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A New Method for the Measurement of Dynamic Shear Mechanical Properties of Materials with a Rheovibron Viscoelastometer

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Synopsis

The Rheovibron viscoelastometer is useful for obtaining dynamic *tensile* mechanical properties of films and fibers over a wide temperature range. Numerous studies of dynamic tensile mechanical properties have been made in the temperature range of −160°C to 250°C in an atmosphere at 0% relative humidity. However, no studies exist which show the measurement of dynamic *shear* mechanical properties of materials using the Vibron instrument. A new shear grip and procedure was developed for measuring dynamic mechanical properties of material in the shear mode using the Rheovibron instrument. The dynamic shear properties on a polyurethane elastomer and polyester film are presented. This technique will be useful in studies on the dynamic shear characterization of materials in conjunction with end use performance.

INTRODUCTION

The Rheovibron Viscoelastometer (Toyo Measuring Instruments) is useful for obtaining dynamic *tensile* mechanical properties of films and fibers over a wide temperature range. Numerous studies of dynamic tensile mechanical properties have been made in the temperature range of −160°C to 250°C in an atmosphere at 0% relative humidity[1,2]. However, no studies exist which show the measurement of dynamic *shear* mechanical properties of materials using the Vibron instrument. In this paper, a new method for investigating dynamic shear mechanical properties of materials is presented and shows the effects of temperature on dynamic shear properties of polyurethane elastomer and polyester film.

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 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

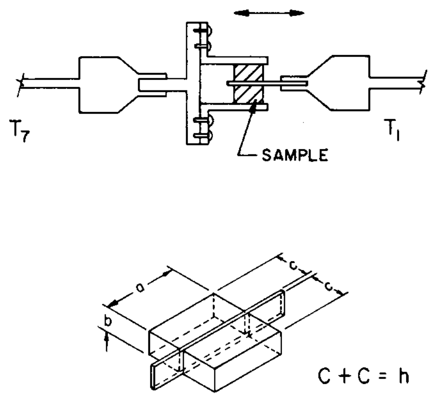

Fig. 1. Schematics of shear grip.

and instrument are described in detail by Takayanagi.[2] In order to measure the dynamic properties in the shearing mode using the Rheovibron viscoelastometer, it was necessary to develop the shear grips to permit characterization of viscoelastic materials in dynamic shear. The shear grip is shown in Figure 1. Two small cubes of specimen are installed in the grips as seen in Figure 1.

Sufficient compressive force can be exerted by the adjustable side plates to contain most samples without slippage since very small dynamic strain is involved. If slippage is troublesome, a small drop of polymer solvent may be applied to the surfaces of the sample to increase the friction. Once the sample is installed in the shear grips, the entire assembly can then be placed in the standard specimen clips in the same manner as a tensile specimen. The back-plate which holds the adjustable side plates should be held in the strain (T-7) clip and the center shear plate should be held in the force (T-1) clip.

The following is the operating procedure for shear testing with the Rheovibron: With the tan δ range switch at 40 amplitude factor switch at 30,

1. Set main selector switch to stress (T-1) gage position.
2. Adjust knob until tan δ meter indicates zero.
3. Set main selector switch to "Amp. F" position.
4. Adjust "Amplitude Adjust" for full scale indication on tan δ meter.
5. Set main selector switch to "Dyn. F" position.
6. Adjust "Phase Adjust" control for correct Lissajou's pattern on oscilloscope (straight line at approximately a 45° angle to horizontal).
7. Adjust "Dynamic Force" potentiometer for full-scale indication on tan δ meter.
8. Turn main selector switch to "tan δ" position and read tan δ.

In order to calculate the dynamic shear modulus G', the following equations have been derived:

$$G' = \frac{\Delta F}{\Delta L} \frac{h}{4(ab)} \qquad \text{(ref. 3)} \tag{1}$$

$$G' = \frac{2}{AD} \times 10^9 \times \frac{h}{4(ab)} \text{ dynes/cm}^2 \tag{2}$$

where G' = dynamic shear modulus in dynes/cm^2, ΔF = oscillating load, ΔL = oscillating displacement, A = amplitude factor, D = the value of dynamic force dial, h = width of two samples, a = length of sample, and b = thickness of sample.

By knowing the dynamic shear modulus G' and tan δ value, the dynamic shear loss modulus G'' can be determined as the following relationship:

$$G'' = \tan\delta\,(G')\,\text{dynes/cm}^2 \tag{3}$$

A number of polyurethane elastomer and polyester sample blocks, 0.6 cm × 0.5 cm and about 0.3 cm thick, were prepared. Dynamic measurements were made at 11 Hz with strain amplitude of about 0.4% to 0.6%. Samples were heated at 1°C/min in nitrogen atmosphere under relaxed conditions, and measurements of the shear modulus G' and loss factor tan δ were made at 5° or 10°C increments. Samples were allowed to equilibrate at temperature for ten minutes before measurements were made.

RESULTS AND DISCUSSION

The dynamic shear modulus G' along with the loss tangent tan δ and the loss shear modulus G'' of polyurethane elastomer are shown in Figure 2. The α peak temperature of this polymer is about −34°C. The dynamic shear modulus is decreased with increasing temperature.

Figure 3 gives the dynamic shear data of polyester film. The α peak temperature of polyester film is about 92°C at 0% R.H. This result suggests that

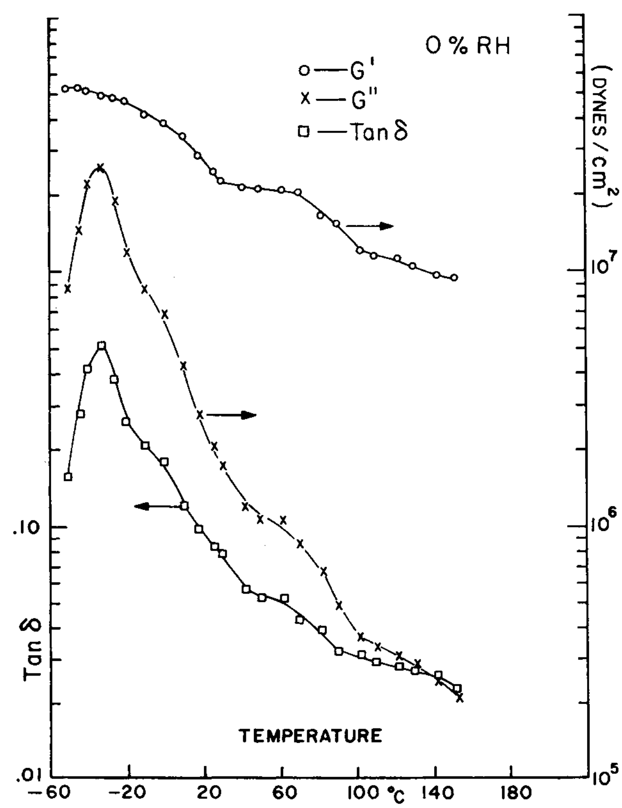

Fig. 2. Dynamic shear mechanical properties of polyurethane elastomer.

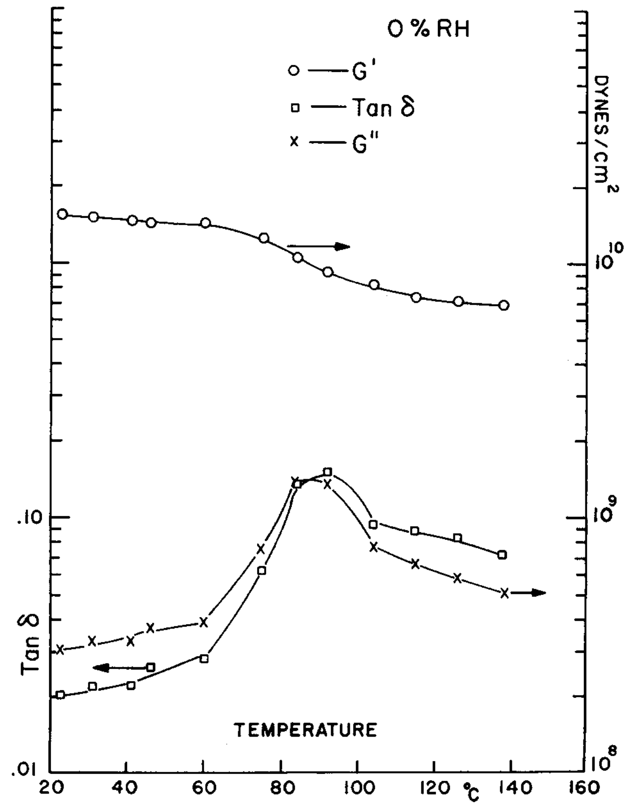

Fig. 3. Dynamic shear mechanical properties of polyester film.

this polyester film has about 20% crystallinity. These results indicate that a new shear grip and procedure make it possible to measure the dynamic mechanical properties of material in the shear mode using the Rheovibron viscoelastometer.

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