Novel Method of Analysis for BioMaterials

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Abstract

Current methods to define Poisson's ratio of a solid are often met with uncertainty. The Young's modulus (E), shear modulus (G), and Poisson's ratio (ν) of a solid are related by the equation G = E/(2+ 2ν), meaning that if two of the quantities are known, so is the third. However, measurement inaccuracies of E and G can inhibit the accuracy of a Poisson's ratio calculations. Currently, much of the literature involving these quantities presents results without self-verification. Our research focused on the determination of G, E, and ν of agarose and collagen hydrogels through Uniaxial tensile testing and Rheometry. A video analysis program was developed to determine Poisson's ratio directly by measuring transverse and axial strain of agarose and collagen hydrogels during uniaxial tensile testing. Measurement of all three properties provides a check of each measurement, validating both methodology and results.

Project Overview

Cyclical loading testing of 1% Agarose Hydrogel

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Rheometry testing of 1% Agarose Hydrogel

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Tensile Testing of 1% Agarose Hydrogel with video recording.

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Analysis and Comparison of data

Background

➢ "…the Poisson ratio has been estimated to be 0.5 for each of the agarose types examined which indicates that these gels are incompressible" [1].

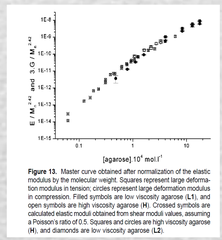


Figure 13. Master curve obtained after normalization of the elastic modulus by the molecular weight. Squares represent large deformation modulus in tension; circles represent large deformation modulus in compression. Filled symbols are low viscosity agarose (**L1**), and open symbols are high viscosity agarose (**H**). Crossed symbols are calculated elastic moduli obtained from shear moduli values, assuming a Poisson's ratio of 0.5. Squares and circles are high viscosity agarose (**H**), and diamonds are low viscosity agarose (**L2**).

[1]

➢ The current macro-mechanical data presented for agarose in various studies assumes a Poisson ratio of 0.5 and then find supporting Shear and Elastic Moduli values.

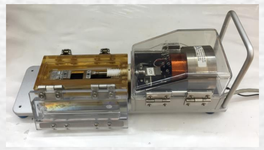
➢ **However, there is little to no verification technique used to ensure a Poisson ratio of 0.5.**

Methodology

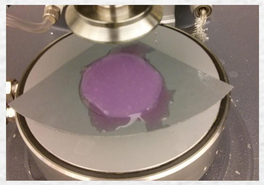
1. Poisson's Ratio from E and G

➢ Traditional Rheometry and Uniaxial Tensile test results were performed in order to find E and G

➢ Force and Displacement data used for E calculations



Bioreactor used for tensile testing.

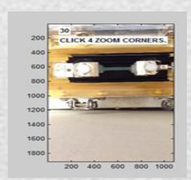


Rheological data collection set-up.

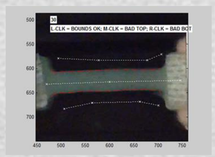
2. Poisson's Ratio from Video Analysis

➢ Transverse and Axial Strain were calculated using a novel video analyzer code developed in Matlab

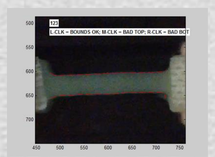
➢ Frame-by-Frame analysis is conducted by zooming in to the main area of a dogbone sample.



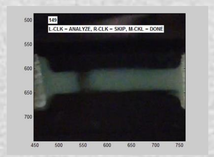
Sample gel in Bioreactor Chamber prepared for testing via a Trapezoid tensile test.



Frame 30, baselines were set and boundary lines were recognized by script.



Frame 123, boundary lines recording gel's length and width under tension.



Frame 149, gel broken.

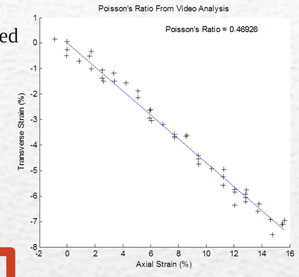
➢ Boundary lines and Baselines are placed within the area of interest in order to define the changes in position of the dogbone edges.

➢ This process was repeated continuously, frame-by-frame until the gel had broken.

Results

E and G were determined via tensile and rheometry testing, respectively, and calculated ν from the given relationship.

$$G' = \frac{E'}{(2+2\nu)}$$



Poisson's ratio determination for 1% agarose sample via video analysis method.

➢ The different ν's are close in calculation.

1% Agarose Properties @ 2 Hz

	G' (Pa)	G" (Pa)	E' (Pa)	ν
1% Macro	3912±75	156±10	12220±4587	0.56±0.21 (G,E) 0.48±0.05 (img)

Conclusions

➢ Our results for both agarose and collagen (from the multi-verification method) correspond with literature value

ν = 0.48±0.05 (Video Analysis)

ν = 0.56±0.21 (E' and G')

ν ≈ 0.5 (Literature)

➢ Verification techniques demonstrate the accuracy of our results and testing methods.

➢ Further studies of collagen to ensure reliability of verification technique.

➢ Future considerations will include new techniques for Poisson's Ratio calculations in micro-mechanics for further comparison between macro and micro properties of hydrogels

[1] V. Narmand, D. L. Lootens, E. Amici, K. P. Plucknett and P. Aymard, "New Insight into Agarose Gel Mechanical Properties," *Biomacromolecules,* no. 1, pp. 730-8, 2000.

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