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

INTRODUCTION

The Rheovibron 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 a liquid or gas medium was reported.[2,3] However, no studies exist which show the measurement of dynamic compression mechanical properties of materials using the Vibron instrument. In this report, a new method for investigating dynamic compression mechanical properties of materials is presented, and the effects of temperature on dynamic compression properties of polyurethane elastomer, rubber, and polyester film are shown.

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 compression mode using a Rheovibron viscoelastometer, it was necessary to develop the compression grips to permit characterization of viscoelastic materials in dynamic compression. The compression grip is shown in Figure 1. A small block or rod of specimen is installed in the grip as seen in Figure 1. The compression grips consist of two sample mounting units and 13-cm-long rods; the weight of the grips is 10.5 g. The tensile clamp is replaced by these compression grips at the connector of T_1 and T_7 of the strain gauge. One side of the sample specimen is adhered to the center of the T_7 sample mounting unit.

The following is the operating procedure for compression testing with the Rheovibron. With the tan δ range switch at 30 and the amplitude factor at 30,

1. Set the main selector switch to stress T_1 gauge position.
2. Turn the handle of the slider of the driving section and apply the initial compression, about 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.

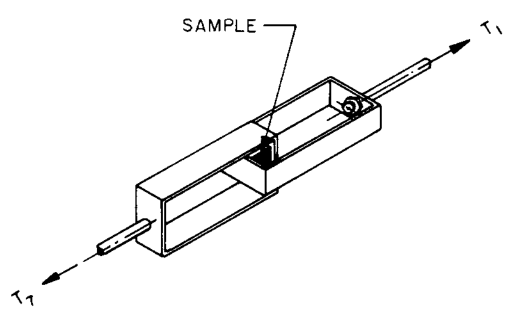

Fig. 1. Schematics of compression grip.

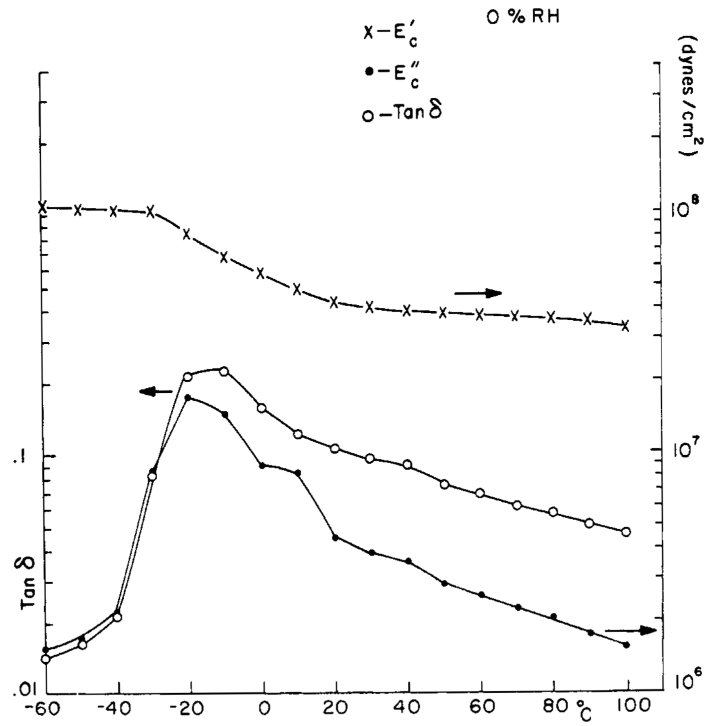

Fig. 2. Dynamic compression mechanical properties of polyurethane elastomer.

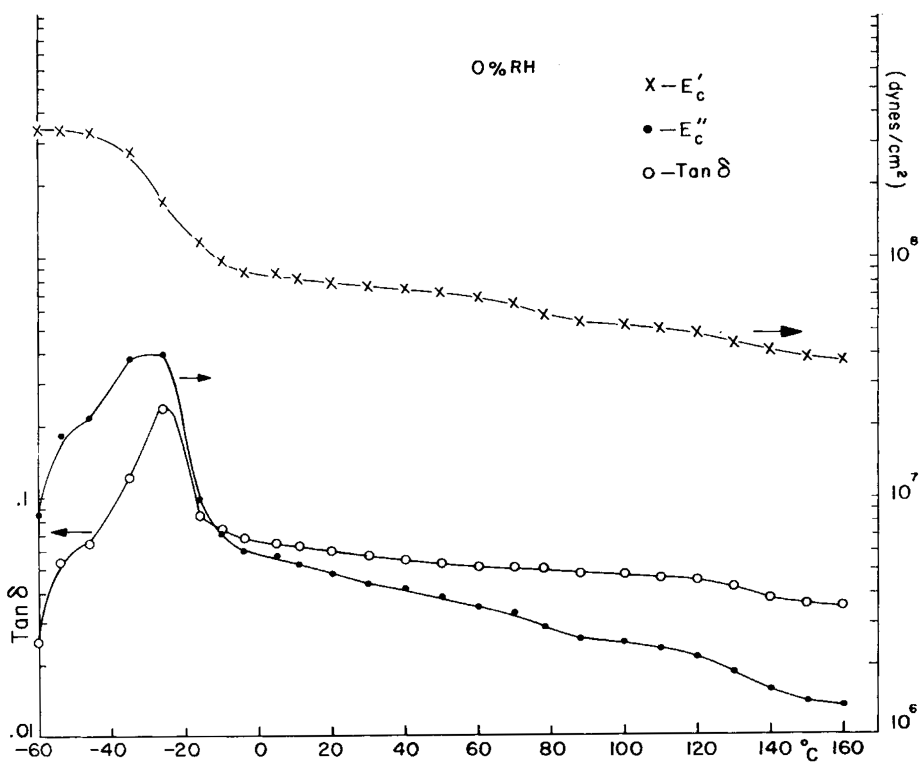

Fig. 3. Dynamic compression mechanical properties of rubber.

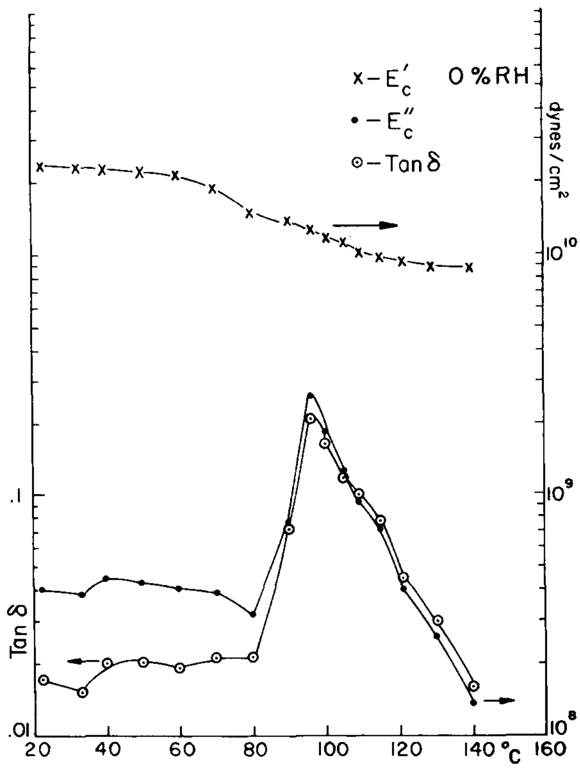

Fig. 4. Dynamic compression mechanical properties of polyester film.

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 tan δ meter.
8. Turn the main selector switch to "tan δ" position and read tan δ.

In order to calculate the dynamic compression modulus E_c', the following equation has been derived:

$$E_c' = \frac{2}{AD} \times 10^9 \times \frac{L}{S} \text{ dynes/cm}^2$$

where E_c' = dynamic compression modulus in dynes/cm^2, A = amplitude factor, D = the value of dynamic force dial, L = length of sample, and S = cross section of sample.

By knowing the dynamic compression modulus E_c' and tan δ values, the dynamic compression loss modulus E_c'' can be determined from the following relationship:

$$E_c'' = \tan\delta\,(E_c') \text{ dynes/cm}^2.$$

A number of polyurethane elastomers, polybutadiene rubber, and polyester sample blocks 0.6 × 0.4 cm and 0.4 cm thick were prepared. Dynamic measurements were made at 11 Hz with strain amplitude about 0.4% to 0.6%. Samples were heated at 1°C/min in nitrogen atmosphere, and measurements of the compression modulus E' and loss factor tan δ were made at 5° or 10°C increments. Samples were allowed to equilibrate at temperature for 10 min before measurements were made.

RESULTS AND DISCUSSION

The dynamic compression modulus E_c' along with the loss tangent, tan δ, and the loss compression modulus of polyurethane elastomer are shown in Figure 2. The dynamic compression modulus is decreased with increasing temperature in a temperature range of −60°C to 100°C. The loss tangent peak (T_g) of this elastomer is about −20°C. However, the intensity of the α peak (tan δ max) is lower than that of the tensile test.

The dynamic compression results of polybutadiene rubber are shown in Figure 3. The T_g of this rubber is about −25°C. The compression modulus is decreased sharply in the temperature range of −60° to −10°C. Figure 4 gives the dynamic compression data of polyester film. The α peak temperature of polyester film is about 96°C at 0% R.H. This is in agreement with the results of the dynamic shear measurement of the same sample. However, the dynamic compression modulus for the sample is higher than the dynamic shear modulus in the temperature range of 23° to 140°C. These results indicate that this polyester film has about 20% crystallinity and anisotropic behavior.

The new method for measurement of dynamic compression mechanical properties is useful for analysis of the characterization of properties of materials.

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