

Characterisation of Brain Tissue at High Strain Rates

Richard Pangonis, Mazdak Ghajari, David J. Sharp

I. INTRODUCTION

Quantifying mechanical behaviour of brain tissue at high loading rates is essential for the development of predictive computational models of traumatic brain injury biomechanics. Under impact or blast loading, brain tissue can undergo a combination of shear, compression or tension. Almost all the high strain rate characterisation efforts in literature are centred around compression or shear experiments [1-2], with very little information on the behaviour of brain tissue at high rates of tension, such as the work by [3] which tested porcine brain at strain rates up to 90 s^{-1} .

This paper details the design and preliminary testing of a portable desktop apparatus to test tissue samples in both tension and compression at strain rates from quasi-static up to 800 s^{-1} , with an emphasis on tensile experiments which are the primary area of interest at this stage.

II. METHODS

We developed a custom portable testing apparatus capable of testing tissue samples in both tension and compression at strain rates of up to 800 s^{-1} . The testing apparatus is powered by a magnetic linear motor (Quickshaft LM 2070-220-11, Faulhaber, Schönaich, Germany) which drives a rod at speeds of up to 2.8 m/s (Figure 1). Once the max speed is obtained this rod applies load to the sample by way of a loss capture mechanism (LCM). The LCM is observed to bounce elastically off the rod upon impact, reaching speeds of approximately 3 m/s , applying this velocity stretch to the sample. The LCM's inertia is sufficient to make the deceleration due to the load applied to the sample negligible and the applied strain rate can be assumed to be at constant velocity over the experimental range. For compression tests the direction of the motor is reversed and the rod is used as an impactor, but otherwise the setup remains the same.

The device outputs load on the sample, using an ultra low capacity load cell, and displacement of the moving plate by way of a linear encoder. Using these outputs the strain rate can be measured from the velocity of the moving plate and a stress-strain graph can be generated to investigate mechanical properties at different strain rates.

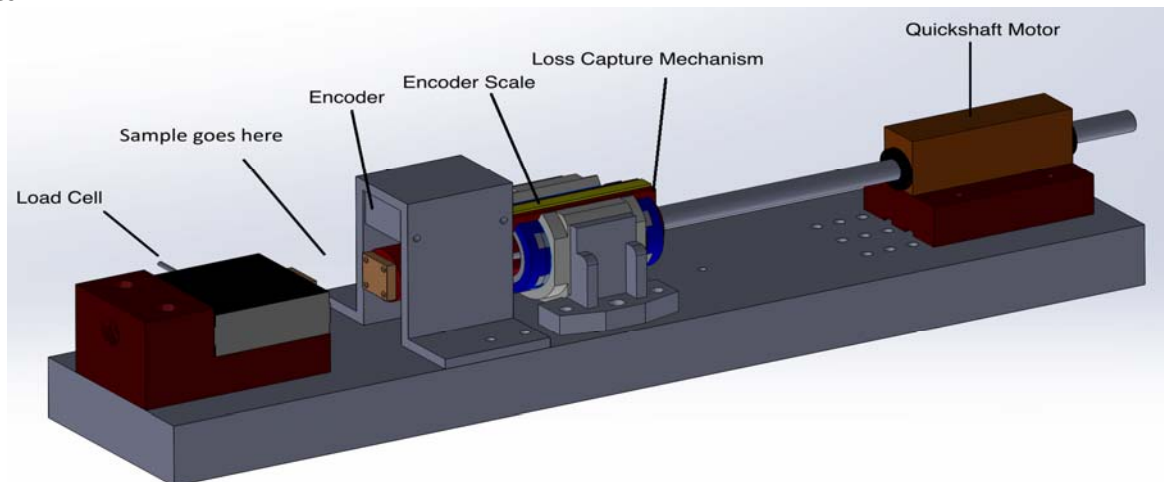


Figure 1: Diagram of the apparatus.

Initial tensile tests were carried out on the grey matter of lamb brains obtained from a local butcher. At this stage of testing no effort was made to minimise the post mortem time before testing and the samples were simply stored in a refrigerator. Cylindrical samples 3mm in diameter, 4mm deep were obtained from the grey

matter of the test brains using a biopsy punch and secured to the plates on the device using a dab of super glue. The rod was accelerated to 2.5 m/s with the bounce enhanced speed of the LCM observed to be approximately 3m/s, making the strain rate tested 750 s^{-1} . The experiment was filmed with a Phantom v210 High speed camera at 8200 frames per second. The encoder was not available for these preliminary tests so only load against time data was obtained and the approximate speed of the LCM was estimated from the high speed video.

III. INITIAL FINDINGS

It was observed during sample preparation that the act of cutting the sample seemed to greatly weaken it. While the brain as a whole was capable of maintaining its macroscopic shape, smaller samples were observed to almost disintegrate, becoming more like a gel than a solid. Initial tests showed a fairly typical load curve shape consistent with a viscoelastic solid, but at lower stress values than expected from literature [4]. The sample exhibited a breaking stress of approximately 100 Pa. Analysis of the high-speed videos (Figure 2) showed the sample deforming uniformly during the experiment, indicating a smooth strain field. The video also confirmed constant velocity stretching.

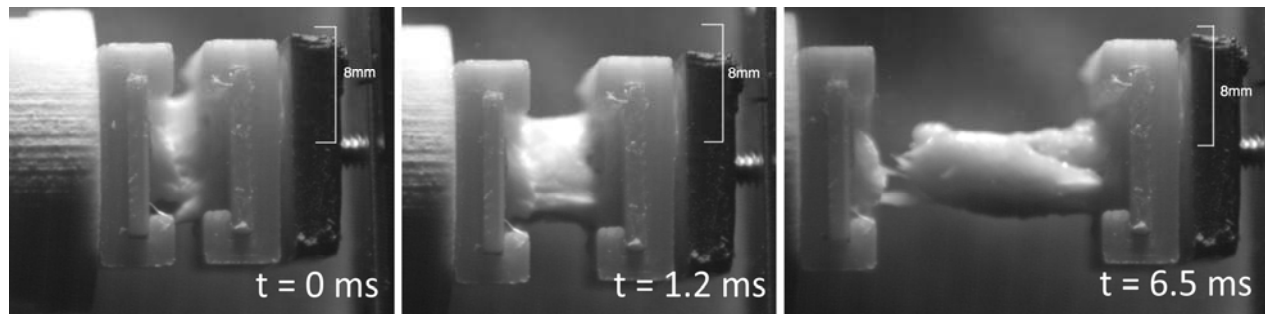


Figure 2: High speed video stills showing i) initial conditions, ii) uniform deformation and iii) breaking point.

IV. DISCUSSION

An apparatus was developed to test brain tissue at high strain rates in both tension and compression, with promising early test results. An interesting observation was that samples appeared weaker than the brain. This phenomenon has not been reported in literature and could be specific to lamb brains or a consequence of the comparatively long post mortem time of the tissue. It is theorised, however, that small samples have considerably less mechanical reinforcement from axons, which typically have a length scale several times larger than the sample size. While these axons exist in the sample, they are no longer anchored in adjacent tissue and this cross section of their length has a much lower *tangle factor*, which could explain this comparative weakness. More tests are needed on a variety of tissue with a stricter post mortem procedure, but these initial results could imply that small sample testing may not be a suitable method for brain tissue characterisation.

V. REFERENCES

- [1] J. a W. van Dommelen et al, *Mechanosensitivity of the Nervous System*, 2009.
- [2] K. B. Arbogast et al, *JBiomech*, 1998.
- [3] B. Rashid et al, *JMech Behav Biomed Mat*, 2014.
- [4] G. Franceschini, *JMech Phys Sol*, 2006.