INVESTIGATION OF THE ELASTIC PROPERTIES AND MECHANICAL ANISOTROPY OF MAN-MADE FIBRES AND FILMS. MATERIALS SCIENCE AND TEXTILE TECHNOLOGY

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An important problem in structural mechanics of man-made fibres, yarns, and films is evaluating the anisotropy of the mechanical and, in particular, the elastic and strength properties of these materials, together with establishing the connection between structural parameters and the mechanical properties of polymers.

Among the various methods of determining the elastic properties of fibres, yarns, and films, acoustic methods occupy a special place; they are based on measuring the rate of propagation of ultrasonic (US) waves in the materials under study.

Until recent times in this country, we had not used acoustical methods of investigating fibres, yarns, and films. Work on the indicated problem was started in 1965 in the Kiev branch of the VNIIVproekt by S. G. Osinin and M. P. Nosov. For the first time in our country, methods were developed for determining the rate of propagation of longitudinal US waves in oriented polymer fibres and on this basis instruments were developed and produced for measuring the rate of propagation of US waves and moving waves with automatic recording of the readings (module-I and module-II).

B. D. Rysyuk and M. P. Nosov developed methods of determining the rate of propagation of shear (torsional) US waves and the dynamic shear modulus of polymer fibres and films, and also methods of simultaneously measuring the rate of propagation of longitudinal and shear US waves and the dynamic elastic constants of oriented fibres, yarns, and films. Acoustical methods were developed for investigating the elastic anisotropy of man-made fibres and films, and methods of determining the molecular orientation of amorphous and amorphous-crystalline polymers.

The acoustical instruments developed on the basis of these concepts do not have analogs in worldwide practice. Among them are instruments for determining the rate of propagation of shear (torsional) US waves and the dynamic shear modulus of oriented polymers, and also for simultaneous determination of the dynamic shear moduli, elastic moduli, and Poisson's coefficient with anisotropic fibres, yarns, and films.

Over the course of many years, in the Kiev branch of the VNIIVproekt, numerous laborious studies have been carried out studying the rate of propagation of shear and lengthwise US waves in fibres, yarns, and films of various chemical nature present in various physical states. As a result, important, and in a number of cases, fundamentally new, information was obtained about the structural causation of the mechanical characteristics of polymer fibres and films.
For the first time, all the main dynamic elastic constants of almost all traditional man-made fibres and films were
determined: the elastic modulus, the shear modulus, Poisson's coefficient, and the bulk elastic modulus. The dependence of the
dynamic elastic constants of man-made fibres on molecular orientation figures was studied. The connection between the dynamic
shear modulus and the confirmations of the molecular chain in the crystallite and the supramolecular structure of the polymers
which make up man-made fibres was studied. On the basis of these data, interesting molecular mechanisms were developed for
the transfer of shear stresses in oriented polymers with various confirmations of the molecular chain and various supramolecular
structures.

Relationships were obtained between the elastic constants and the structural parameters of polymers. The dependences
of the elastic and strength properties of man-made fibres on the conditions of orientation stretching and structural transforma-
tions of the material were investigated.

The acoustical methods which were developed made it possible for the first time to carry out systematic complex studies
of the anisotropy of mechanical properties of oriented polymers of various types. The authors have experimentally investigated
the anisotropy of the dynamic elastic modulus of man-made fibres and films. Four types of elastic anisotropy diagrams were
found, caused by the various chemical natures and structural features of the investigated materials.

Dynamic shear modulus anisotropy, the dynamic Poisson coefficient, and the molecular orientation index of a number of
the most widespread polymeric fibres and films were studied.

This cycle of researches was developed and generalized in a monograph by B. D. Rysyuk and M. P. Nosov, "Mechanical
Anisotropy of Polymers," in which contemporary theoretical concepts were set forth about the anisotropy in elastic and strength
properties of polymers [1].

The proposed methods afford a basis for developing automated systems of quality control and for regulating the
physicochemical properties of fibres produced directly during the course of the technological process.

**Strengthening Synthetic Yarns**

Over the course of a number of years, the author and his coworkers have carried out a series of researches investigating
the technological principles in strengthening polyamide yarns. To this they carried out physicochemical studies of the molecular
mechanism of stretching synthetic fibres. The basic problem was to determine the structural transformations at various levels and
to find out structural—mechanical dependences. As a result, already by the middle of the 60s, a series of general principles
governing orientation strengthening of polyamide fibres had been found. Among these, the most important are the dependence
of the ultimately attainable strength on preorientation of the freshly spun yarn, establishment of the effect of instability in the
stretching process, the effect of limiting the maximum attainable stretch ratio, and an unequivocal correlation between the
attainable strength and the stretch ratio.

On the basis of these results, technological principles were formulated for obtaining high-strength polyamide fibres, and
in conjunction with A. B. Savitskii, for the first time in the USSR, specimens of ultrastrong Kapron monofilaments were
obtained (1.4-1.6 GPa) [2].

The first domestic assembly for the preparation of polyamide monofilaments of the AMS-36 type was developed jointly
with the VNIIMSV and the Chernigov "Khimvolokno" PO.

**Structural Causation of the Texture Effect in Synthetic Yarns**

Texturized polyamide yarns occupy the leading position as raw materials for tufting and tricotage carpets. Up to 1970,
there was no industrial production of polyamide texturized yarns for carpeting in the USSR. Neither were there domestic
developments in the region of the technology, machine construction, or materials science of texturized synthetic yarns.

In spite of the wealth of publications devoted to various aspects of the technology of texturizing, to investigating various
structural changes and the mechanical properties of texturized yarns, up till now there have been no clear views on the connection
between structural features and the mechanical properties of texturized yarns.

Together with the basic mechanical characteristics of texturized yarns such as strength, elastic modulus, and stiffness, the
specific properties of these fibres present much interest: the stretchability, crimp parameters, bulk, and shrinkage.