Novel Ideas for Evaluating Material Properties of Brain during Blasts

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Introduction

Primary blast-induced traumatic brain injury (bTBI) has become a topic of research interest due to recent military conflicts and terrorists attacks. Primary injury from blast is due to the initial overpressure wave and its propagation through tissue.

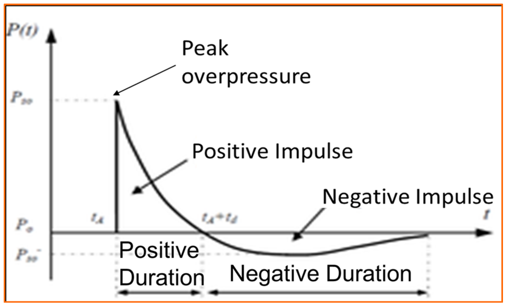


Figure 1. Friedlander Waveform which is the ideal wave form resembling a free-field wave.

Why Focus on Blast TBI?

- Existing experimental models treat brain as a homogeneous material, ignoring differences between white and grey matter.
- Shuck et al. found that human brain tissue had a storage modulus ranging from 7.6 kPa to 33.9 kPa[1,2].

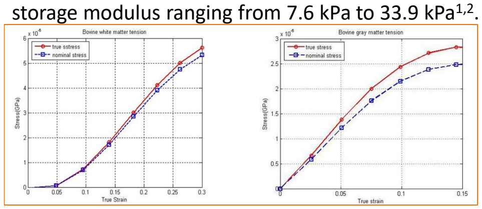


Figure 2. Stress-strain curves highlighting the differences between white and grey matter[3].

- Injury can occur when tissue of differing densities undergo shear, especially at junctions between white and grey matter.

The Objective

Create a brain surrogate model with varying material properties to investigate how white and grey matter may receive different biomechanical pulses.

Methodology

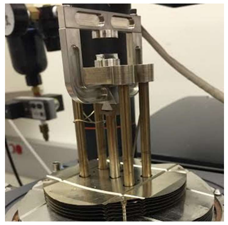


Figure 3. Samples of the Sylgard mixtures were prepared to perform dynamic mechanical analysis (DMA).

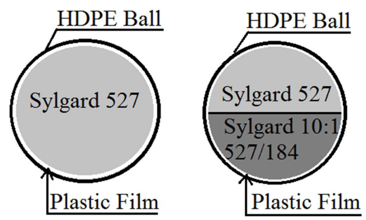


Figure 4. High density polyethylene (HDPE) spheres were lined with a thin plastic film and filled with Sylgard and pressure sensors. Cured at room temperature for 24 hours.

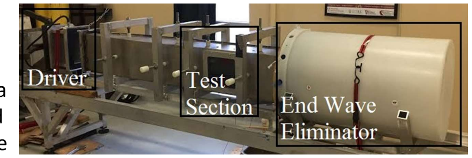
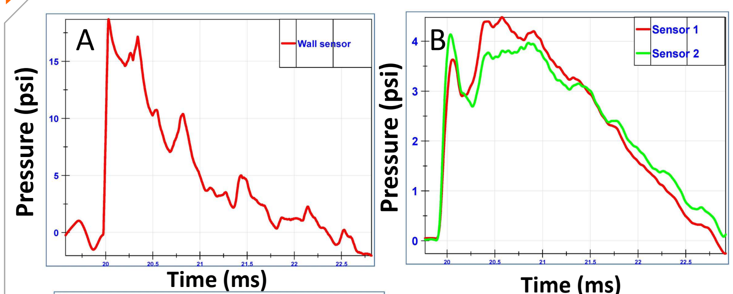


Figure 5. Custom built Advanced Blast Simulator (ABS). The surrogates were subjected to blast waves with an overpressure of 18 and 24 psi. The Sylgard 527/184 side faced the driver of the ABS.

Results

Surrogate Testing



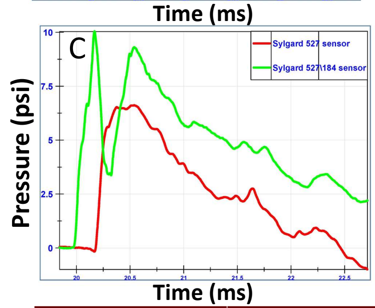


Figure 6. A- Pressure wave profile in ABS from 18 psi blast. **B-** Pressure wave profile inside Sylgard 527 homogenous surrogate from 18 psi blast. **C-** Pressure wave profile inside Sylgard 527 (red) and Sylgard 527/184 mix (green) from 18 psi blast.

Material	Average peak pressure (18 psi)	Average peak pressure (24 psi)
Sylgard 527/184 mix	11.955	14.79
Sylgard 527 in mix	9.065	14.07
Homogenous Sylgard 527	8.366	5.58

Table 1. Average peak pressures inside surrogates.

DMA Results and Material Properties

Material Composition	Density (g/cm^3)	Storage Modulus (kPa)
Sylgard 527	0.975	9.67-14.79
Sylgard 527/184 10:1	0.989	49.48-74.53

Table 2. Summary of material properties of Sylgard.

Conclusions

- There is noticeable attenuation of the peak overpressure of the shock wave inside the brain surrogates.
- The nonhomogeneous surrogate exhibited higher pressures in both materials compared to the homogenous surrogate.
- There is a delay in the shock front reaching the second sensor in the Sylgard mixture which shows that the shock wave travels slower in the more dense, stiffer material.

References

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3. Mehdizadeh, S., Khoshgoftar, M., Najarian, S., Farmanzad, F., & Ahmadi, S. A. H. (2008). Comparison between brain tissue gray and white matters in tension including necking phenomenon. American Journal of Applied Sciences, 5(12), 1701–1706.

Acknowledgements

This research was sponsored by the National Science Foundation REU Program #EEC-1359073.

Presented at the 2015 Undergraduate Summer Research Symposium, 30 July 2015, Virginia Tech