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Thermal properties of elastic fibers

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Abstract

Spandex has now become a standard fiber in lingerie, hosiery, leisurewear, and sportswear. New applications, from men's suits to children's wear, diapers to footwear, continue to be developed. Manufacturers have refined their technology, making possible the explosion of new applications. In this study, some commercially available spandex filaments were evaluated for their mechanical and thermal properties. The differences in performance of soft, medium and high modulus spandex fibers are elaborated. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Spandex, whose stretch and recovery abilities first put in women's undergarments, is now expanding into all areas of clothing. From men's suits to children's wear, diapers to footwear, the use of spandex is growing at an incredible rate [1–3]. As a result, there is continued industrial expansion for the production of elastic fibers and yarns. Helping this expansion is the introduction of melt spun spandex [4]. Some of the fibers are produced by reaction melt spinning as opposed to pure melt spinning. Melt spun elastic fibers provide the advantage of lower heat setting temperature, lower sheen, and improved chemical and environmental resistance compared to dry-spun fibers.

Spandex is a manufactured fiber in which the fiber forming substance is a long chain polymer containing at least 85% of segmented polyurethane. Recently, other combinations containing polyester and polyether segments have been introduced. The physical and chemical properties of the fibers are dependent on the chemical structure of the fibers and their morphology, which is dependent upon the processing conditions [5–8].

Thermal properties of these fibers are important to understand their processing characteristics as well as performance in the final product [9,10]. Whereas some of the properties are important for application, others are critical in processing to form the final product. Tensile properties and elastic recovery characteristics are the most important as far as the performance of the products is concerned. A modern elastic fiber must satisfy more prerequisites, whether for the processing or for use. These include the endurance on way to becoming a finished product, such as stability under dyeing and finishing conditions, easy processing with non-elastic yarns, and stability under normal washing conditions. Elastic fibers from different sources and covered yarns produced from them were characterized by thermal analyses and other physical characterization methods.

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2. Experimental

The samples used in this study were commercially available fibers. The details of the sample are shown in Table 1. These fibers were produced by different leading manufacturers using a variety of production methods: dry, wet or reaction spinning. Lycra, Cleerspan, Dorlastan, and Linel are registered trademarks of DuPont, Globe Manufacturing, Bayer Faser GmbH, and Fillattice SPA companies, correspondingly. Differential scanning calorimetry of the samples was carried out using the Mettler DSC25. The samples were scanned at a heating rate of 20°C/min. Thermomechanical responses were recorded using the Mettler TMA40 with a heating rate of 10°C/min. Gauge length was 10 mm and a very low tension of 10^{-4} N/tex was applied to the filaments during thermomechanical testing. Five filaments, having the denier in the range 120–210, were tested together in order to keep the tension very low and thus to avoid extension of the filaments in the beginning of the experiment.

Tensile testing of the filaments was done using the United Tensile Tester with a gauge length of 5.08 cm (2 in.) and an extension rate of 10.16 cm/min (4 in./min). A paper window was used to mount the samples.

Table 1
Details of the samples

Sample ID	Trade name	Producer
Lycra-I	Lycra	DuPont
Dorlastan	Dorlastan	Bayer
Cleerspan-I	Glospan	Globe
Lycra-II	Lycra	DuPont
Linel	Linel	Fillattice
Cleerspan-II	Glospan	Globe
Cleerspan-III	Glospan	Globe

Elastic power of the filaments was measured using a Dynamic Tensile Tester. The filaments were stretched up to 300% extension and then recovered in a testing cycle. Elastic power was measured in terms of stress at specified elongation during unloading in the fifth testing cycle.

3. Results and discussion

The results from tensile testing are shown in Table 2. The tenacity and breaking elongation values of the different fibers vary over a reasonably small range. The differences between fibers can be seen more clearly from the modulus values. Modulus values are low for all the elastic fibers. Among the fibers, there seem to be three categories, i.e., hard, medium and soft modulus fibers. The first two are hard modulus, the last two are soft modulus, and the three fibers in the middle of the table that of medium modulus. The breaking elongation also seem to follow a similar trend as the soft modulus fibers have higher values in the range of 800% compared to 500–600% for the hard modulus fibers.

DSC scans of the spandex fibers are shown in Fig. 1. None of these fibers show an endotherm as they are not typical thermoplastics and have a cross-linked network. They all show an exotherm. The temperature where the exotherm appears and the enthalpy of exotherm are different for the fibers due to the differences in their composition. All of the tested fibers showed thermal stability as far as decomposition was concerned till about 200°C. By the time the samples experienced that temperature, crystalline parts or hard segments would have melted leading to flow in the material as evidenced by the TMA results.

Table 2
Tensile properties of the filaments

Sample ID	Tenacity (gpd)	Elongation at break (%)	Initial modulus (gpd)	Toughness (gpd)
Lycra-I	1.1	550	0.08	19
Dorlastan	1.4	530	0.08	20
Cleerspan-I	1.2	690	0.05	12
Lycra-II	1.0	660	0.06	10
Linel	0.8	590	0.05	15
Cleerspan-II	0.8	800	0.03	11
Cleerspan-III	1.0	760	0.03	10

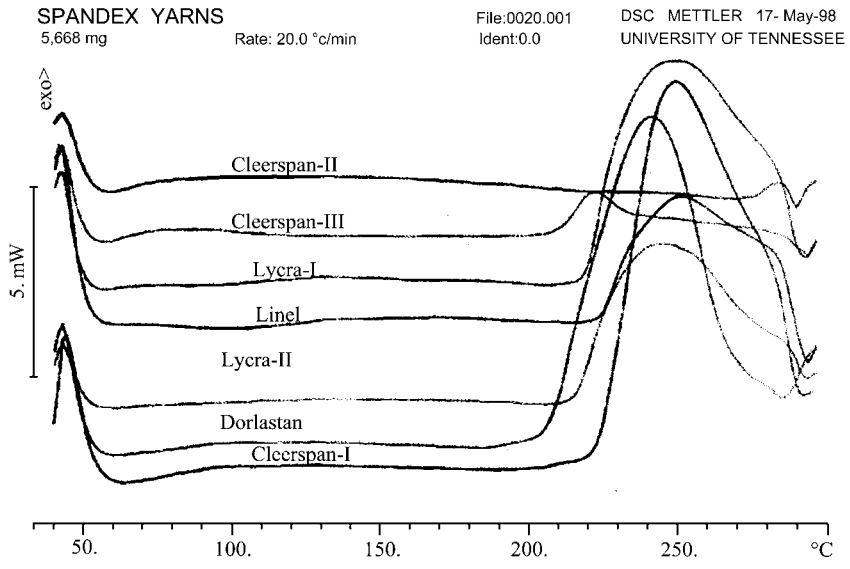

Fig. 1. DSC scans of different spandex filaments (20°C/min).

The TMA scans shown in Fig. 2 reveal the deformation behavior of these fibers under heat and tension. From the scans, it is evident that all the fibers show complete stretching comparable to that of melting in the range of 190–205°C. This is also termed as heat distortion temperature. Physical cross-linking between hard segments gets totally destroyed around 200°C in all the cases. The differences between the fibers are in their shrinkage behavior, the temperature at which shrinkage starts and the maximum shrinkage values. These data as calculated from the TMA scans are summarized in Table 3.

The shrinkage values follow the same trend as that of the modulus. Hard modulus fibers show higher total

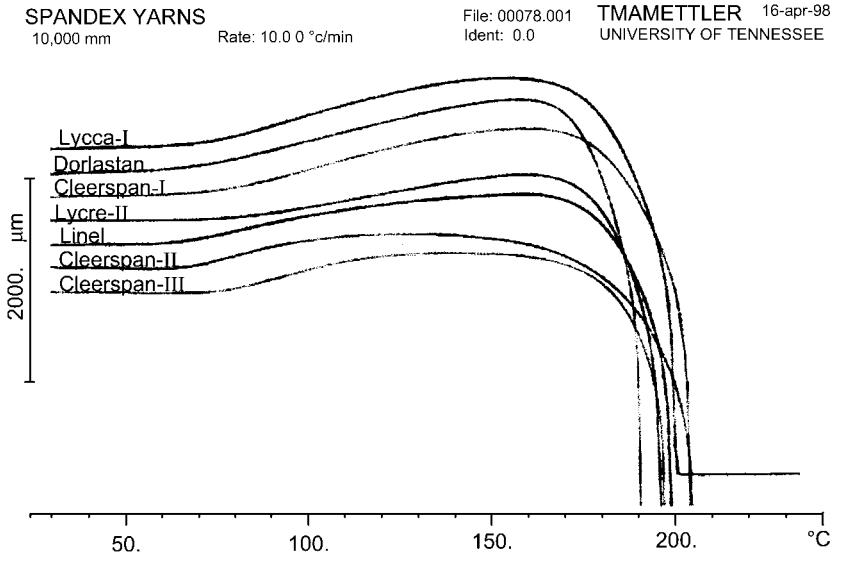

Fig. 2. TMA scans of different spandex filaments (10°C/min).

Table 3
Results of thermomechanical analysis

Sample ID	Shrinkage-onset temperature (°C)	Temperature at maximum shrinkage (°C)	Failure temperature (°C)	Shrinkage (%)
Lycra-I	38	153	196	8.5
Dorlastan	40	157	187	6.8
Cleerspan-I	45	160	197	6.8
Lycra-II	75	159	189	4.2
Linel	60	157	192	4.8
Cleerspan-II	68	124	196	3.6
Cleerspan-III	75	137	193	3.4

shrinkage values than that of the medium modulus fibers and the medium ones showed higher shrinkage than that of the soft modulus fibers. The shrinkage of the hard modulus fibers started at lower temperatures as they were scanned, but the shrinkage continued till about 150°C. On the other hand, for the soft modulus fibers, shrinkage did not start till a relatively higher temperature, and the maximum shrinkage temperature was only about 130°C. This is an interesting observation as to the differences in thermomechanical responses. Knowledge of these responses is important as these have consequences in processing, and use of these filaments, where they are likely to get exposure to higher temperature and tension.

4. Conclusions

The stretchable fibers tested consisted of three categories as far as the modulus was concerned, viz., hard, medium and soft. High modulus fibers showed higher tenacity but lower breaking elongation than medium and low modulus fibers. High modulus filaments exhibit higher toughness, and therefore, are expected to perform better on the processing machines. Elastic power of high modulus filaments was found to be good but not necessarily better than that of lower modulus fibers. Elastic power of a fiber determines the total quantity of elastic material to be incorporated in a fabric in order to get desired recovery characteristics.

A good correlation was observed between hysteresis, shrinkage-onset temperature and slope of the TMA curve in the low temperature region (60–80°C). Higher TMA shrinkage, lower shrinkage-onset temperature, and lower slope of TMA curve (i.e. lower rate of shrinkage) in the case of high modulus yarns suggested the presence of higher overall molecular orientation and/or higher crystallinity. This needs to be confirmed with the help of other techniques such as X-ray diffraction. DSC analysis suggested that low, medium, and high modulus fibers differed not only physically but also chemically.

References

[1] H. Miller, Int. Fiber J. 13 (1998) 20–26.
[2] W.N. Rozell, Textile World 147 (1) (1997) 80–88.
[3] W.N. Rozell, Textile World 145 (6) (1995) 109–113.
[4] J.W. Moore, C.S. Moore, Int. Fiber J. 13 (1998) 30–34.
[5] R. Meredith, I.A. Fyfe, Textile Inst. Ind. 2 (1964) 154–157.
[6] C.R. Cuthberston, R.J. Kelly, L.R. Logan, D.S. Porter, P.D. Brass, in: H.F. Mark, S.M. Atlas, E. Cernia (Eds.), Man Made Fibers: Science and Technology, Vol. 3, Interscience, New York, 1968, pp. 401–424.
[7] J.E. Boliek, A.W. Jensen, in: J.I. Kroschwitz (Ed.), Encyclopedia of Chemical Technology, 4th Edition, Wiley, New York, 1991, pp. 624–638.
[8] H.S. Lee, J.H. Ko, K.S. Song, K.H. Choi, J. Polym. Sci. B 35 (1997) 1821–1832.
[9] R.V. Meyer, Melliand Textilberichte 3 (1993) 194–198.
[10] M. Fabricus, T.H. Gries, B. Wulfhorst, Melliand Textilberichte 11 (1995) 980–990.