www.elsevier.com/locate/jmbbm

Mechanical Characterization of Brain Tissue in Simple Shear at Dynamic Strain Rates

Badar Rashid, Michel Destrade, Michael D. Gilchrist

PII: S1751-6161(13)00249-X
DOI: http://dx.doi.org/10.1016/j.jmbbm.2013.07.017
Reference: JMBBM919

To appear in: *Journal of the Mechanical Behavior of Biomedical Materials*

Received date: 5 November 2012
Revised date: 28 June 2013
Accepted date: 15 July 2013

Cite this article as: Badar Rashid, Michel Destrade, Michael D. Gilchrist, Mechanical Characterization of Brain Tissue in Simple Shear at Dynamic Strain Rates, *Journal of the Mechanical Behavior of Biomedical Materials*, http://dx.doi.org/10.1016/j.jmbbm.2013.07.017

Mechanical Characterization of Brain Tissue in Simple Shear at Dynamic Strain Rates

Badar Rashid[a], Michel Destrade[b,a], Michael D Gilchrist[a*]

[a]*School of Mechanical and Materials Engineering, University College Dublin, Belfield, Dublin 4, Ireland*

[b]*School of Mathematics, Statistics and Applied Mathematics, National University of Ireland Galway, Galway, Ireland*

**Corresponding Author*

Tel: + 353 1 716 1884/1991, + 353 91 49 2344 Fax: + 353 1 283 0534

Email: badar.rashid@ucdconnect.ie (B. Rashid), michel.destrade@nuigalway.ie (M. Destrade), michael.gilchrist@ucd.ie (M.D. Gilchrist)

Abstract Mechanical characterization of brain tissue has been investigated extensively over the past fifty years. During severe impact conditions, brain tissue experiences a rapid and complex deformation, which can be seen as a mixture of compression, tension and shear. Diffuse Axonal Injury (DAI) occurs in animals and humans when both the strains and strain rates exceed 10% and 10/s, respectively. Knowing the mechanical properties of brain tissue in shear at these strains and strain rates is thus of particular importance, as they can be used in finite element simulations to predict the occurrence of brain injuries under different impact conditions. However, very few studies in the literature provide this information. In this research, an experimental setup was developed to perform simple shear tests on porcine brain tissue at strain rates ≤ 120/s. The maximum measured shear stress at strain rates of 30, 60, 90 and 120/s was 1.15 ± 0.25 kPa, 1.34 ± 0.19 kPa, 2.19 ± 0.225 kPa and 2.52 ± 0.27 kPa, (mean ± SD), respectively at the maximum amount of shear, $K = 1$. Good agreement of experimental, theoretical (Ogden and Mooney-Rivlin models) and numerical shear stresses was achieved ($p = 0.7866 \sim 0.9935$). Specimen thickness effects (2.0 – 10.0 mm thick specimens) were also analyzed numerically and we found that there is no significant difference ($p = 0.9954$) in the shear stress magnitudes, indicating a homogeneous deformation of the specimens during simple shear tests. Stress relaxation tests in simple shear were also conducted at different strain magnitudes (10% - 60% strain) with the average rise time of 14 ms. This allowed us to estimate elastic and viscoelastic parameters (initial shear modulus, μ = 4942.0 Pa, and Prony parameters: $g_1 = 0.520$, $g_2 = 0.3057$, $\tau_1 = 0.0264$ s, $\tau_2 = 0.011$ s) that can be used in FE software to analyze the non-linear viscoelastic behavior of brain tissue. This study provides new insight into the behavior in finite shear of brain tissue under dynamic impact conditions, which will assist in developing effective brain injury criteria and adopting efficient countermeasures against Traumatic Brain Injury.

Keywords *diffuse axonal injury (DAI), Ogden, Mooney – Rivlin, Traumatic Brain Injury (TBI), Homogeneous, Viscoelastic, Relaxation*