Application Brief

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Dynamic Mechanical Measurements by TMA/SS

1. Introduction

Mechanical property of the polymer material is regarded as important property at various applications. To know the mechanical property, the measurement of the material modulus is important. In this brief, the periodic loading measurement mode of the TMA/SS is used. The example of the calculation of the Young's modulus from the stress and the strain is introduced.

Young's modulus (*E*) is shown as follows:

$$E = \frac{\sigma}{\varepsilon} = \frac{(F / A)}{(\Delta L / L_0)}$$

σ : stress　　ε : strain
F : load　　A : cross section of sample
L_0 : initial length of sample　　ΔL : amount of displacement

TMA/SS enables the calculation of the mechanical property of the thin film because of the high accurate measurement at the minute load. Spring as perfectly elastic body and the rubber, and low-density polyethylene (LDPE) film is used as sample.

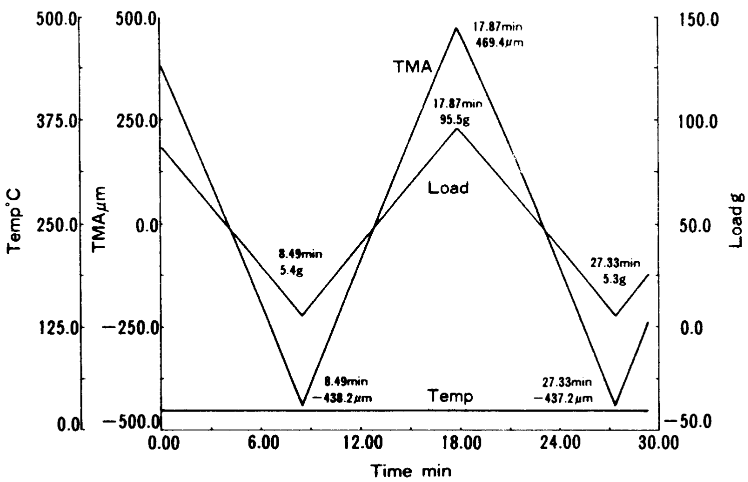

Figure 1　TMA/SS measurement results for spring
Sample length : 14mm
Load rate : 10g/min

2. Measurements

2-1 Modulus of spring

Figure 1 shows the measurement result of spring by the triangular-wave control. It shows that spring is linear relation of load and displacement. Thus the stress-strain graph of this measurement result shows straight line (Figure 2), and Young's modulus can be calculated from the slope of this straight line.

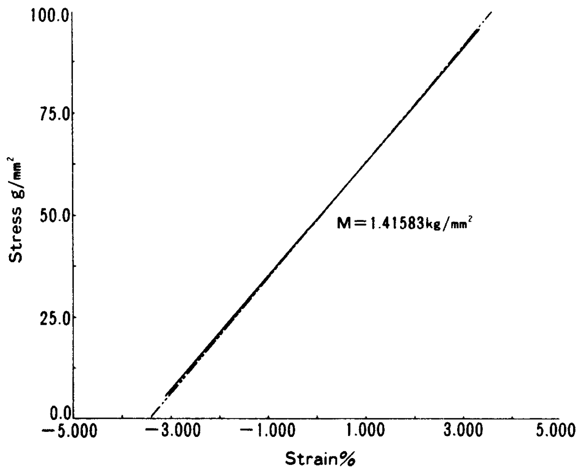

Figure 2 Stress-Strain graph for spring

2-2 Modulus of spring

Figure 3 and 4 show the measurement results of rubber and LDPE film by the sinusoidal oscillation measurement. In the measurement result of the rubber, very little phase difference is observed; however, that of LDPE film is observed.

Figure 5 and 6 show the stress-strain graphs of these measurement results. In the measurement results of Figure 5, very little phase difference is observed. Therefore the relationship of stress strain shows almost straight same as that of the spring (Figure 2). However, the relationship of LDPE film stress strain shows oval shape due to the viscous term. The loss energy of internal friction can be calculated by this oval area.

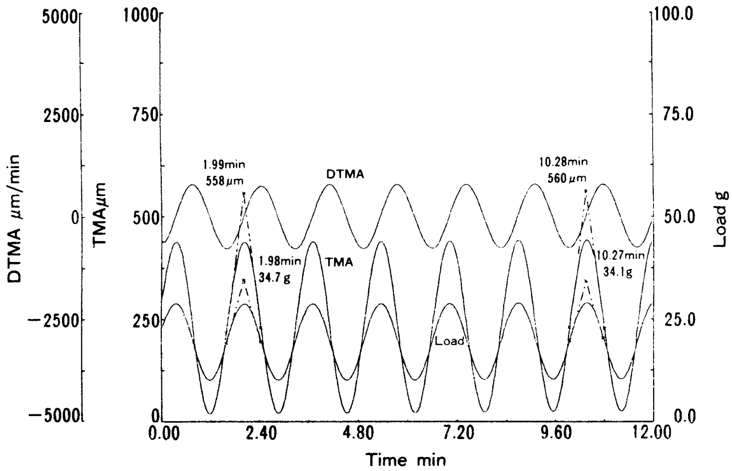

Figure 3 TMA/SS measurement results for rubber

Sample length : 10mm

Cross section of sample : 2.993mm^2

Frequency : 0.01Hz

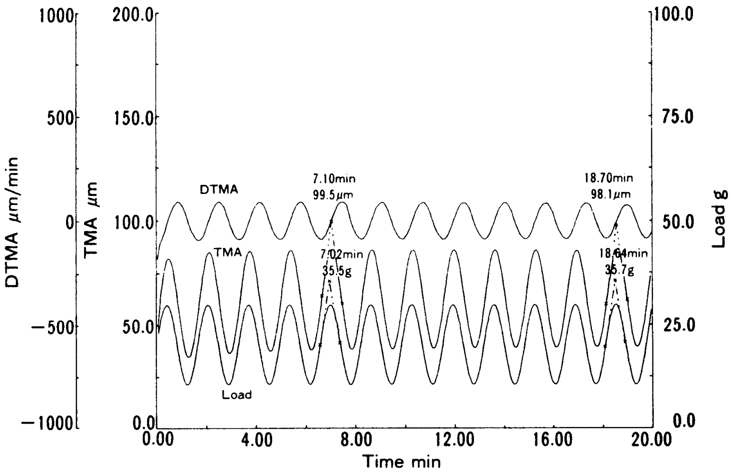

Figure 4　TMA/SS measurement results for LDPE film
Sample length : 10mm
Cross section of sample : $0.132mm^2$
Frequency : 0.01Hz

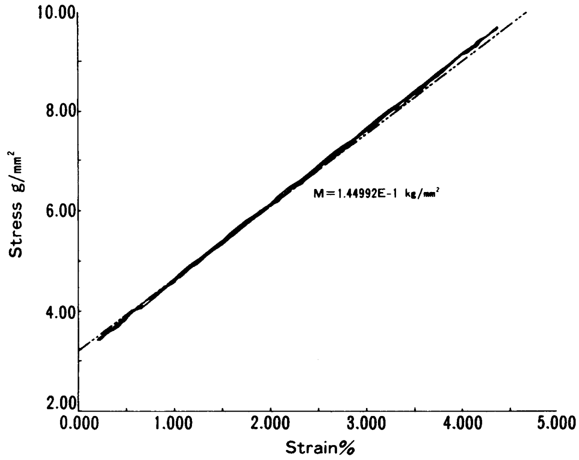

Figure 5　Stress-Strain graph for rubber

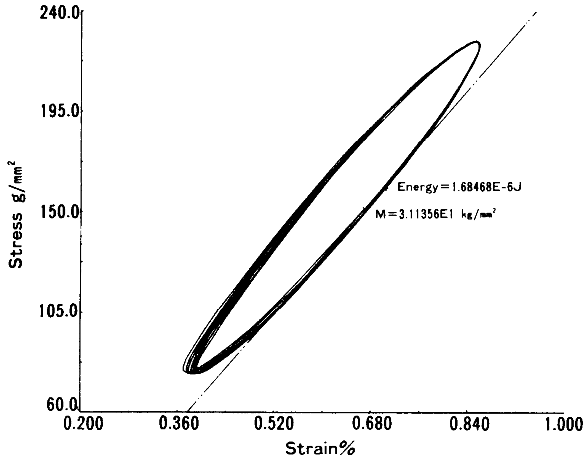

Figure 6　Stress-Strain graph for LDPE film

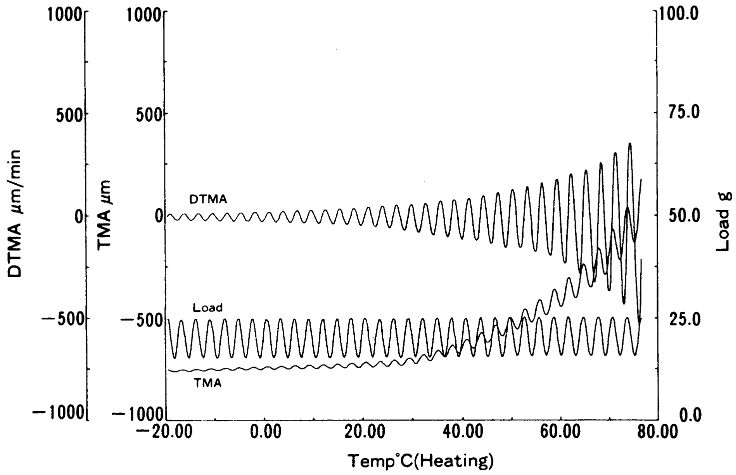

Figure 7　TMA/SS measurement results for LDPE film
Sample length : 10mm
Cross section of sample : 0.132mm^2
Frequency : 0.01Hz
Heating rate : 2°C/min

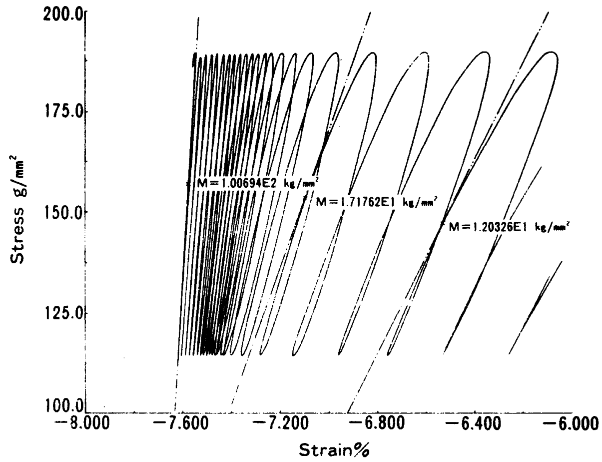

Figure 8　Stress-Strain graph for LDPE film (heating process)

2-3　Temperature dependency of Young's modulus

TMA/SS can calculate Young's modulus at each temperature at a time because the temperature can be scanned during the periodic loading control. Figure 7 shows the measurement result of sinusoidal oscillation measurement for LDPE film.

Periodic loading DTMA signal (time-derivative of TMA signal) amplitude is expanding gradually from the vicinity of 0°C and Young's modulus is decreasing. Figure 8 shows the stress-strain curve of this measurement result. 100.7kg/mm^2 at -20°C, 17.2kg/mm^2 at 30°C, and 12.0kg/mm^2 at 40°C of Young's modulus are obtained. Young's modulus decreases along with heating.