (10%).

The capacity of a dried thread for swelling when brought into repeated contact with water can be used as a structural characteristic of the thread after drying. It is shown in [4, 5] that the thread acquires its final structure only when it is wetted and dried repeatedly.

In this connection, the influence of the drying–wetting cycles on the structuring and final deformation of viscose threads is investigated by the present authors with two series of experiments on drying threads at 313 and 373°K. Each series of experiments consists of seven consecutive drying–wetting cycles on the same bunch. The relative moisture content of the heat-transfer agent in all the experiments is constant and equal to 30%.

A cyclogram of changes in bunch length is shown in Fig. 2a, from which it can be seen that after each wetting the bunch length is not restored to the original value but is reduced and this is also observed after each drying cycle. Quantitatively, these changes in the bunch from cycle to cycle are dependent on the drying temperature. The changes in the maximum relative deformation of the bunch of threads with the number of cycles are shown in Fig. 2b. The magnitude of the relative deformation of the bunch of threads in a cycle is defined as the ratio of absolute deformation to the length of a bunch wetted as much as possible in that cycle. As can be seen from Fig. 2b, considerable changes occur in the relative deformation after the first drying and wetting cycles, and the value of ε then remains virtually constant.

Concurrently with the investigation into the influence of the cyclic recurrence of drying and wetting on the final relative deformation of the threads, changes in the volume of the pores in the threads are determined as a function of the number of times these threads are dried using the drying thermograph trace method.

The dependence of the volume of the thread pores on the number of wetting–drying cycles is shown in Fig. 3.

An analysis of the curves in Fig. 3 reveals that the reduction in the final relative deformation of chemical fiber threads in the first 3-4 drying–wetting cycles is due principally to a reduction in the volumes of the macropores and partially to a reduction in the volumes of the micropores.

TABLE 2. Influence of Form of Moisture Bonding and Drying Temperature on the Kinetics of the Process of Thread Deformation

Experimental temperature, °K	Moisture content corresponding to beginning of deformation, %	Moisture content corresponding to maximum rate of deformation, %	Maximum rate of deformation %/min	Relative deformation of threads, %			
				maximum	corresponding to elimination of moisture from macropores	corresponding to elimination of moisture from micropores	corresponding to elimination of adsorbed moisture
313	140	20-45	0.25	5.9	3.2	1.4	1.3
353	165	30-60	1.03	6.5	4.0	1.8	0.7
393	170	30-60	1.60	6.9	4.3	1.9	0.7

Thus, shrinkage effects in viscose threads when dried are governed principally by the forms of bonding of the water eliminated, and the stabilization of the porous structure of the threads is governed by the number of repeated drying and wetting operations. Cyclical wetting–drying thus generates a significant reduction in the volumes of the macropores and micropores.

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INTERRELATED HEAT AND MASS TRANSFER IN A FLUIDIZED BED IN AN OSCILLATING MODE

V. A. Sheiman

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The problem of the interrelated heat and mass transfer in a fluidized bed in an oscillating mode is formulated with allowance for the circulating motion of the particles, and its solution is obtained with some assumptions.

As is known, a specific property of heat exchange in a fluidized bed consists in the fact that the particles of the bed undergo a brief temperature pulse in a thin layer near the grid owing to heat transfer from the fluidizing agent to the particle surface. The temperature of a particle falls with greater distance from the gas-distributing grid because of the effective heat conduction of the bed and the conductive propagation of heat into the particle, and starting with a certain height the bed becomes isothermal. Thus, the temperature of a particle in the layer near the grid differs from its temperature in the remaining volume. This temperature difference can reach considerable amounts. For example, according to the experimental data of [1] the surface of a moist grain particle is heated by 20°C in 0.2 sec, by 30° in 0.3 sec, and by 40° after 0.5 sec. Upon further heating the temperature difference between the surface and center decreases, although even after 3 sec it was still

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A. V. Lykov Institute of Heat and Mass Transfer, Academy of Sciences of the Belorussian SSR, Minsk.
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