The Measurement of Dynamic Flexile Properties of Fibers with a Rheovibron Viscoelastometer

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Synopsis

A new method for measurement of dynamic flexile mechanical properties was developed by a modification of the Rheovibron viscoelastometer. The Rheovibron instrument is useful for obtaining dynamic tensile mechanical properties of films and fibers over a wide temperature range. A new flexile grip and procedure were used for measuring dynamic mechanical properties of material in the flexile mode using the Rheovibron instrument. The dynamic flexile properties on polyester, nylon 66, and acrylic fiber are presented.

INTRODUCTION

The Vibron viscoelastometer (Toyo Measuring Instruments) is useful for obtaining dynamic tensile mechanical properties of films and fibers over a wide temperature range of −160 to 250°C in an atmosphere at 0% relative humidity.[1] In recent years a modification which makes possible measurement on materials in the shear and compression mode has been reported.[2,3] However, no studies exist which show the measurement of dynamic flexile properties of materials using the Vibron instrument. In this report a new method for investigating dynamic flexile properties of new materials is presented and shows the effects of temperature on dynamic flexile properties of polyester, nylon, and Acrilan fiber.

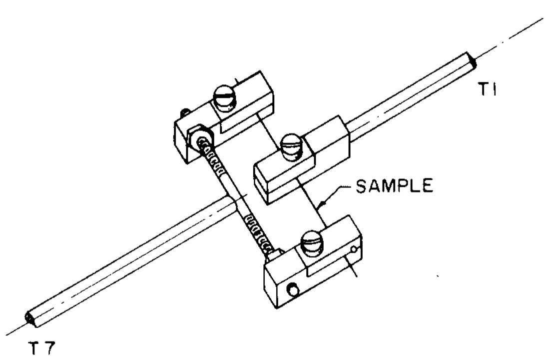

Fig. 1. Schematics of flexile grip.

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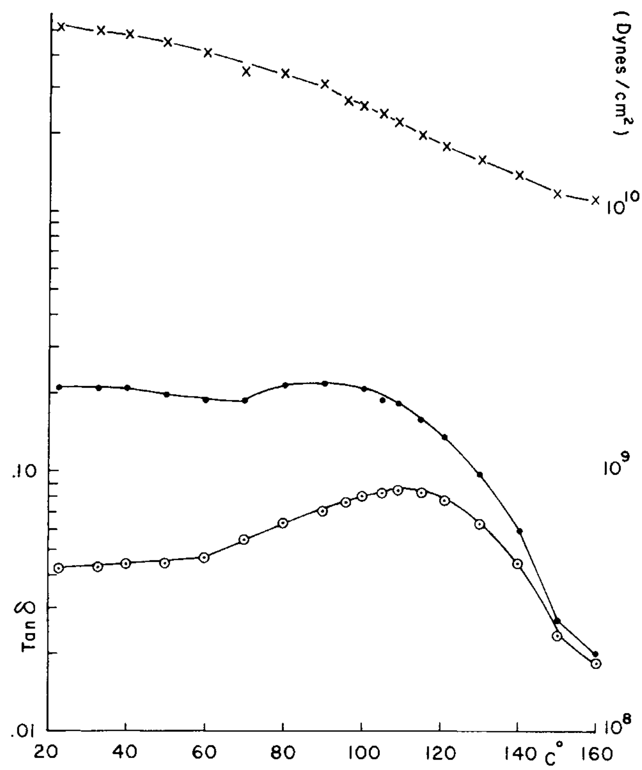

Fig. 2. Dynamic flexile properties of nylon 66 monofilament: (x) E'_F; (●) E''_F; (⊙) tan δ.

EXPERIMENTAL

The Rheovibron applies a sinusoidal tensile strain to one end of a sample and measures the stress output at the other end. The instrument operates at frequencies of 3.5, 11.0, 35.0, and 110 Hz. Two transducers are used to read directly the absolute dynamic modulus $|E^*|$ (the ratio of maximum stress amplitude to maximum strain amplitude) and the phase angle δ between stress and strain. From these two quantities the real part E' (dynamic modulus) and the imaginary part E″ (loss modulus) can be calculated from the complex dynamic tensile modulus $|E^*|$.

The principles of this direct reading method and instrument are described in detail by Takayanagi.[1] In order to measure the dynamic properties in the flexile mode using a Rheovibron viscoelastometer, it was necessary to develop the flexile grips to permit characterization of viscoelastic materials in dynamic flexing. The grip is shown in Figure 1. The grips consist of one sample mounting unit and clamp with 15-cm-long rods; the weight of the grips is 13.7 g. The tensile clamp is replaced by these flexile grips at the connectors of T_1 and T_7 of the strain gauge. The sample is vertically mounted at the clamp T_7. In case of film or monofil sample, the T_1 clamp is used to fasten the center of the sample. In the measurement of the bundle yarn, the end of the T_1 clamp is replaced by the latched needle for avoiding flat yarn. The length of the specimen is 2 cm.

The operating procedure for flexile testing with the Rheovibron is as follows: With the tan δ range switch at 30 and the amplitude factor at 30, (1) set the main selector switch to the stress (T-1) gauge position. (2) Turn the handle of the slider of the driving section and apply the initial bending, about 0.2–0.5 g to the sample. (3) Set the main selector switch to "Amp. F" position and turn the tan δ meter switch to 40 and the amplitude factor switch to 30 or 20. (4) Adjust "Amplitude Adjust" for full-scale indication on the tan δ meter. (5) Set the main selector switch to "Dyn. F" position. (6) Adjust the "Phase Adjust" control for correct Lissajou's pattern on the oscilloscope. (7) Adjust the "Dynamic Force" potentiometer for full-scale indication on the tan δ meter. (8) Turn the main selector switch to "tan δ" position and read the tan δ.

In order to calculate the dynamic flexile modulus E'_F, the following equation has been derived:

$$E'_F = \frac{2}{AD} \times 10^9 \times \frac{L^3}{96\pi\gamma^4}$$

where E'_F = dynamic flexile modulus in dynes/cm^2, A = amplitude factor, D = the value of dynamic force dial, L = length of sample, and γ = radius of sample. By knowing the dynamic flexile modulus E'_F and tan δ value, the dynamic flexile loss modulus E''_F can be determined from the following relationship:

$$E''_F = \tan\delta(E'_F) \qquad \text{dynes/cm}^2$$

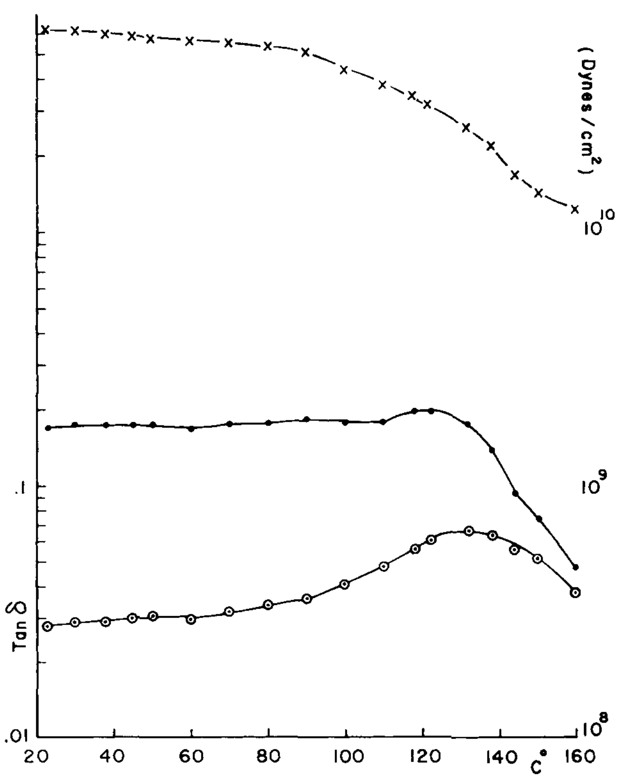

Fig. 3. Dynamic flexile properties of polyester monofilament: (x) E'_F; (●) E''_F; (⊙) tan δ.

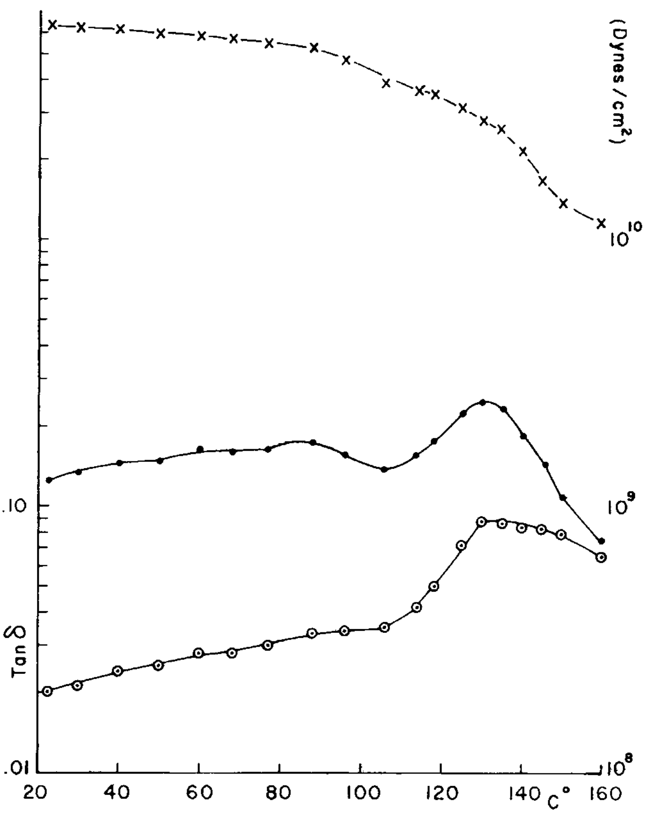

Fig. 4. Dynamic flexile properties of polyester yarn: (x) E'_F; (●) E''_F; (⊙) tan δ.

A number of polyester, nylon 66 monofil, and acrylic fibers were prepared. Dynamic measurements were made at 11 Hz with a strain amplitude about 0.5%. Samples were heated at 1°C/min in nitrogen atmosphere, and measurements of the flexile modulus E'_F and damping factor tan δ were made at 5° or 10°C increments. Samples were allowed to equilibrate at temperature for 15 min before measurements were made.

RESULTS AND DISCUSSION

The dynamic flexile modulus E'_F along with the loss tangent tan δ and the loss flexing modulus of nylon 66 monofilament are shown in Figure 2. The dynamic flexile modulus is decreased with increasing temperature in the temperature range of 50° to 160°C. The loss tangent peak T_g of this nylon 66 is about 110°C. However, the intensity of the α peak (tan δ_{max}) is slightly lower than that of the tensile test.

The dynamic flexing results of polyester monofilament and yarn are shown in Figures 3 and 4. The T_g of these polyester samples is about 130°C. The dynamic flexile modulus is lower than that of the tensile modulus in the temperature range of 25 to 160°C. The α peak temperature is in agreement with the results of the dynamic tensile measurement. However, the value of loss tangent in the flexile measurement is lower than that of the tensile measurement.

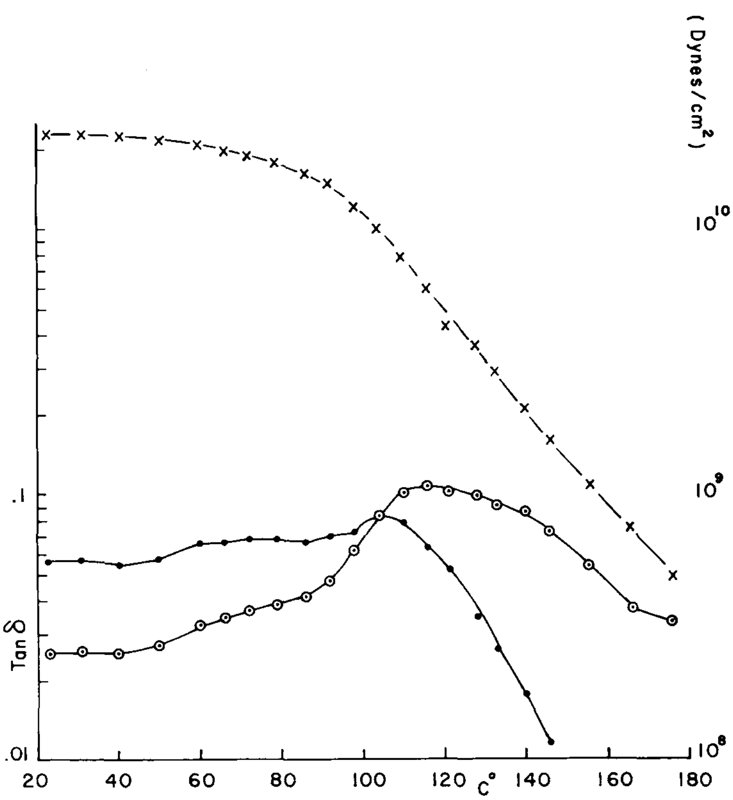

Fig. 5. Dynamic flexile properties of acrylic fibers: (x) E'_F; (●) E''_F; (⊙) tan δ.

Figure 5 shows the results of acrylic fiber. The dynamic flexile modulus is decreased sharply in the temperature range of 60 to 160°C. The new method for measurement of dynamic flexile properties is useful for analysis of the characterization of properties in the flexile mode in connection with end use performance or fiber structure.

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References

1. M. Takayanagi, *Mem. Fac. Eng. Kyushu Univ.*, **23**, 1 (1963).
2. T. Murayama, *J. Appl. Polym. Sci.*, **19**, 3221 (1975).
3. T. Murayama, *J. Appl. Polym. Sci.*, **20**, 2593 (1976).
4. I. W. Ward, *Mechanical Properties of Solid Polymers*, Wiley, New York, 1971.

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