Study of the Structure and Elasticity of Polyurethanic Yarns with Elastomeric Core

ELENA ANCUTA TULBURE[1], IOAN GABRIEL SANDU[2], GHEORGHE VIRGIL ATODIRESEI [1], ION SANDU[3]*

[1] Ion Ionescu de la Brad University of Agricultural Science and Veterinary Medicine of Iasi, 3 Aleea M. Sadoveanu, 700490, Iasi, Romania

[2] Gheorghe Asachi Technical University, Faculty of Material Science and Engineering, 61A Dimitrie Mangeron, 700050, Iasi, Romania

[3] Alexandru Ioan Cuza University of Iaşi, Laboratory of the Scientific Investigation and Conservation Cultural Heritage, ARHEOINVEST Interdisciplinary Platform, Blvd. Carol I, no. 11, 700506, Iaşi, Romania

Textile materials are subject to several actions that causes mechanical deformations of tension, compression, bending stress. In the case of textile products made by polyurethane fibers, the analysis of the mechanical/ rheological properties and of the structure of the fibers allow to establish the correct steps of the manufacturing process for the materials with imposed elasticity. An optimal analysis of the elasticity of polyurethane fibers on the basis of their structure implies the study of the viscoelasticity using its components: instant recovery ε_1*, delayed recovery* ε_2*, and plastic deformation* ε_3*.*

Keywords: tensile stress, deformation components, rheological properties, polyurethanic yarn

The polyurethanic elastic fibres are copolymers obtained by reactions of polyaddition between diisocyanates and diols, diamines and other bifunctional monomers. The characteristic of these polymers is the alternation of rigid segments with elastic ones. In the high-molecular chains rigid segments are caused by the creation of polydiisocyanates, and the soft, flexible ones considered elastic by polyols or polyesters. At straining, the flexible segments of polyols or polyesters, which are folded up randomly are extended, and the rigid ones or urethane are closing one to another, forming strong hydrogen bonds which create a crystalline network, which opposes to further strain [1 - 9].

At spinning of polyurethanic filaments with other fiber components, as in the case of working with nylon and other fibres [10-14], the polyurethane occupies the middle position of the yarn, called core, and the non elastic components are placed externally as a sheath with the shape of a loop twisted around the core [15-17].

The paper presents an analysis of mechanical-rheological and structures properties of polyurethane yarns subject to deformation processes by stretching, compression and bending, which allow the correct processing steps of these materials with elastic core. For a proper analysis of elasticity polyurethane wire in conjunction with their structure to study visco-elasticity of the material by its components: *instant recovery*, ε_1, *delayed recovery*, ε_2, and *plastic deformation* ε_3.

Experimental part

The behavior at tensile stress of polyurethanic yarns

The stress-strain diagrams of investigated yarns are used for choosing the level of total deformation so yarns load-deformation diagrams can highlight the necessary tension to maintain a fixed deformation.

The yarn versions treated to strain and relaxation-creep behaviour are: elastomeric core yarn (core - elastan 156dtex and sheath – PA 44dtex/10 filaments, simply covered by impeller method), elastomeric core yarn (core – Lycra 22dtex and sheath – PA 13dtex/5 filaments, simply covered by impeller method), elastomeric core yarn (core – Roica 17dtex and sheath – PA 44dtex/34 filaments, simply covered by air-jet method), elastomeric core yarn (core – Elastan 156dtex and sheath – PA 44dtex/12 filaments, simply covered by air-jet method).

The tensional properties of investigated yarns have been determined by tensile stress of yarns, individually on tensile strength tester Mesdan Tensolab 10, according to standard SR EN ISO 2062. The tensile strength tester Mesdan Tensolab works on the “load constant gradient” providing force and deformation electronic measurement, having as sensible elements parametric transducers through which these are converted in electric signals, workable in a good computing system.

Results and discussions

The yarn test sample has been gradually exposed to tensile stress, uniformly and continuously until the breaking moment, and the yarn behaviour at strain is assigned exclusively to the properties of raw material which is made of graphic representations in figure 1.

For the analysis of deformation alterations which take place in time under external forces there have been assigned the values of strain forces for investigated polyurethanic yarns namely 30cN, 60 cN, and 90 cN, these coming under various variation limits from load-strain diagram.

The polyurethanic yarn behaviour at creep

The length deformations alterations which take place in time under the action of drawing external forces and the relaxation after removing them, offers important informations regarding the elastic and mechanic properties of polyurethanic yarns. The kinetics of elastic recovery for deformation behavior with constant force of polyurethanic filament yarns have been an important pursuit for this study.

The analysis of total yarns’ deformation under constant external forces can be tracked by the 2 time components [4]:

* email: ion.sandu@uaic.ro

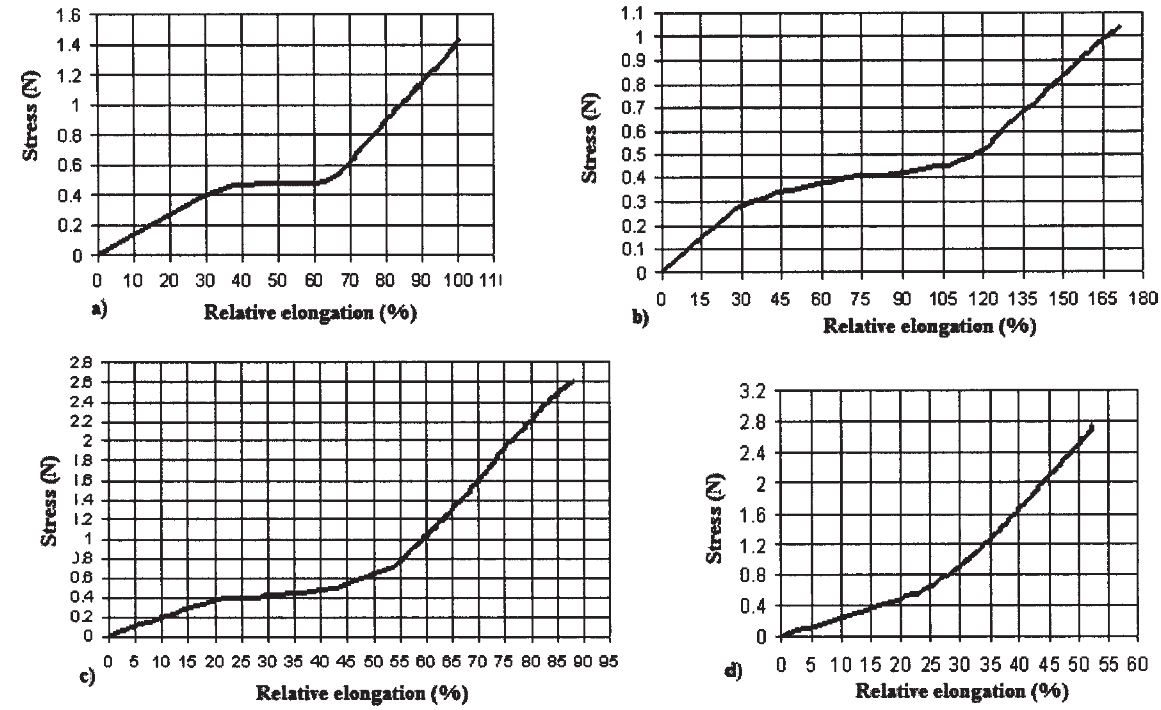

Fig.1. Load-strain diagram for versions of investigated yarns: a) Yarn with elastomeric core (Core – Lycra 22dtex Sheath – PA13dtex/5filaments); b) Yarn with elastomeric core (Core – Roica 17dtex Sheath – PA 44dtex/34 filaments) c) Yarn with elastomeric core (Core – Elastan 156dtex Sheath – PA 44dtex/12 filaments); d) Yarn with elastomeric core (Core – Elastan 156dtex; Sheath – PA 44dtex/10 filaments)

Table 1
VALUES OF ELASTICITY DEGREE OF INVESTIGATED YARNS

Yarn Tipe	P(cN)	ε_1(%)	ε_2(%)	ε_3(%)	Gel (%)
With elastomeric core ***Core*** *–Lycra 22 dtex* ***Sheath*** *– PA13 dtex/5filaments,* ***Simply covered by impeller method***	30	3.29	0.41	96.30	3.70
With elastomeric core ***Core-*** *Roica 17dtex* ***Sheath*** *-PA 44dte /34 filaments;* ***Simply covered by air-jet method***	30	0.97	0.97	98.07	1.93
	60	4.48	0.90	94.62	5.38
	90	6.52	0.43	93.04	6.96
With elastomeric core ***Core*** *– Elastan 156 dtex* ***Sheath*** *–PA 44 dtex/12 filaments* ***Simply covered by air-jet method***	30	2.83	1.42	95.75	4.25
	60	4.95	1.35	93.69	6.31
	90	6.78	0.42	92.80	7.20
With elastomeric core ***Core*** *– Elastan 156 dtex;* ***Sheath*** *– PA 44dtex/10 filaments,* ***Simply covered by impeller method***	30	4.15	1.38	94.47	5.53
	60	7.42	0.87	91.70	8.30
	90	8.30	1.24	90.46	9.54

- the t_1 lapse considered the stress duration, which defines the total deformation ε_t, characterized by the following phenomena: primary creep which is a complex deformation caused by structural elements disalignment; secondary creep which is a time proportional deformation and tertiary creep which is the deformation before breaking.

- the t_2 lapse considered the relaxation period, characterized by: instant recovery ε_1 done with speed of sound, delayed recovery ε_2 which is the primary inverse creep and plastic deformation ε_3. The relaxation process of investigated yarns has been measured by the following deformation components: *instant recovery* (ε_1), *delayed recovery* (ε_2) and *plastic deformation* (ε_3).

The calculus of deformation components [18] is made with the ratios:

Total deformation under load:

$$D_t = (l_2 - l_0 / l_0) 100\% \qquad (1)$$

where: l_0 – represents the initial length of sample; l_1 – sample length after 5 s from force application; l_2 – is the sample length at t moment, when the force is removed;

Instant recovery, ε_1, *delayed recovery* ε_2, and *plastic deformation* ε_3 are calculated with the following ratios:

$$\varepsilon_1 = (l_2 - l_3 / l_2 - l_0) 100\% ;$$
$$\varepsilon_2 = (l_3 - l_4 / l_2 - l_0) 100\% ; \qquad (2)$$
$$\varepsilon_3 = (l_4 - l_0 / l_2 - l_0) 100\%$$

where: l_3 – sample length at 5 s after removal of force; l_4 – sample length at experimental t time;

To follow up the structural alterations evolution of yarn, according to the strain force magnitude and its duration there were asserted certain conditions according to a series of mechanical characteristics.

These conditions are:

- strains with forces of 30 cN/yarn, 60 cN/yarn, 90 cN/yarn;

- forces strain duration is 10 minutes (reading being made at 5“,1’,2’,5’,10’ min).

The values of deformation components represented by *instant recovery* (ε_1%), *delayed recovery* (ε_2%) and *plastic deformation* (ε_3%) and *elasticity degree* Gel % are presented in table 1.

From table 1 we can see that at the same time with boosting of strain forces, the most pronounced cuts are registered by inverse creep, at a maximum force of 90cN/yarn. At the same time with creep cut, the remanent component declines noticeably.

It is observed that high strain forces lead to permanent deformation boost because of delayed recovery cut. This aspect can be observed at the strain duration increase too (from 5 s to 10 min) for the same force magnitude. This aspect proves that mostly the delayed recovery is replaced by permanent deformation.

The elastomeric yarns Core – Elastan 156dtex; Sheath – PA 44dtex/10 filaments and Core – Elastan 156dtex, Sheath –PA 44dtex/12 filaments eventhough they have the same finesse as elastan core and sheath with similar linear density they have different values of the elasticity degree at a maximum force of 90cN strain, these being influenced directly by the yarn covering way.

Conclusions

To characterize the materials, and in particular the polymer with any type of fiber, involves the description of the various manifestations due to mechanical requests and establishes correlations between structure and their performance. The different composition of the polyurethane fibers through due to the replacement of polyester glycol by polyether glycol in reaction with different diisocyanates and diamine influences the effect under mechanical requests, and in particular changes their elasticity. In the design of textiles, the determination of the elasticity through the three components of distortion, as instant recovery ε_1, delayed recovery ε_2, and plastic deformation ε_3, allows the optimization of the manufacturing tecnological parameters.

Acknowledgements: This work was cofinanced from the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013, Project number POSDRU/89/1.5/S62371

References

1.BASU, A., Influence of Yarn Structural Parameters on Rotor-spun Yarn Properties, The South India Textile Research Association, Coimbatore, India, 1998.

2.BHAT, G., CHAND, S., YAKOPSON, S., Thermal Properties of Elastic Fibers, Thermochimica Acta, **367-368**, 2001, p. 161.

3.BLASCU, V., Fibre textile cu densitati speciale si inalt performante, Vol II, Ed Performantica, Iasi, 2007.

4.GRIBINCEA, V., Fizico - chimia si proprietatile fibrelor textile, Ed. Performantica, Iasi 2007.

5.IMMEDIATO, F.R., LUONGO, R.R., Method for dyeing fabric comprising elastomeric fiber, Patent US6613103 (B2), 2003.

6.ISHTIAQUE, S.M., GHOSH, A., RENGASAMY, R.S., Translation of structure and strength properties of different spun yarns on fabric strength, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016, India, 2009.

7.IBRAHIM, S.M.: The Stretch and Recovery Behaviour of Elastomeric Yarns, Journal of The Textile Institute, 59, (6), 1968, p. 296.

8.PIETRUSZEWSKA, R., KOWALSKI, K., Friction Properties of Elastomer Threads, FIBRES & TEXTILES in Eastern Europe, October / December, **13**, No. 4(52), 2005, p. 70.

9.TARABOANTA, I., BALAU, I., Fibre poliuretanice: corelatie structura - proprietati, Simpozionul Anual al specialistilor din industria de tricotaje si confectii, 13-15 noiembrie Iasi, 2008.

10.SCARLET, R., MANEA, L.R., SANDU, I., CRAMARIUC, B., SANDU, A.V., Rev.Chim. (Bucharest), **63,** no. 8, 2012, p. 777.

11.SCARLET, R., MANEA, L.R., SANDU, I., MARTINOVA, L., CRAMARIUC, O., SANDU, I.G., Rev.Chim. (Bucharest), **63,** no. 7, 2012, p. 688.

12.DELIU, R., SANDU, I., BUTNARU, R., SANDU, I.G., LUKAS, D., Rev.Chim. (Bucharest), **63,** no. 6, 2012, p. 603.

13. TURA, V.,TOFOLEANU, F., MANGALAGM, I., MINDRU, T.B., BRINZA, F., SULITANU, N., SANDU, I., RAILEANU, I.D., IONESCU, C., Journal of Optoelectronics and Advanced Materials, **10,** 12, 2008, p. 3505.

14.TOFOLEANU, F., MINDRU, T.B., BRINZA, F., SULITANU, N., SANDU, I.G., RAILEANU, D., FLORISTEAN, V., HAGIU, B.A., IONESCU, C., SANDU, I., TURA, V., Journal of Optoelectronics and Advanced Materials, **10,** 12, 2008, p. 3512.

15.BORCAN, F., SOICA, C.M., DEHELEAN, C.A., GANTA, S., AMIJI, M.M., Rev.Chim. (Bucharest), **63,** No. 11, 2012, p. 1164.

16.ILISEI, S., CIOBANU, G., LUCA, C., Matt. Plast., **49,** 4, 2012, p.285.

17.POPESCU, L.M., PITICESCU, R.M., BURUIANA, T., Mat. Plast., **48,** 1, 2011, p.45.

18.YOSHIMURA, G.-I., IWAKI, N., SHINTAKU, S., TAKAYAMA, T., Mechanical Properties of Covered Yarn, Journal of the Textile Machinery Society of Japan, Transactions, **16**, No. 3, 1970, p. 77

Manuscript received: 12.04.2013