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Dynamic Mechanical Property Analysis of Hydrogel Biomaterial

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Statement of Purpose: The objective of this work was to employ the Dynamic Mechanical Analysis (DMA) software with the ElectroForce® BioDynamic® testing platform to evaluate the mechanical properties of hydrogels. The Wintest® DMA software has been developed to determine the dynamic viscoelastic properties of biomaterials or tissues as a function of wide range of test conditions such as frequency, strain and temperature. The BioDynamic testing platform allows for continuous characterization and stimulation in a fully integrated and instrumented configuration by providing material characterization (viscoelastic properties, strength, creep and stress relaxation) within a physiological environment (sterile, nutrient flow, pressure loading, pH, dissolved oxygen, and temperature).

Methods: The BioDynamic instrument was used along with DMA software to test the mechanical properties of hydrogels to demonstrate its ability to measure the dynamic mechanical properties of tissue and biomaterials (such as stress-strain relationship, stiffness, modulus, hysteresis, etc. with respect to loading frequency). The dynamic mechanical properties of polyvinyl alcohol hydrogels (Cambridge Polymer Group, Boston, MA) were evaluated with our unique computer-controlled moving magnet linear motor that provides load, displacement, and strain or pressure profiles (Figures 1-2). The hydrogel samples were 10 mm in diameter and 3-5 mm in height, and testing was performed in compression with a 5 mm displacement transducer and a 50lb force transducer.

Figure 1. Biodynamic® system setup for hydrogel DMA tests

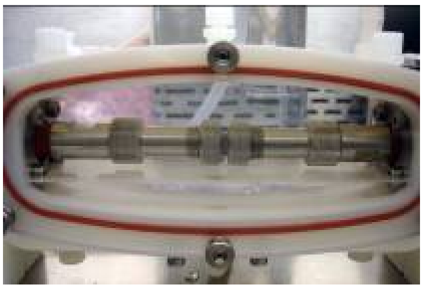

Figure 2. Sterile hydrogel sample with porous perfusion platens

The DMA software applies a user-defined 0.5N compression load to the hydrogel sample as a contact load, and then it applies 5% cyclic sinusoidal strain on the specimen for automatic calculated cycles enough to demonstrate preconditioning at a rate 0.2Hz, and then it repeats the sample procedure at other frequencies (from 0.2Hz to 10Hz). The user-defined parameters allow the study of the samples' dynamic viscoelastic properties as a function of a wide range of testing conditions.

Results / Discussion: The relationship between the complex modulus and the loading frequency as well as the tan delta and the loading frequency are shown in Figure 3, where complex modulus is the measure of dynamic mechanical properties of a material, taking into account energy dissipated as heat during the deformation and recovery, and tan delta is the tangent of phase between the reference channel and feedback. The plotted data shows that the complex modulus value increases as loading frequency increases, while tan delta value decreases as loading frequency increases. Figure 4 shows four cycles of the sinusoidal compression waveform at the rate of 1Hz.

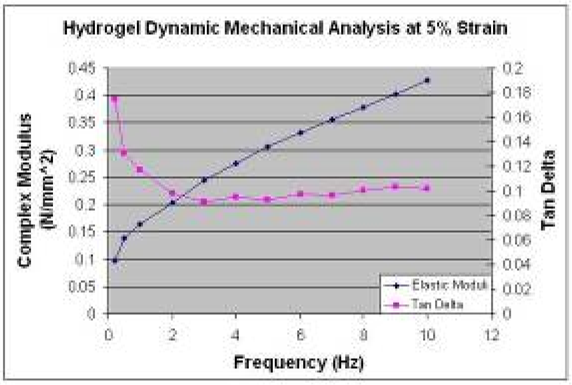

Figure 3. Hydrogel modulus and tan delta as a function of frequency at 5% strain

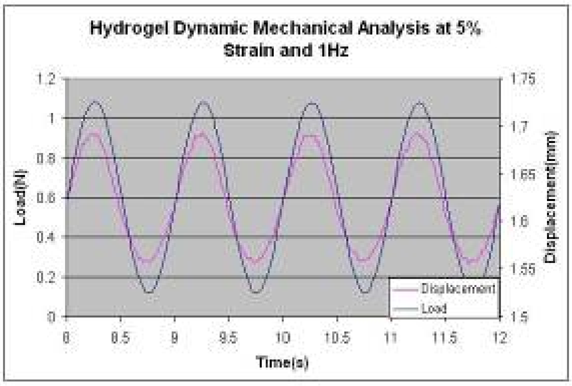

Figure 4. Dynamic material properties of a polyvinyl alcohol hydrogel

Conclusions: This study showed that the BioDynamic system along with DMA software is a very powerful tool to study the dynamic mechanical properties of biomaterials in a sterile biological environment.