SPHERICAL INDENTATION CREEP AND LOAD-RELAXATION

M.L. OYEN*

*Center for Applied Biomechanics
Dept. of Mechanical and Aerospace Engineering
University of Virginia
Charlottesville, VA 22902, USA
mloyen@virginia.edu

Depth-sensing indentation testing is a common way to characterize the mechanical behavior of stiff, time-independent materials but presents both experimental and analytical challenges for compliant, time-dependent materials including polymers and hydrated biological tissues. In the current work, analytical approaches for viscoelastic indentation problems are considered for the spherical indenter tip geometry in both load- and displacement- control.

Elastic-viscoelastic correspondence [1,2] is used to generate spherical indenter solutions for a number of indentation testing protocols including creep following loading at a constant rate [3] or relaxation following displacing at a constant rate. Experiments are performed using different combinations of load- or displacement-level with different ramp rates to test the assumptions of linearly viscoelastic behavior. Both polymeric and hydrated biological materials are examined in indentation experiments. Measured data are fit to the spherical indentation solutions to obtain the short- and long-time modulus limits and values of the time-constants. A sensitivity analysis is performed to examine potential errors in the measured modulus values based on experimental conditions such as the choice of measurement time-frame relative to material time-frame. The relationship between creep and relaxation data for the same materials is also examined analytically and with measured indentation data.

For polymeric materials, good agreement is found between the experimental results and known modulus values. For biological materials, results are consistent with published measurements of modulus values obtained from experiments using other testing modalities. Having established a method for measuring creep and relaxation behavior by indentation, the technique is used to examine the effect of hydration state on both soft (cartilage) and mineralized (bone) biological materials.

References:

[1] E.H. Lee and J.R.M. Radok, Contact problem for viscoelastic bodies, *Journal of Applied Mechanics* 27, 438 (1960).
[2] K.L. Johnson, Contact Mechanics, (Cambridge University Press, Cambridge, UK, 1985).
[3] Oyen ML, Spherical Indentation Creep Following Ramp Loading, *Journal of Materials Research*, 20 2094 (2005).

Keywords: indentation, viscoelastic, creep, relaxation