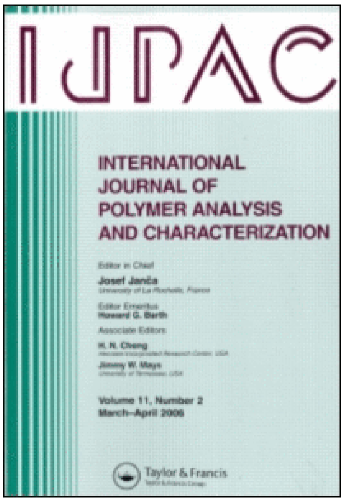

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A Comparative Study on Time-Dependent Recovery Behavior of PTT and PET Multifilament

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A COMPARATIVE STUDY ON TIME-DEPENDENT RECOVERY BEHAVIOR OF PTT AND PET MULTIFILAMENT

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Tensile recoveries of PET and PTT multifilament are measured by the variations of time for extension and recovery. The correlations depicted graphically are given for PTT and PET, respectively. It has been found that the recoveries of both PTT and PET are sensitive to the time for extension and recovery. PTT is slower to relax and faster to recover, and the difference between them is nearly an order of magnitude. The deformation of PTT by extension can be entirely compensated for by the recovery procedure, whereas PET recovers only partially.

Keywords: Fibrous materials; Tensile recovery; Time-dependent

INTRODUCTION

Poly(trimethylene terephthalate) (PTT), based on the three methylene groups in the glycol repeating unit, possesses many properties different from those of poly(ethylene terephthalate) (PET). Fibers and fabrics made from PTT offer many desirable characteristics such as higher stretch and recovery. Studies on the tensile recovery of PTT fibers and related products are not rare (see, for example, Ward and Wilding,[1] Hockenberger and Koral,[2] and Chen and Tang.[3]) In this work, our attention is focused mainly on the time-dependent recovery of PTT and PET multifilament, which has relatively little been studied in open publications to date. We investigated the simultaneous influence of both the time for extension and the time for recovery on the tensile recovery behaviors of both PTT and PET multifilaments, which were studied with the aim to discriminate the difference between PET and PTT by tensile recovery responses[4] and to explore an identical effect on the recovery of fibers by committing different extension and recovery times in order to optimize the manufacturing and applications of fibrous materials.

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Table I. Basic tensile properties of PTT and PET multifilaments

Properties	PET	PTT
Linear density (dtex)	330	330
Tenacity (cN/dtex)	3.85	2.29
Elongation at break (mm)	54.8	91.5
Initial modulus (cN/dtex)	98.3	24.1

Gauge length = 200 (mm); crosshead speed = 200%/min; pretension = 2 cN.

EXPERIMENTAL SECTION

Both PTT and PET multifilaments used were fully drawn on the bobbin with the same linear velocity. Some basic mechanical properties of the multifilaments are listed in Table I. All measurements were made on an Electronic Dynamometer YG061 Tester at constant rates of extension and retraction at 200% per minute with a gauge length of 200 mm, at 25°C and relative humidity of 65%. The multifilament is extended to a predetermined percentage of the gauge length and held at the fixed extension for a predetermined time, t_e, during which stress relaxation occurred. PTT fiber usually has an elastic strain about 5% higher than PET, which is caused by a more flexible internal rotation due to the conformation of the macromolecule.[5,6] To prevent overestimation for PTT, the elongations to 10% and 15% of the gauge length are applied for PET and PTT, respectively. The bottom jaws of the tester were returned to their original positions after a given recovery time, t_r, and the multifilament was extended again. Details are presented in Figure 1. The time relations are specified in Equations (1) and (2):

$$t_1 = t_z = t \tag{1}$$

$$T = 2t + t_e + t_r \tag{2}$$

where T is the time for one cycle of tensile recovery measurement; t_e and t_r are the times for extension and recovery, respectively; and t_1 and t_2 are the times spent for

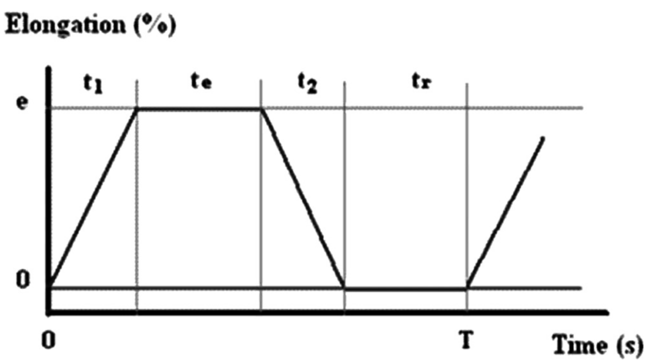

Figure 1. Elongation profile of one cycle.

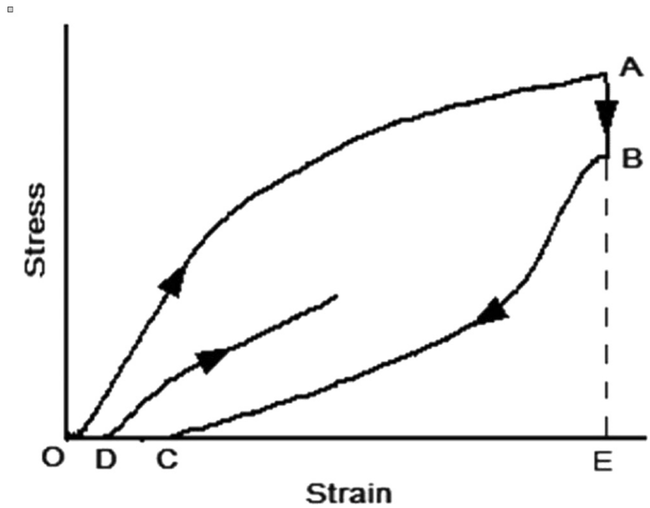

Figure 2. A typical stretch and recovery curve for measurements.

Table II. Two-dimensional orthogonal array of the measurements of PET and PTT

	t_e					
$t_r \backslash t_e$ (sec)	0	10	30	120	600	1500
$t_r = 0$	X	X	X	X	X	X
$t_r = 10$	X	X	X	X	X	X
$t_r = 30$	X	X	X	X	X	X
$t_r = 120$	X	X	X	X	X	X
$t_r = 600$	X	X	X	X	X	X
$t_r = 1500$	X	X	X	X	X	X

X shows where the measurement was performed.

constant rate extension and recovery, respectively. The definition of tensile recovery, R, is specified in Equation (3) and depicted in Figure 2.

$$R = \frac{OE - OD}{OE} * 100\% \tag{3}$$

The times held for extension and recovery are 0, 10, 30, 120, 600, and 1500 s. A design of two-dimensional orthogonal array of the measurement is presented in Table II. Both PTT and PET multifilaments are examined under each of these 36 total conditions.

RESULTS AND DISCUSSION

The results of all measurement are presented in Figure 3 for PET and Figure 4 for PTT. For the problem of the time-consuming operations, we selected only the maximum time of 1500 s both for t_e and t_r. Tensile recovery R increases

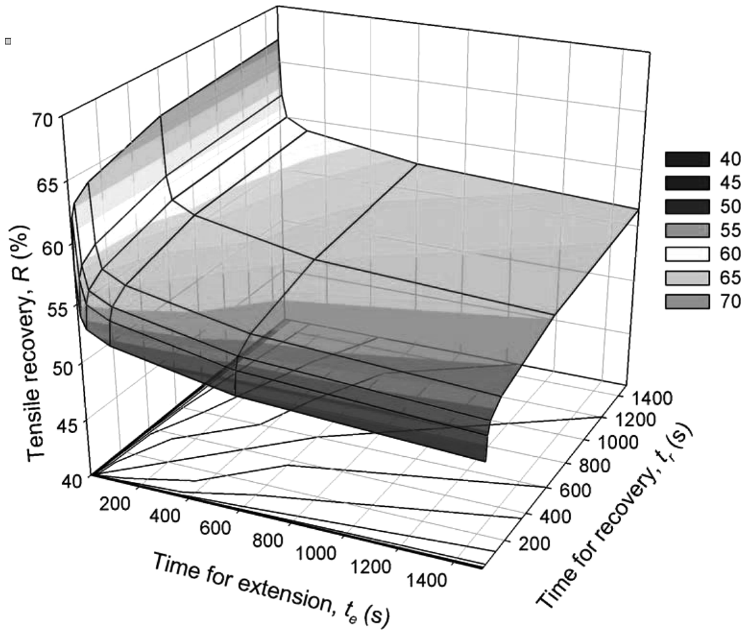

Figure 3. The Mesh and contour plot of the correlation between R of PET vs. t_e and t_r.

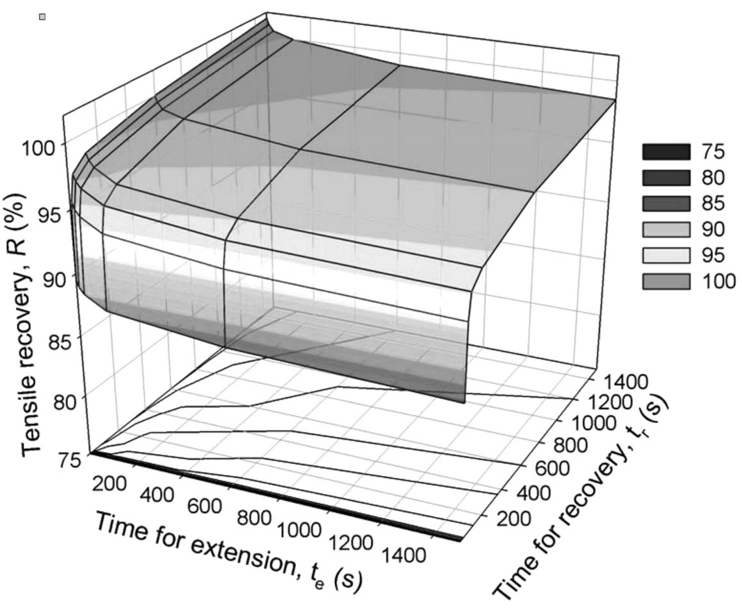

Figure 4. The Mesh and contour plot of the correlation between R of PTT vs. t_e and t_r.

as t_r increases but decreases when t_e is increased. This effect becomes more obvious at small values of t_r and t_e, which is the same trend for both PTT and PET multifilament. A contour line is a congregation of identical recovery effects following different t_e and t_r actions. In the region of t_e from 0 to 30 s, R goes down by about 10% rapidly, and the corresponding contour lines concentrate in parallel towards the axis of t_r, manifesting the drastic changing of the gradient along the axis t_e almost normal to these contours. This implies that a fast relaxation of PET occurred in the aforementioned region, compared to PTT in Figure 4.

In contrast, R for PTT multifilament is decreased by only about 3% in the region of t_e from 0 to 30 s, which means that PTT needs a longer relaxation time, and tensile recovery R stays at a higher level of more than 85%, while it is 50% for PET. This also can be clearly seen from the distribution of the regional contours, which is scattered (rather than concentrated) around the axis of t_r, and much sparser than that of PET. It is interesting to find a recovery over 100% only by mechanical stretching and releasing. A recovery over 100% means that point D is in the negative half of abscissa of the strain in Figure 2, therefore (OE-OD)/OE is more than 100% from Equation (3). Tensile recovery could be influenced mainly by primary creep (delayed elasticity) that 100% recovers[7,8] and thermal-induced recovery, which shows shrinkage in length.[9] For PTT, this phenomenon might be induced by the combination of the primary creep and thermal-induced recovery. PTT has a glass transition range 20°C lower than PET, which is more sensitive to the heat generated during the mechanical hysteresis cycle in Figure 2 and has a bigger portion of primary creep under these testing conditions.[5] The relaxation time for PET needed to reach 50% of the maximum value of recovery loss, which is less than 30 s, while that of PTT is more than 200 s. This means that PTT is harder to relax than PET and that PTT is almost an order of magnitude harder to relax than PET in this region of extension time. In the region from 200 to 1500 s for time of extension and recovery, the changes of the recovery of both PTT and PET are comparatively flattened, which can also be seen from the contours averagely distributed.

In the whole range of t_e from 0 to 1500 s, followed by t_r from 0 to 30 s, the recovery R of PTT yarn rapidly increased by about 10% to the level above 95%, while PET increases by only about 3% to the level below 55%. This shows that the longitudinal deformation difference between PTT and PET after mechanical stretching and relaxing becomes larger and is one of the contributions to the curliness in multicomponent fibres.

The differences between PET and PTT are obvious by comparing the contours in Figures 3 and 4. The contours of PTT converge parallel towards the t_e axis and are almost indiscernible in the narrow region of t_r from 0 to 30 s, whereas those of PET are much more scattered along the direction normal to the contours, indicating a more moderate gradient of recovery R. Moreover, even after 1500 s of t_e for relaxation, PTT still can recover to about 95% within 30 s of t_r. In Figure 4, the time needed for PTT yarn to recover to 50% of its maximum amplitude of recovery is below 30 s, while PET needs more than 200 s to reach that amount. Therefore, we deduce the inverse-relaxation (recovery) time of PTT is almost by an order of magnitude faster than that of PET. The deformation occurring in extension can be fully compensated for during the recovery process for PTT, while PET recovers only by less than 70% of the original length.

CONCLUSIONS

The 3-D graphs plotting the cooperative effect of t_e and t_r on tensile recovery behaviors of PTT and PET multifilaments present some intrinsic recovery differences that exist between PTT and PET and show the identical effect on recovery by different durations of t_e and t_r. PTT and PET have the same trend, i.e., recovery R increases with t_r and inversely with t_e. PTT multifilament yarn is harder to relax and faster to recover than PET. The difference between them is almost an order of magnitude in the measurement range.

Under the same measurement conditions, the prolongation of t_r of PET cannot compensate for the deformation introduced during the extension cycle, while the prolongation of t_r of PTT can fully compensate for the deformation occurring in extension as long as 1500 s. The enlargement of longitudinal deformation only by mechanical stretching and relaxing is clearly observed.

REFERENCES

1. Ward, I. M., and M. A. Wilding. (1976). The mechanical properties and structure of poly(m-methylene terephthalate) fibers. *J. Polym. Sci. Polym. Phys.* **14**, 263–274.
2. Hockenberger, A. S., and S. Koral. (2005). Recovery from strain and shrinkage measurements of poly(*m*-methylene terephthalate) and poly(ethylene 2,6-naphthalate) fibers. *Text. Res. J.* **75**, 111–116.
3. Chen, K. Q., and X. Z. Tang. (2004). Instantaneous elastic recovery of poly(trimethylene terephthalate) filament. *J. Appl. Polym. Sci.* **91**(3), 1967–1975.
4. Prisacariu, C., E. Scortanu, and C. P. Buckley. (2009). *Int. J. Polym. Anal. Charact.* **14**, 527–539.
5. Chuah, H. H. (2003). In *Encyclopedia of Polymer Science and Technology*, 3rd ed. New York: John Wiley, Vol. 3, pp. 544–557.
6. Desborough, I. J., I. H. Hall, and J. Z. Neisser. (1979). The structure of poly(trimethylene terephthalate). *Polymer* **20**, 545–552.
7. Leaderman, H. (1943). Creep and creep recovery in plasticized polyvinvl chloride. *Ind. Eng. Chem.* **35**, 374–378.
8. Ren, W. (1992). Inverse relaxation: Model and relation to recovery internal friction. *Colloid Polym. Sci.* **270**, 990–998.
9. Stalevich, A. M. (1976). Temperature and load as factors in the creep of high-orientation synthetic filament yarns. *Fibre Chem.* **4**, 415–421.