EFFECTS OF THE FATIGUE PROCESS UPON THE STRUCTURE OF A BICONSTITUENT FIBER

TARABOANTA Irina

Technical University"Gh.Asachi", Faculty of Textile,Leather and Industrial Management,Iaşi, Department of Chemical Engineering, D.Mangeron street, no.28, 700050, Iasi, Romania, taraboanta.irina@yahoo.com

Corresponding author: Tărăboanţă Irina, E-mail: taraboanta.irina@yahoo.com

Abstract: *Knowing the processes that take place in the macromolecular and morphological structure following repeated mechanical stresses, during the technological processing of chemical fibres and yarns is mostly important for the specialists in the field. This aspect is also motivated by the fact that, due to the viscoelasticity of the thextile fibres, during stresses, especial the tensile ones, with small forces but repeated at short times, fatigue appears represented by structural changes, difficult to be noticed, and in the most severe cases of stress destruction occurs.*
During the fatigue process in the fibre there are several non homogeneous deformations especially in the microcavities and areas where the structure has imperfections. Thus, modified isolated structures will be obtained, representing the primary destruction of the fabric by forming micro-fissures that progress rapidly by propagation, affecting the fibre in several areas, and in the end it results in the tearing of the fibres.
The action of the mechanical forces upon the fibre triggers several chemical reactions that result in the breaking of the chemical bonds and the birth of free macroradicals, the concentration of which will depend on the intensity of stresses. These aspects of the fatigue process will influence correspondingly the fibre's physicochemical and chemical properties.
This paper reports the experimental results regarding the effect of some cyclical stresses with constant force on the main properties of the textured filament yarn made of Polyethylene terephthalate (PET) and Polybutylene terephthalate (PBT) with a fibrillar matrix structure, of 110/32 dtex.

Key words: *viscoelasticity, biconstituent, polyethylene terephthalate, polybutylene terephthalate, extension, stress*

1. INTRODUCTION

This work represents the experimental results of a study the effect of some cyclical stresses with constant force on the main properties of the textured filament yarn made of polyethylene terephthalate (PET) and polybutylene terephthalate (PBT) with a fibrillar matrix structure (inslands-in-the-sea), of 110/32 dtex.

In the case of the bioconstituent yarn, the chemical and morphological structure is different, i.e. the matrix is made of polyethylene terephthalate (PET) whose chain structure is more rigid, and the fibrils are made of polybutylene terephthalate (PBT) whose structure unit has an aliphatic element (butylene) with a higher flexibility, thus being suitable for a better orientation and organization during the elongation stresses. In the same time, the different weighting of the two elements, as well as their non homogenous distribution in the yarn, also contribute to the evolution of the mechanical characteristics but not always in the same direction [1], [2].

2. RESULTS AND DISCUSSIONS

The fatigue of the abovementioned yarn was achieved by cyclical stresses for loading-unloading (at InstronMechanical Testing Machine) with constant forces for the elastic field (2 forces of 60 and 100 cN/yarn), postelastic field (1 force of 150 cN/yarn) and two forces of 250 and 300 cN/yarn for the final area of the effort-elongation curve (Fig.1).

For each stress force, loading-unloading cycles were executed for four time lengths: 1, 2, 4 and 8 minutes, followed by a 3-minute relaxation, after which the effort-elongation curves were registered until tearing on the same device. The average values of the parameters that characterize the effort-elongation curves compares to the control sample (effort-elongation curve of the unstressed yarn) show that, compared to the control sample (M), the efforts executed with the first four stressing forces lead to a rigidity of the yarn by increasing the initial module (E_1) for stresses lasting for up to 4 minutes, after which it decreases and it stays higher than the control sample (Fig.1). Under the highest stress (300 cN), the elasticity module grows only until 2 minutes of stress, after which it decreases noticeably, still remaining higher than the control sample's.

This aspect shows a change in structure, firstly of the orientation of macromolecular chains in the amorphous and transitory areas [3], and secondly, when the duration of stressing forces are higher, changes are more spectacular, as a result of the orientation of crystallites. Simultaneously, in addition to the breaking of secondary forces and of some chemical bonds, whose energy was defeated by the mechanical one, resulting in the formation of free macroradicals [4], [5].

Thus, if we look in figure 2 at the evolution of the elastic effort (δe) compared to the stress force for different durations, we notice that it grows compared to the control sample only during the 1st stress phase (60 cN) up to 4 minutes, after which it decreases. During the second stress phase (100 cN) (also in the elastic field, but closer to the passage towards viscoelasticity), the elastic stress decreases for all the effort length, but not too much compares to the control sample.

Instead, for the other stress areas, the elastic stress decrease significantly compared to the control sample, even for a stress period of 1 minute.

Therefore we conclude that structure changes are significant in the cases where stress forces exceed the elastic limit.

A considerable change appears in the yielding deformation (ε_c) that decreases continuously and considerably for the small stress forces (fig. 3). Under these conditions it is estimated that although the yielding effort decreases, the corresponding deformation decreases even more and the post-elastic area of the yarn becomes rigid.

Following the values of the yield stress (δ_c) under the same testing conditions, we notice that it decreases slightly during the first two loading phases up to 1 minute, after which it grows rapidly for the 100 cN force up to 4 minutes of stress and then it decreases again. The same tendency is seen in the other stress forces, but with values much lower compared to the first two stress phases, and the decrease of the stress starts earlier, after 2-minute stress (fig. 4).

The tearing limit (δ_r and ε_r) varies within contradictory limits, with a tendency to decrease the specific effort compared to the control sample for the stress conditions in the elastic field, more pronounced at the maximum effort duration (fig. 5) and (fig. 6) and its increase upon high stresses of 250 and 300 cN (fig. 7) and (fig. 8).

The mechanic work specific to deformation of the curves recorded after stresses decreases compared to the control sample and is continuously decreases as the stress intensifies. In such circumstances, the yarn will have an ever smaller capacity to render the stored elastic energy and the energy dissipated into the fabric will lead to the breaking of valence bonds and to the appearance of the fatigue process [6].

By following the optical birefringence performed on the requested yarn samples, with growing forces at minimum and maximum duration (1 and 8 minutes), a slight orientation towards the control sample is noticed at the 60 cN stress, and a more prominent one at 100 and 150 cN stresses. This orientation takes place in the amorphous and transitional areas of the yarn, while at high stresses of 250 and 300 cN the increased values of birefringence are due to the orientation of the crystallites. However it is noticed that orientation decreases under these forces for long stress durations compared to the short ones, as proof of the destruction of the regularity of morphological formations and conformation changes at the level of smaller or larger segments of the macromolecular chains [7].

It can be easily observed that during the fatigue process in the fibre there are several non homogeneous deformations especially in the microcavities and areas where the structure has imperfections. Thus, modified isolated structures will be obtained, representing the primary destruction of the fabric by forming micro-fissures that progress rapidly by propagation, affecting the fibre in several areas, and in the end it results in the tearing of the fibres.

Therefore, the action of the mechanical forces upon the fibre triggers several chemical reactions that result in the breaking of the chemical bonds and the birth of free macroradicals, the concentration of which will depend on the intensity of stresses.

These aspects of the fatigue process will influence correspondingly the fibre's physicochemical and chemical properties.

3. CONCLUSIONS

By correlating all the analyzed parameters under the stress conditions discussed above, the result is as below:

- the subsequent application of cyclical elongation forces in the elastic field, during short times, lead to the improvement of the mechanical characteristics of the yarn, but during long times, the fatigue effects appear;
- by adding to the stress intensifying forces that exceed the elastic field, structural changes are obvious. Thus, the ever enhanced process of yarn rigidity, especially in the postelastic area, reveals the same morphological changes with effects on the yarn's properties;
- analysing the fatigue process inside a fabric, only after its breaking final values, are not always satisfactory because during stresses there are complex processes with different directions whose overlapping lead to the fact that tearing does not truly reflect the fatigue mechanism;
- the fair interpretation of the fatigue process of fibres and yarns creates the premises for avoiding the progressive destruction during long static stresses and, therefore, for preserving their integrity, in order to reduce to a minimum the number of macroradicals and, as a consequence, of the mechanical-chemical processes taking place before the final destruction - tearing.

As a result of this study, due to the viscoelasticity of the textile fibres, during stresses, especial the tensile ones, with small forces but repeated at short times, fatigue appears represented by structural changes, difficult to be noticed, and in the most severe cases of stress destruction occurs.

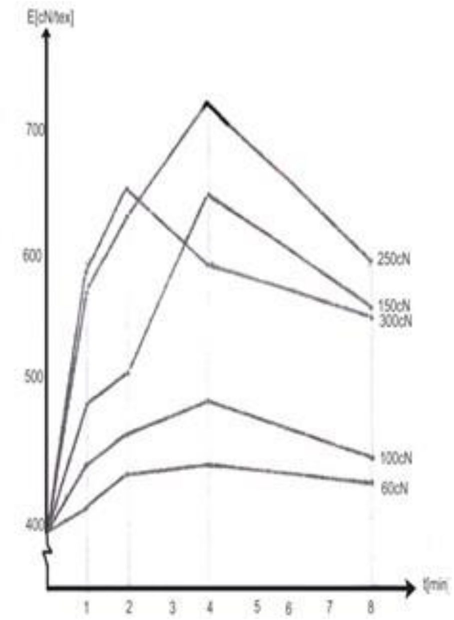

Fig. 1:*Effect of time and load level in the E-moduls*

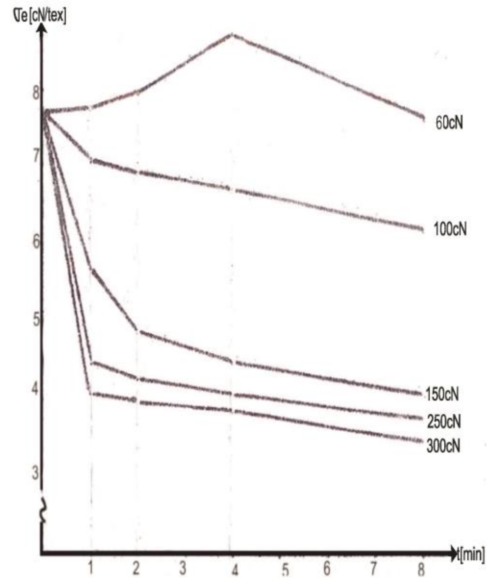

Fig. 2:*Effect of time and load level in the elastic stress*

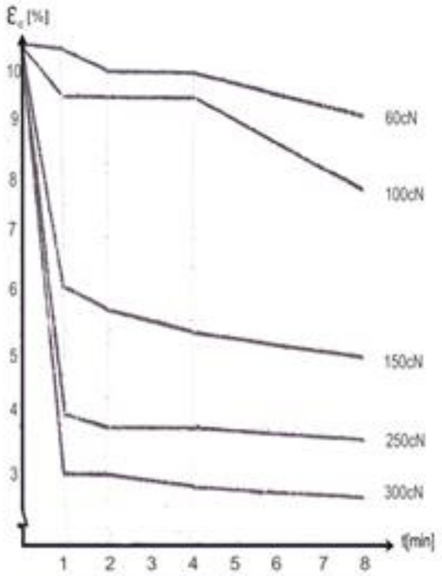

Fig. 3:*Effect of time and load level in the yield strain*

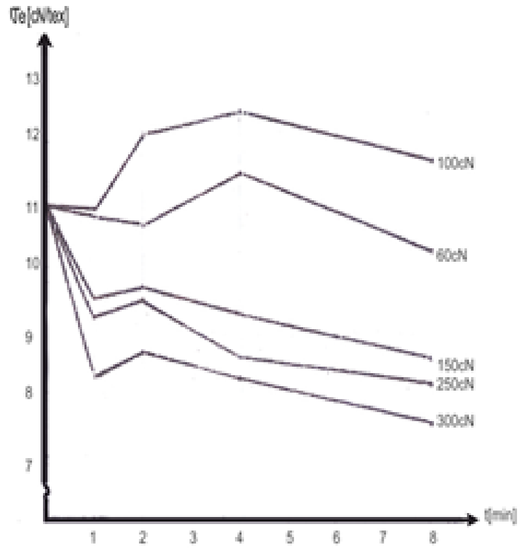

Fig. 4:*Effect of time and load level in the yield stress*

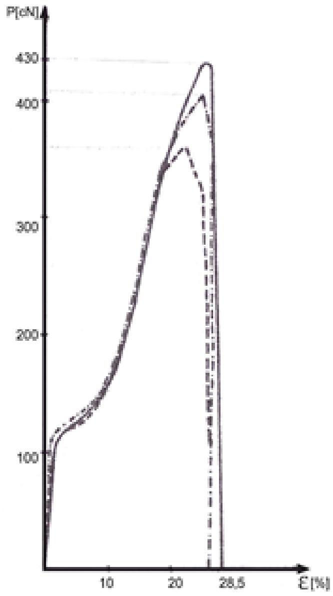

Fig. 5:*Load elongation curves at P=60cN*
Legend:
control stample
loaded stample 1 min
loaded stample 8 min

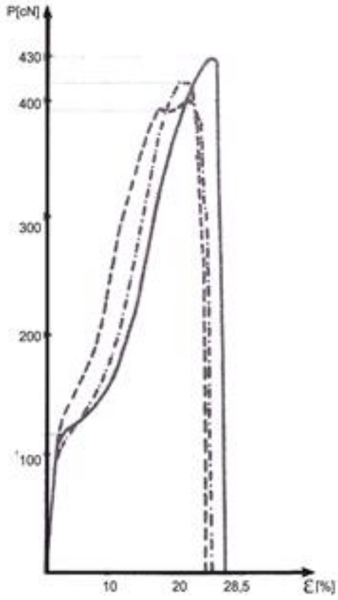

Fig. 6:*Load elongation curves at P=100cN*
Legend:
control stample
loaded stample 1 min
loaded stample 8 min

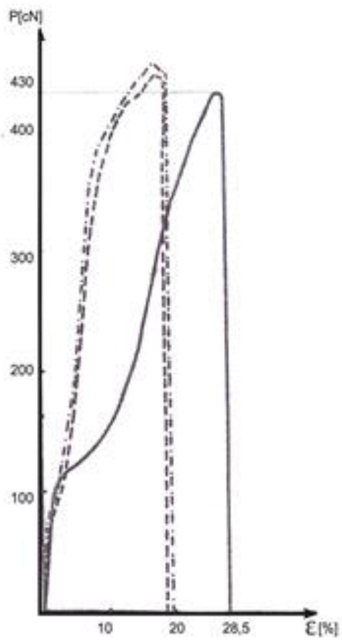

Fig. 7:*Load elongation curves at P=250cN*
Legend:
control stample
loaded stample 1 min
loaded stample 8 min

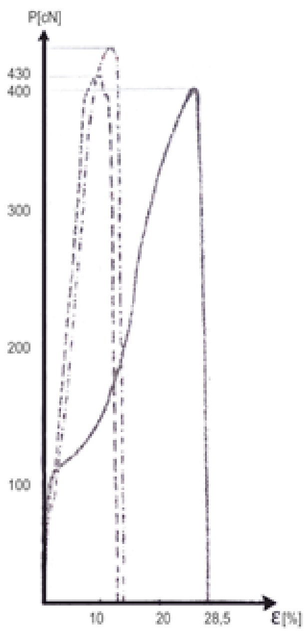

Fig. 8:*Load elongation curves at P=300cN*
Legend:
control stample
loaded stample 1 min
loaded stample 8 min

REFERENCES

[1] I.Taraboanta, *"Study on bico fibers"* in Proc.ISC-ISSDTLI, vol.XIV, 2013, pp.129-130

[2] A.R.Bunsell, J.W.S. Hearle, *"The fatigue of synthetic polymeric fibers"* in Journal of Applied Polymer Science, vol. 18, 1974, pp. 267-291

[3] A.Peterlin, *"Structural model of mechanical properties and failure of crystalline polymer solids with fibrous structure"*, in International Journal of Fracture, vol.11, 1975, pp.761-780

[4] F. Reifler, F. Sellami, P. Barbadoro, R. Hufenus, *"Overjacketing extrusion technology for novel bicomponent fibers"* in Fiber Journal, February 2013, pp.34

[5] S. Houis, F. Schreiber, T. Gries, *"Fibre – Table according to P.A. Koch, Bicomponent fibers"* in Shaker: Aachen, Germany, 2008, pp.78

[6] F. Fourne, *"Synthetic Fibers"*, Hanser Publishers, Munich, 1999, pp.910

[7] H.C. Tang, T. Nguyen, T. Chuang, J. Chin, H. Felix, J. Lesko in *"Fatigue model for fiber – reinforced polymeric composites"* in Journal of Materials in Civil Engineering, vol. 12, no. 2, 2000, pp. 97