Numerical Experiments for Estimation of Dynamic Properties of Polymers with Instrumented Nanoindentation

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Introduction

Because of an emphasis on lighter weight and multifunctional materials, polymers and polymer composites (traditional and nanocomposites) play critical roles in many current and future Army applications including blast and impact mitigation (i.e., armor). New polymers and polymer composites, produced in the laboratory in small sample sizes, can be produced much faster than they can be quantitatively characterized. Recent advancements in instrumented nanoindentation have resulted in capabilities for characterizing mechanical behavior in small-sized samples from quasi-static rates to ultrasonic frequencies. Current capabilities for deriving quantitative mechanical properties of polymers from nanoindentation tests are severely limited, because (a) the current dynamic models used to describe the tip-sample interactions only crudely approximate viscoelastic behavior, and (b) current data-analysis practice involves computing parameters at one frequency at a time.

In this paper we report on numerical experiments for estimating dynamic properties of rubbery polymers from nanonindentation measurements, in order to better understand the effect of measurement error on industry-standard data analysis procedures. Several parameters were explored through the simulated experiments, including amount of damping in the sample, the indenter size, the resonant frequency of the nanoindenter instrument, and, the amount of additive error included in the simulated data.

Results

The results show that accuracy is highest near the natural frequency of the instrument, and the accuracy decreases at frequencies away from the natural frequency of the instrument. Results for a typical numerical experiment are shown in Figure 1, showing the known moduli (solid line) and the estimated moduli (discrete points) for 1% additive error applied to the data.

Ongoing Work

The present work involves a Kelvin-Voight model of the sample (spring and dashpot). We have begun working with an axisymmetric model of the indenter-sample interaction, which should provide a better description of the physics of the experiment.

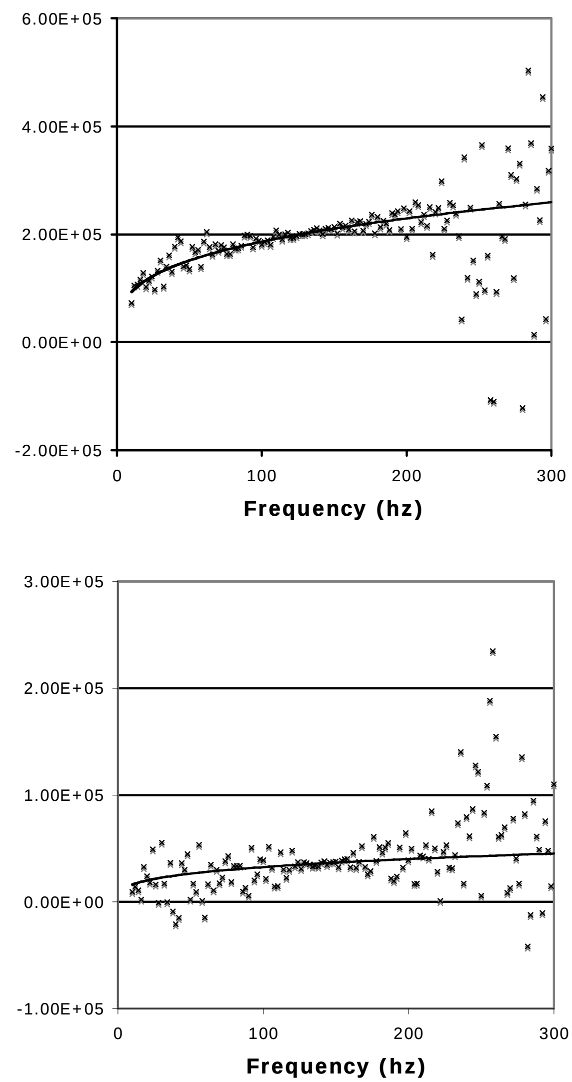

Figure 1. Storage modulus and loss modulus estimated from simulated data with 1% additive error. Known values are shown with a solid line. Instrument resonance is 147 Hz.