Composite Material Modeling for Fragment Impact

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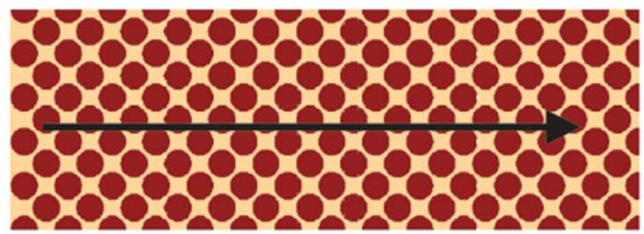
Introduction

- ***Composites are being used as missile structures and predicting their response to fragment impact is of interest for insensitive munitions***

- ***Composite shock properties are directionally dependent but data and modeling methods are limited [1,2]***

Longitudinal Shock



Transverse Shock

1. Key, C. T. and Schumacher, S. C., Anisotropic Shock Response of Unidirectional Composite Materials, 15th European Conference on Composite Materials, Venice, Italy, 24-28 June 2012.

2. Schumacher, S. C., Composite Layering Technique for Use in a Eulerian Shock Physics Code, Proceedings of the 17th American Physical Society on Shock Compression of Condensed Matter, Chicago, Illinois, 2011.

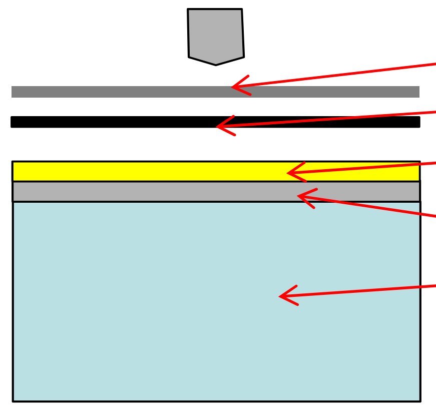
Introduction

- Many combinations of carbon fibers and matrices are currently used in missile and warhead applications and obtaining shock properties using traditional methods are costly
- Micromechanics models can be used to estimate the shock properties of composites if the constituent properties are known
- The shock properties of many polymers have been characterized but there are many new specialty polymers that have not
- Group interaction modeling [3] can be used to estimate polymer shock properties at reduced cost via bench top experiments common to polymer laboratories

3. Porter, D. and Gould, P. J., Predictive Nonlinear Constitutive Relations in Polymers through Loss History, International Journal of Solids and Structures, 46 (2009) pages 1981-1993.

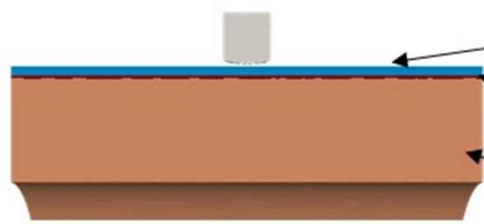
Hydrocode Analysis

- **Insensitive munitions fragment impact testing has shown that composites improve response in both warheads [4] and rocket motors [5]**



- **The warhead utilized a particle impact mitigation sleeve (PIMS) adjacent to the steel warhead case for shock mitigation**

- **The rocket motor used a composite motor case in place of the aluminum case for improved response**



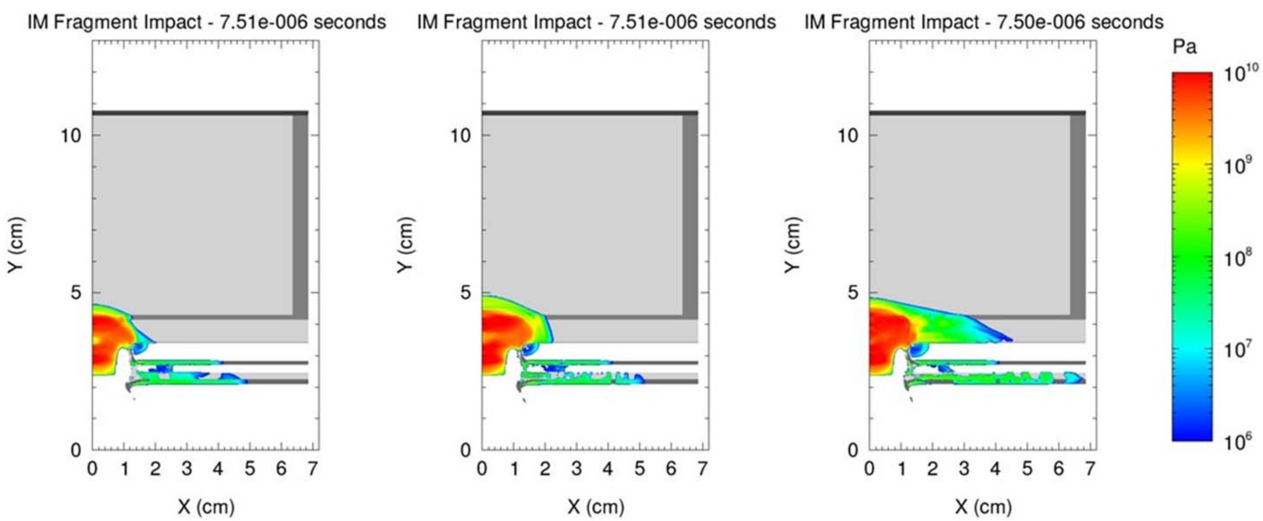
4. Peterson, N. R. and Sweitzer, J. C., Composite Material Particle Impact Mitigation Sleeve Testing, 13th Hypervelocity Impact Symposium, Boulder, Colorado, 26-30 April 2015.

5. Esslinger, J. R. et.al., Evaluation of Less Shock Sensitive Minimum Smoke Propellants in High Performance Composite Cases, 2010 NDIA Insensitive Munitions & Energetic Materials Technology Symposium, Munich, Germany, 14 October 2010.

Hydrocode Analysis

- **Hydrocode analysis of the warhead was performed modeling the PIMS as polyetherimide (PEI) and composite with and without anisotropic shock**

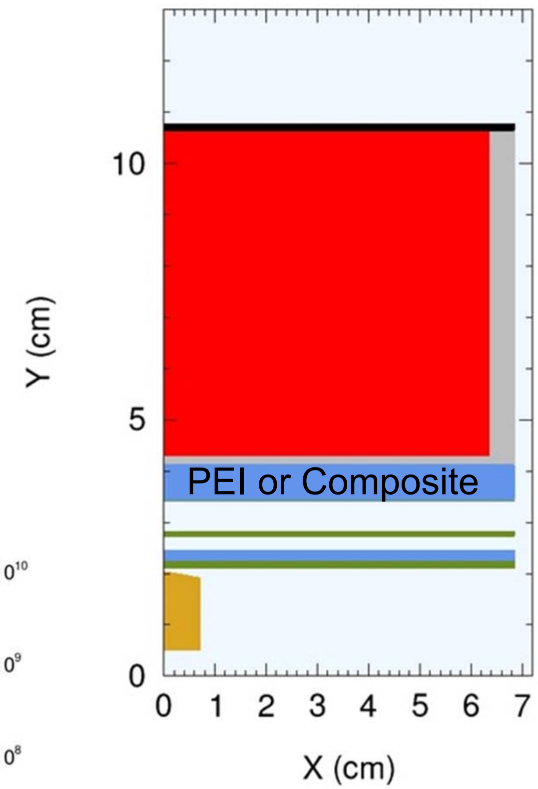
- **Pressure contours at the same point in time show a discernable difference in the pressure wave propagation**



PEI

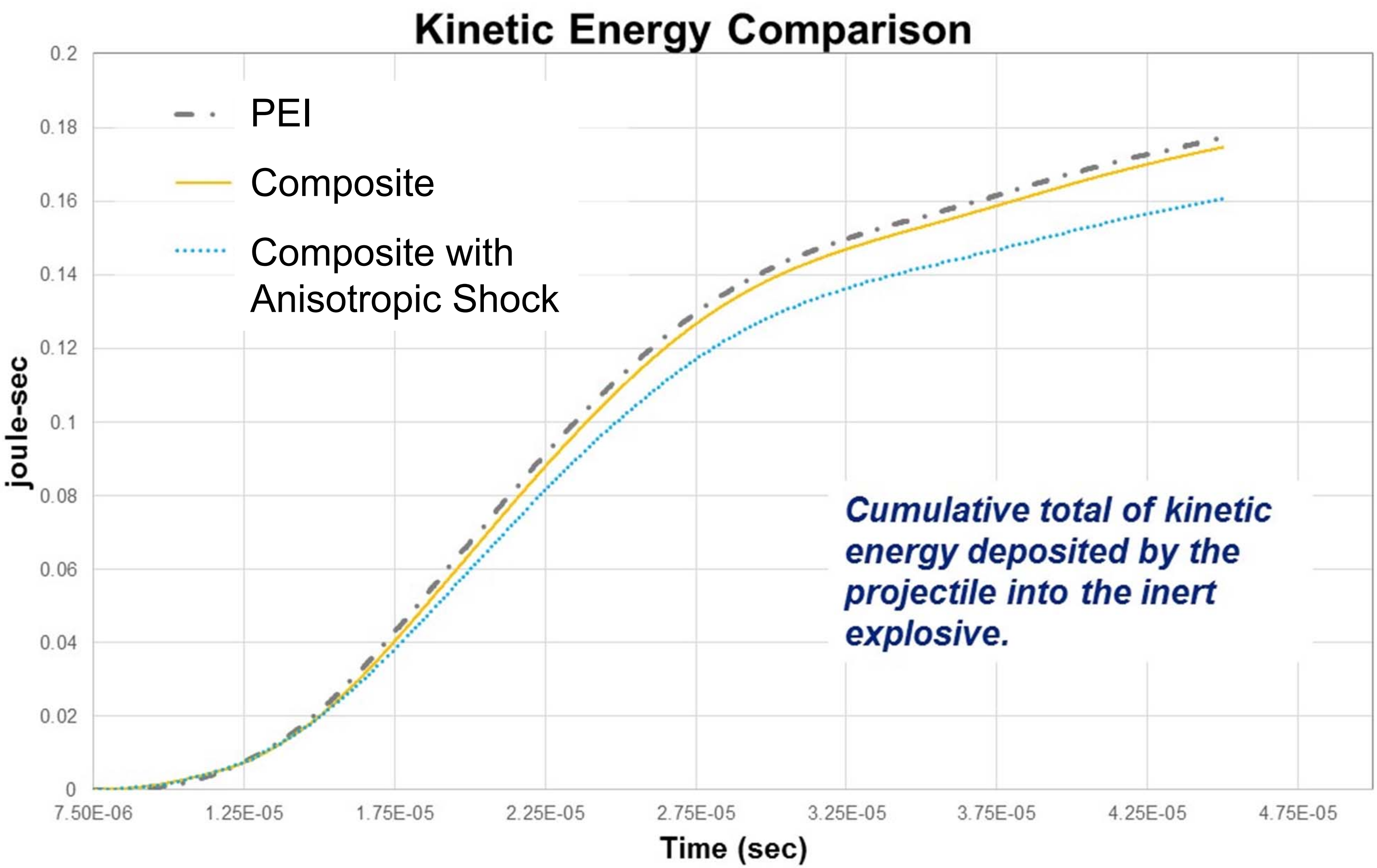
Composite

Composite Anisotropic Shock



Hydrocode Analysis

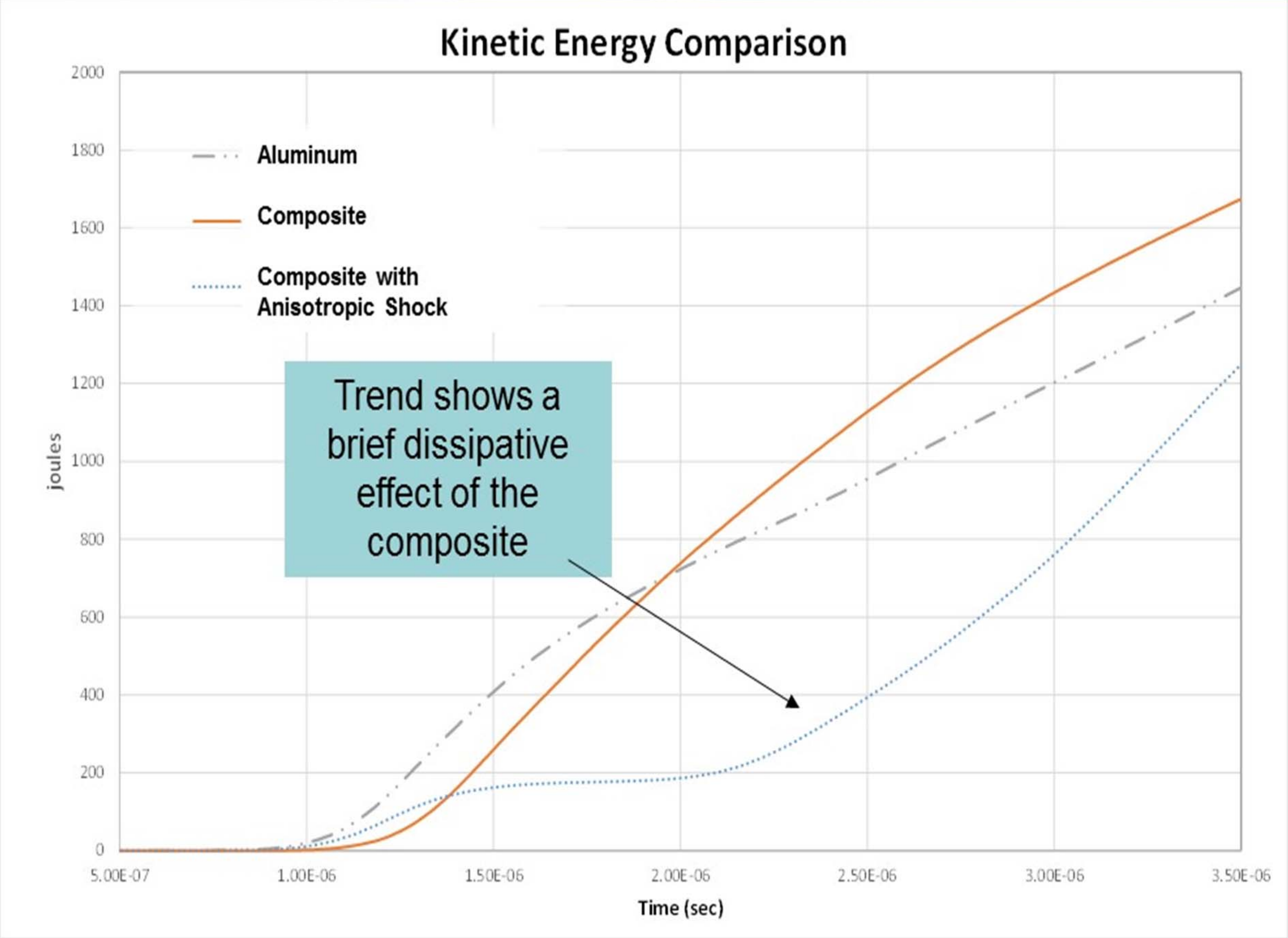
- **Energy deposited into the energetic is reduced with the anisotropic shock model**



Hydrocode Modeling

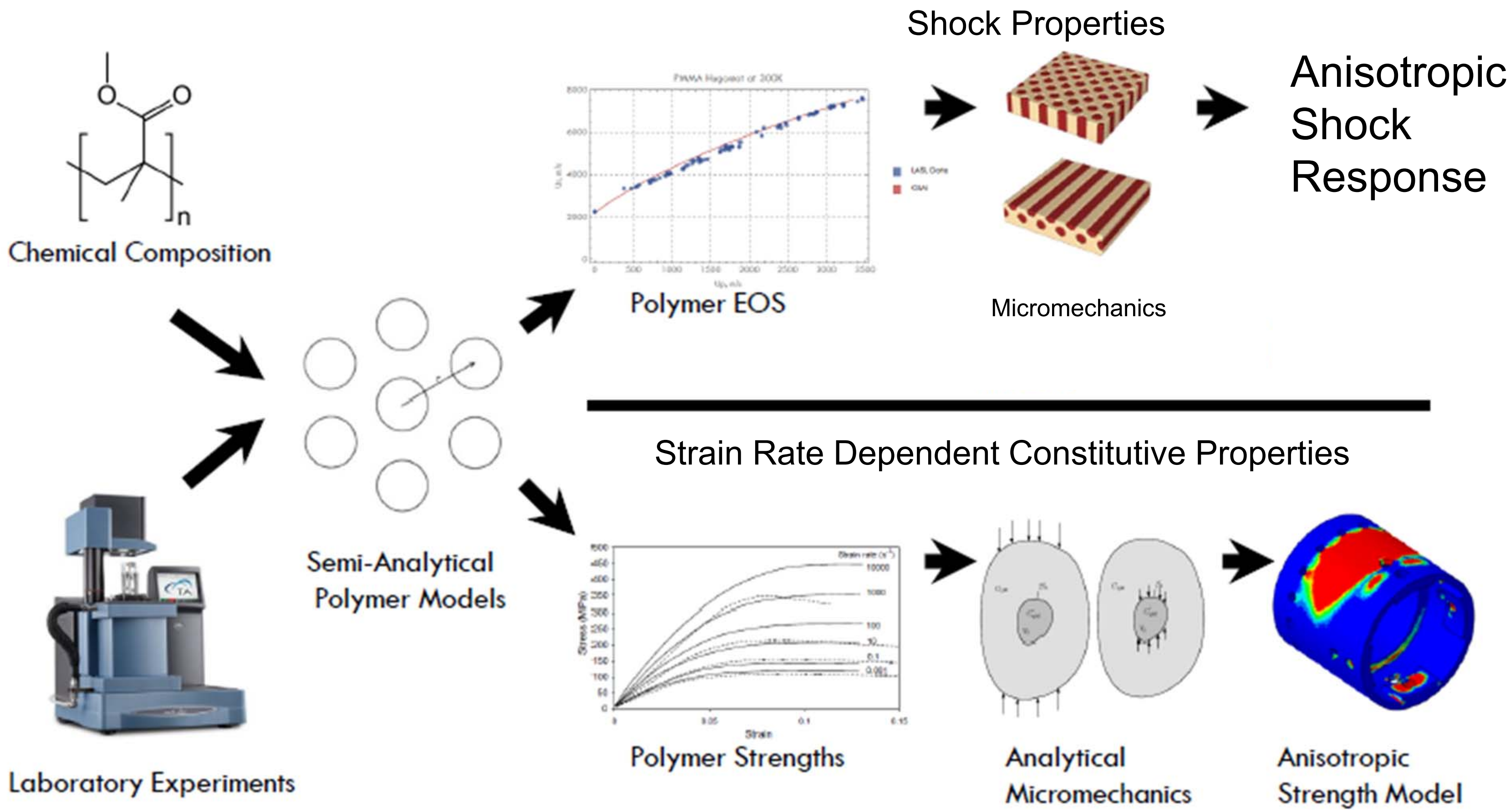
- **Hydrocode analysis of the motor case was performed using aluminum and composite with and without anisotropic shock**
- **The results show very little difference in the total energy deposited**
- **Very early in the impact event the energy in the propellant is lower for the composite with anisotropic shock**
- **The currently implemented anisotropic shock model corrects the hydrostatic pressure based on the elastic stiffness constants and couples it with the strength model, but still requires the isotropic EOS to be representative of the effective shock response of the composite in the direction of loading**
  - Investigating model inputs, e.g., EOS parameters, strengths, etc. , to determine if they should be adjusted to provided a better representation of the composite material for the current regime of shock loading

Hydrocode Analysis



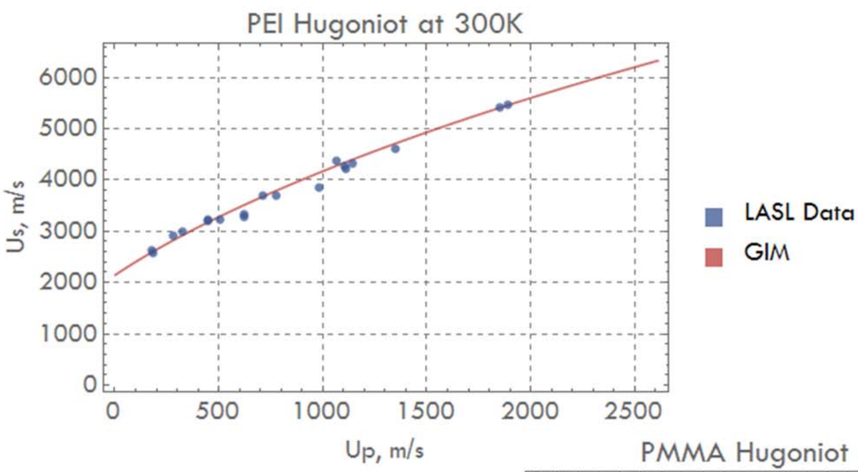
Polymer Modeling

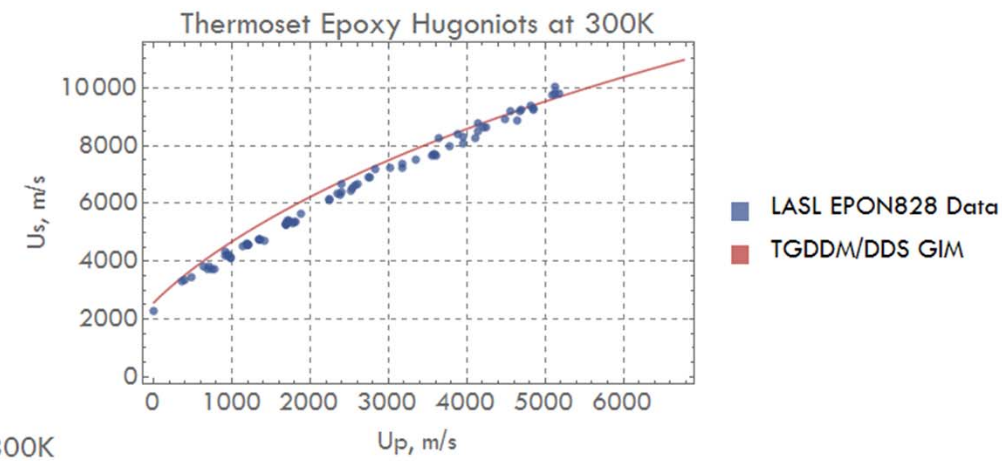
- ***Semi-analytical modeling of polymers to obtain strain rate dependent properties and EOS for polymers***

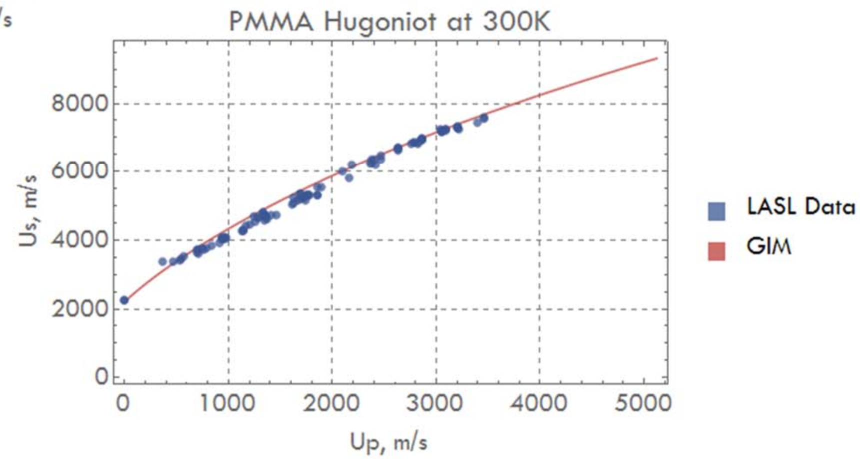


Polymer Modeling

- ***DMA (Dynamic Mechanical Analysis) on polymer samples to obtain parameters for PEI, toughened epoxy, un-toughened epoxy, simple epoxy***
- ***Model versus existing EOS data for PEI, simple epoxy, PMMA***







Polymer Modeling

- Parameters that can be obtained by standard laboratory testing (DMA, etc.)
  - Molecular Mass, van der Waals Volume, Cohesive Energy, Mer Unit Length in the Chain Axis, and Stiffness Along the Chain Axis
- Parameters that require non-standard 50 Kelvin specific heat testing
  - Thermal Degrees of Freedom and Reference Temperature
- For polymers with a known chemical composition, the model parameters can be estimated using existing data for functional groups commonly found in polymers

Conclusions

- ***Hydrocode Modeling***
  - ***Composite anisotropic shock modeling does show a discernable difference in propagation in a warhead PIMS***
  - ***Composite anisotropic shock modeling shows a reduction of energy deposited to the energetic for a warhead but only a reduction very early in the impact event for a rocket motor***
  - ***While these results by themselves do not explain the improved response for the warhead and rocket motor applications described it does provide a baseline for further studies to mature and validated composite shock modeling methods***
- ***Polymer Modeling***
  - ***DMA and specific heat testing provides parameters to calculate EOS***
  - ***Combined with micro-mechanics this approach could be used to obtain parameters for the composite anisotropic model***