Time-Dependent Deformation of Polycarbonate

K. E. Johanns, J. L. Hay, and P. Sudharshan Phani, Nanomechanics, Inc.

Introduction

Measurement of viscoelastic properties are integral to the design and manufacture of plastic-based engineering components. Here, we show how the iNano nanoindentation system from Nanomechanics, Inc. can quickly and accurately quantify time-dependent deformation in polycarbonate, a thermoplastic polymer. A constant-load-hold technique with a Berkovich indenter was used to measure indentation strain rate as a function of mean contact pressure. The results were found to be extremely repeatable, showing that this type of non-destructive testing can be used for both material characterization and quality control.

Materials and Methods

Polycarbonate, a thermoplastic polymer, was obtained from Goodfellow Corp., USA.

Constant indentation load and hold has become a unique technique to measure time dependent deformation [1]. Here, the sample was initially loaded as an exponential function of time to a target load (e.g., Fig. 1). Following the loading segment, the instrument held the applied load, *P*, on the sample constant for a set period of time over which the indentation depth, *h*, was monitored (e.g., Fig. 2). The sample was completely unloaded following the end of the hold. Each indentation test time was ~75s, and a total of 9 indentations were performed.

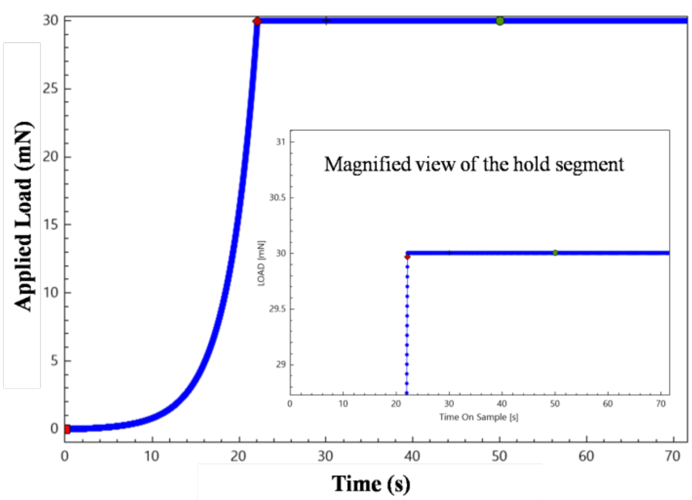

Figure 1 – Load time history for the creep testing. Initially, the sample is loaded at a constant indentation strain rate followed by a hold segment where the creep rates are measured.

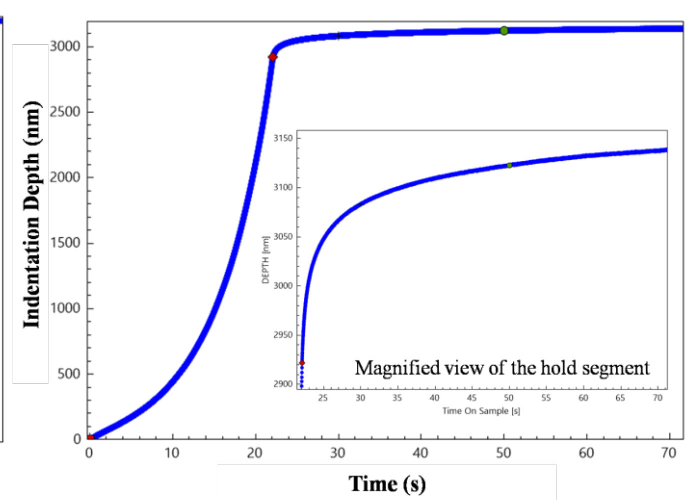

Figure 2 – Indent depth time history resulting from the loading. Depth changes with time during the load hold segment are directly related to creep deformation.

Indentation strain-rate, $\dot{\varepsilon}$, was calculated from the indentation depth, *h*, and time, *t*, given in Eq. (1). Assuming that the contact depth is equivalent to the indentation depth, the contact area, *A*, was calculated according to Eq. (2) for a Berkovich indenter. The mean contact pressure, *H*, was calculated by Eq. (3).

$$\dot{\varepsilon} = \frac{1}{h}\frac{dh}{dt} \quad (1)$$

$$A = 24.5h^2 \quad (2)$$

$$H = \frac{P}{A} \quad (3)$$

Results and Discussion

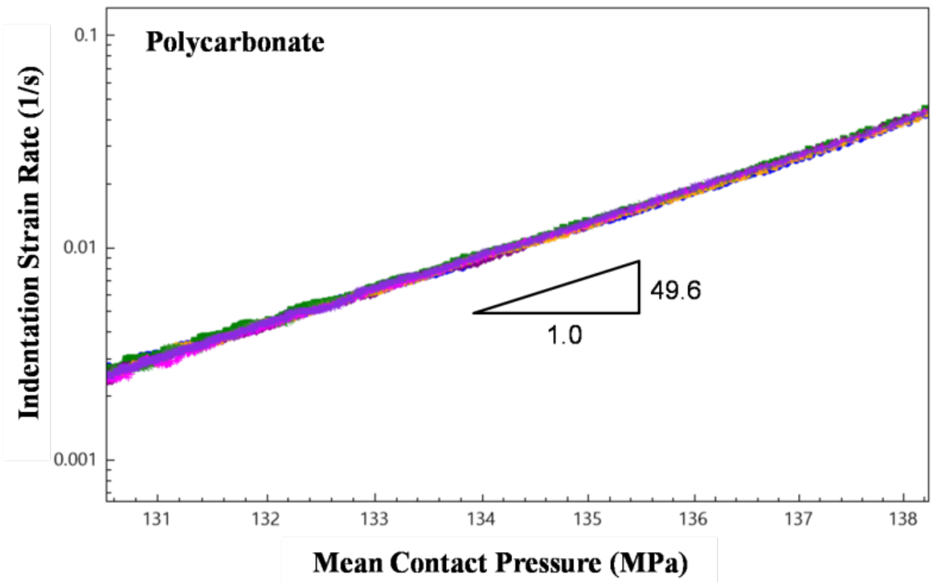

Figure 3 – Indentation strain rate plotted as a function of mean contact pressure (log-log scale) for all 9 tests. The slope of the data determines the creep behavior of the material.

Indentation strain-rate as a function of mean contact pressure is plotted in Fig. 3. A change in mean contact pressure of 7 MPa resulted in a change in indentation strain-rate of nearly 2 orders of magnitude. This time-dependent behavior is consistent with conventional viscoelastic theory, i.e., larger applied pressures result in higher strain-rates [2]. For material characterization purposes, the data in Fig. 3 can be fit to a power-law behavior to give the change in strain-rate with respect to change in applied pressure. The resulting slope for this particular grade of polycarbonate was found to be 49.6 as shown in Fig. 3.

Conclusions

The iNano nanoindentation system from Nanomechanics, Inc. offers the capability to rapidly and accurately characterize time-dependent behavior in polymers and other viscoelastic plastics. In this work, a constant-load-hold test with a Berkovich indenter revealed a positive and repeatable relationship between strain rate and contact pressure. The precision and simplicity of the iNano makes it well suited for quality-control applications in industry.

References

[1] C. Su, E.G. Herbert, S. Sohn, J. A. LaManna, W. C. Oliver, and G. M. Pharr, JMPS, 2013.

[2] E. G. Herbert, K. E. Johanns, R. Singleton, and G. M. Pharr, JMR, 2013.