TA Instruments

Thermal Analysis & Rheology

RHEOLOGY SOLUTIONS

DETERMINING THE LINEAR VISCOELASTIC REGION IN POLYMERS

PROBLEM

Materials such as polymers exhibit viscoelastic behavior which is directly related to molecular structure and formulation differences. To accurately evaluate the relationships between molecular structure and viscoelastic behavior requires that experiments, such as rheological measurements, be conducted in regions where the viscoelastic properties observed are independent of imposed stress or strain levels. That is, experiments must be conducted in the linear viscoelastic region.

SOLUTION

Controlled stress rheology provides two techniques for determining a polymer's linear viscoelastic region. These are creep and dynamic oscillation. In creep, a constant stress is applied to the material, and the resultant strain is monitored with time. By sequentially increasing the stress, a series of creep curves is obtained such as those for polystyrene in Figure 1. Replotting these curves as compliance, a viscoelastic function defined as strain divided by stress, yields the results shown in Figure 2. In the polymer's linear viscoelastic region, the compliance curves should overlap. In this example, the curve produced by Stress C does not overlap, indicating that the linear viscoelastic region is exceeded.

In the dynamic oscillation approach, increasing cyclic levels of stress and strain are applied at a constant frequency. The point at which a dynamic viscoelastic function (either G* or η*) deviates by more than 10% from a constant (plateau) value indicates departure from linear viscoelastic behavior. Figures 3 and 4 illustrate the oscillatory stress and strain results respectively for polystyrene. Departure from linear behavior occurs at about 9 k Pa in the former case and at about 20% strain in the latter.

Figure 1. CREEP STRAIN (%) CURVES

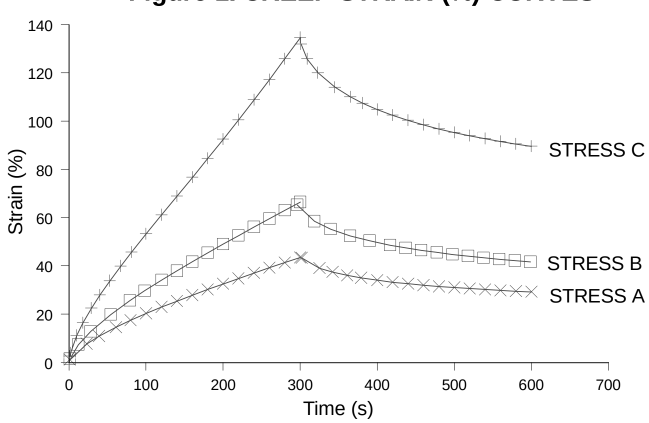


Figure 2. CREEP COMPLIANCE CURVES

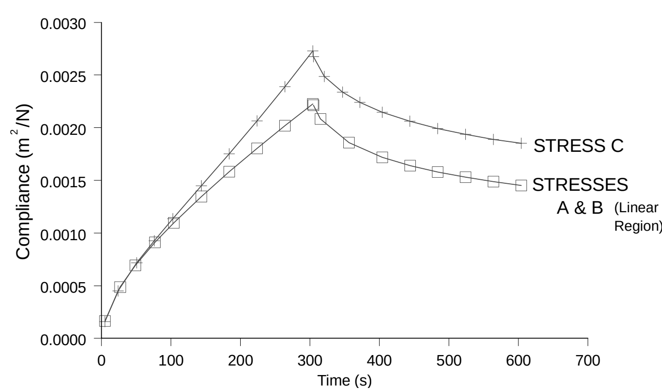


FIGURE 3. G* AND η* VERSUS SHEAR STRESS

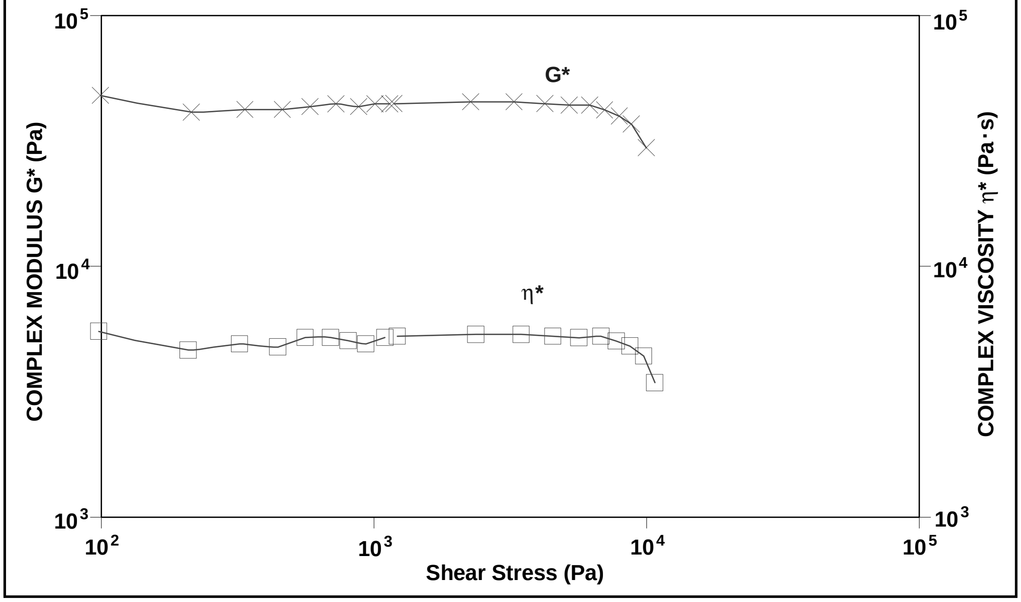
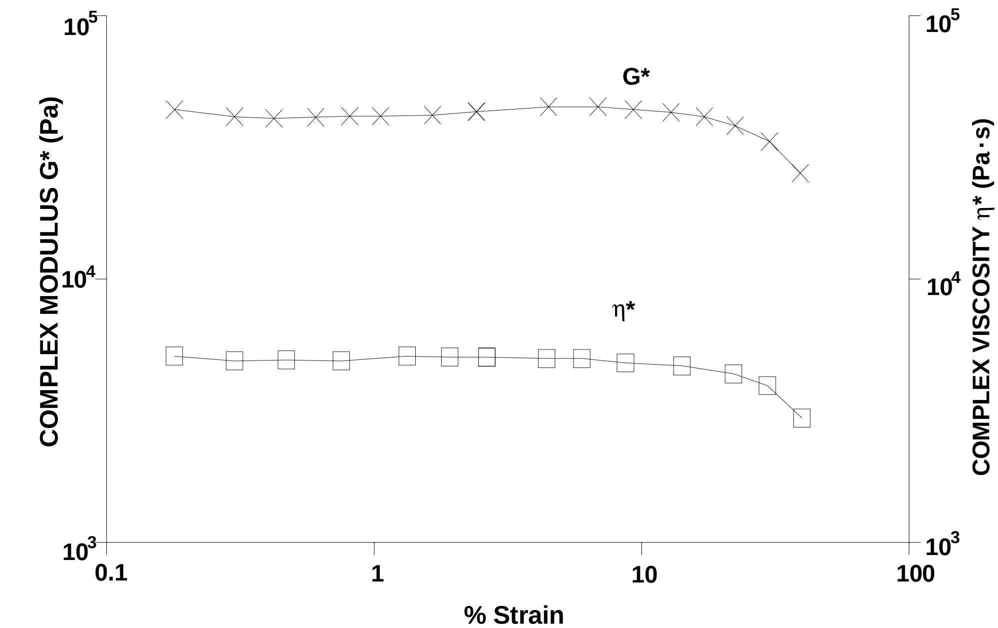


FIGURE 4. G* AND η* VERSUS SHEAR STRAIN



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