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Title: Material and Stack Up Models

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Material and Stack Up Models

Pending LA-UR review. These charts were determined unclassified by Erik F. Shores, XTD-SS GL.

Foundational Science

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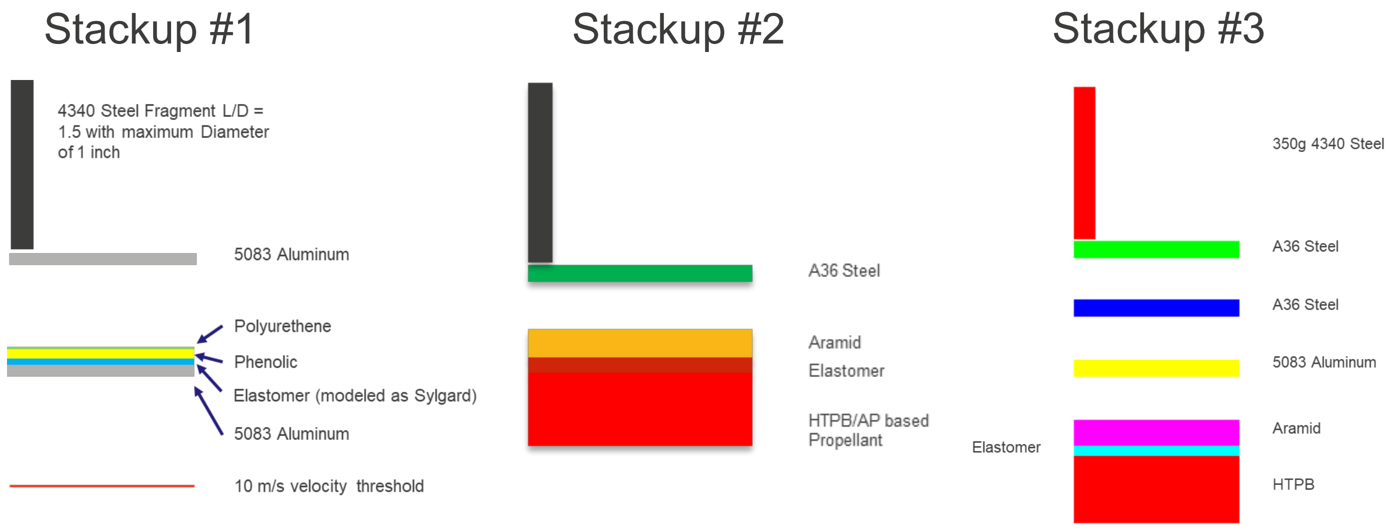
BLUF Three stackups were calculated (drawings not to scale)



Fragments
<u>4340 Steel</u>
L/D=1.5 cm
with max
D=2.54 cm

Materials Modeled and Key Notes:

Aluminum 5083 - New Modified Johnson Cook Model experimentally validated (documented)

Aramid - EOS: Epoxy SESAME, Strength: EP, Fixed yield strength, Varied shear modulus to match experimental data (documented)

A36 Steel - EOS: Us/Up model, Strength: Johnson-Cook, Fracture: Johnson-Cook

Polyurethane - EOS: SESAME 7561, Strength: Elastic-Plastic, Fracture: P_{min}

Phenolic - EOS: SESAME 7542, Strength: Elastic-Plastic ,Fracture: P_{min}

Elastomer - Modeled as Sylgard, EOS: SESAME 7931, No strength or fracture model

HTPB – New Material Properties (documented), Mie-Gruneisen EOS, EP strength, No burn

Fragments – Stackup #1 has residual velocity of 10 m/s following last Al layer, Stackup #2, #3, had fragments reach HTPB

Detailed Outline

- Modified Johnson Cook
- Aluminum 5083
- Aramid
- HTPB
- Other material models
- Stack ups
- Results
- Concluding remarks

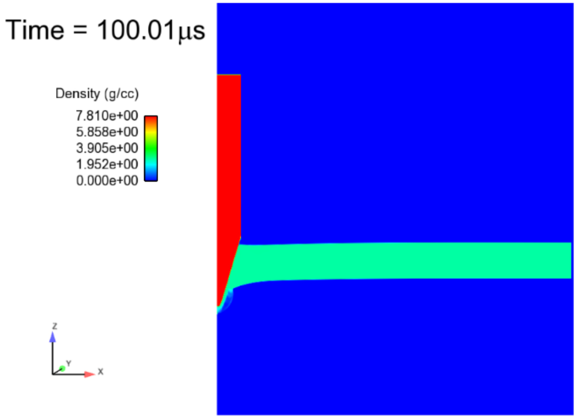
Modified Johnson Cook (MJC)

- MJC Strength model added to PAGOSA
- MJC Damage model added to PAGOSA
- MJC Strength removes natural log
  - $Y = [A + B(\varepsilon^p)^n](1 + \dot{\varepsilon}^*)^C(1 - T^{*m})$
- MJC Damage remove natural log
  - $e^f = \left(D_1 + D_2 e^{D_3\sigma^*}\right)(1 + \dot{\varepsilon}^*)^{D_4}(1 + D_5 T^*)$

1. A. H. Clausen and et al., Flow and Fracture Characteristics of Aluminum Alloy AA5083-H116 as Function of Strain Rate, Temperature and Triaxiality, Mat. Sci. Eng A364 p 260-272, 2004.

Aluminum 5083 Model

- Model parameters were taken from [2]
  - rho=2.7 g/cc, A=167 MPa, B=596 MPa, n=0.551, C=0.001, m=0.859
  - D1=0.0261, D2=0.263, D3=-0.349, D4=0.147, D5=16.8
- New MJC model was compared to experimental data [2]



2. T. Borvik and et al., Perforation of AA5083-H116 Aluminum Plates with Conical-Nose Steel Projectiles– Experimental Study, Int. J. Imp. Eng. V 30 p 367-384, 2004.

Aramid Model

- Epoxy SESAME EOS
- EP Strength
- Fixed yield strength
- Varied shear modulus to match experimental data [3]
- Rho of 1.65 g/cc is higher than expected application

Given the lack of fiber orientation, layup, and density this is a conservative approach

3. C.Y. Tham and et al., Ballistic Impact of KEVLAR Helmet: Experiment and Simulations, Int. J. Imp. Eng. V 35 p 304-318, 2008.

HTPB Model

- Material properties from [4]
  - Mie-Gruneisen EOS
  - EP strength
- No burn

4. D. A. Crawford, A Model for the Energetic Response of 1.3 Propellants Under Shock Loading Conditions, SAND2009-6338, 2009.

A36 Steel Model

- EOS: Us/Up model
- Strength: Johnson-Cook
- Fracture: Johnson-Cook

Polyurethane Model

- EOS: SESAME 7561
- Strength: Elastic-Plastic
- Fracture: P_{min}

Phenolic Model

- EOS: SESAME 7542
- Strength: Elastic-Plastic
- Fracture: P_{min}

Elastomer Model (Modeled as Sylgard 184)

- EOS: SESAME 7931
- No strength or fracture model

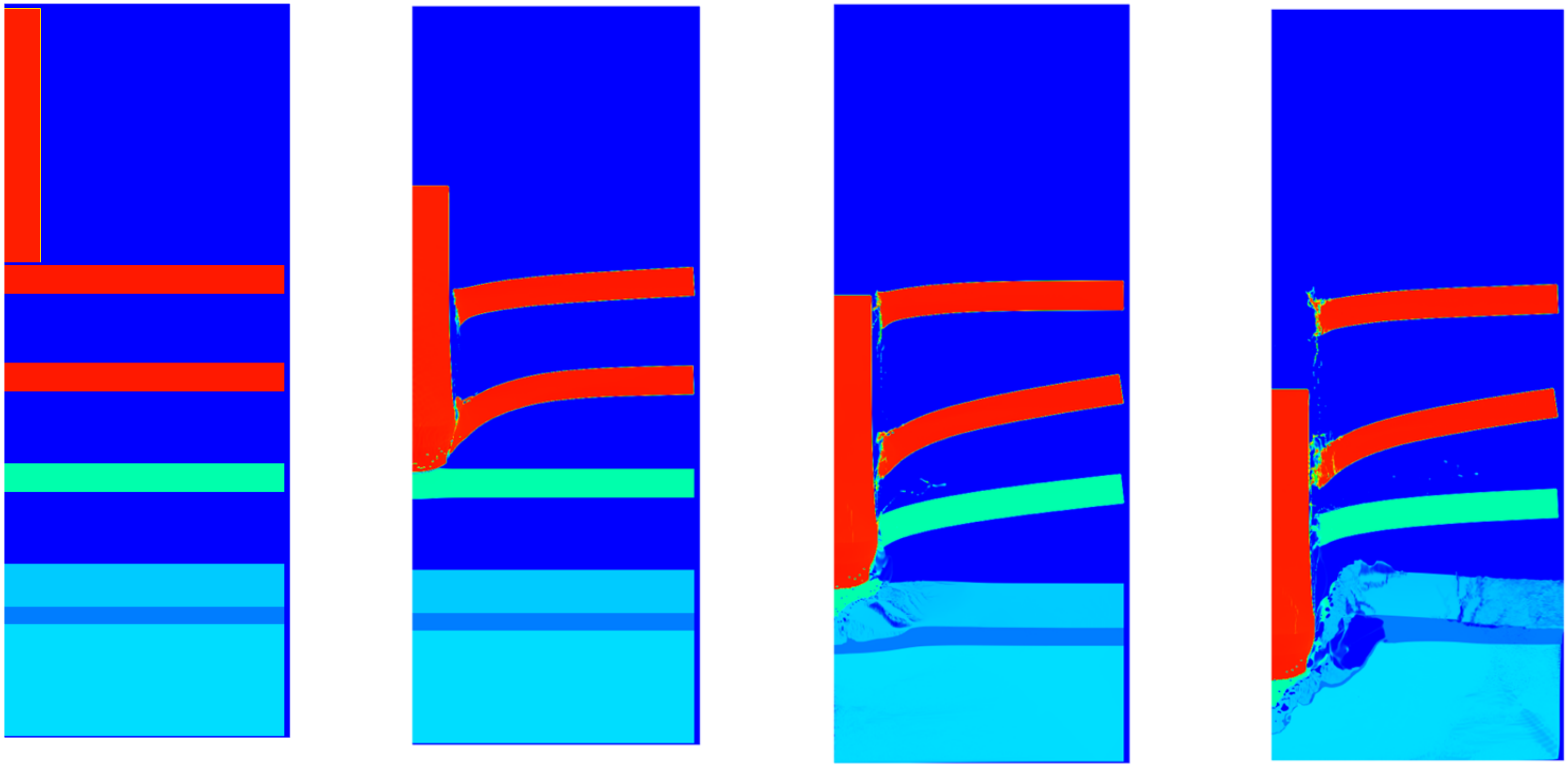
Stack Up #3 Result for 350g Fragment

Time = 0.0μs

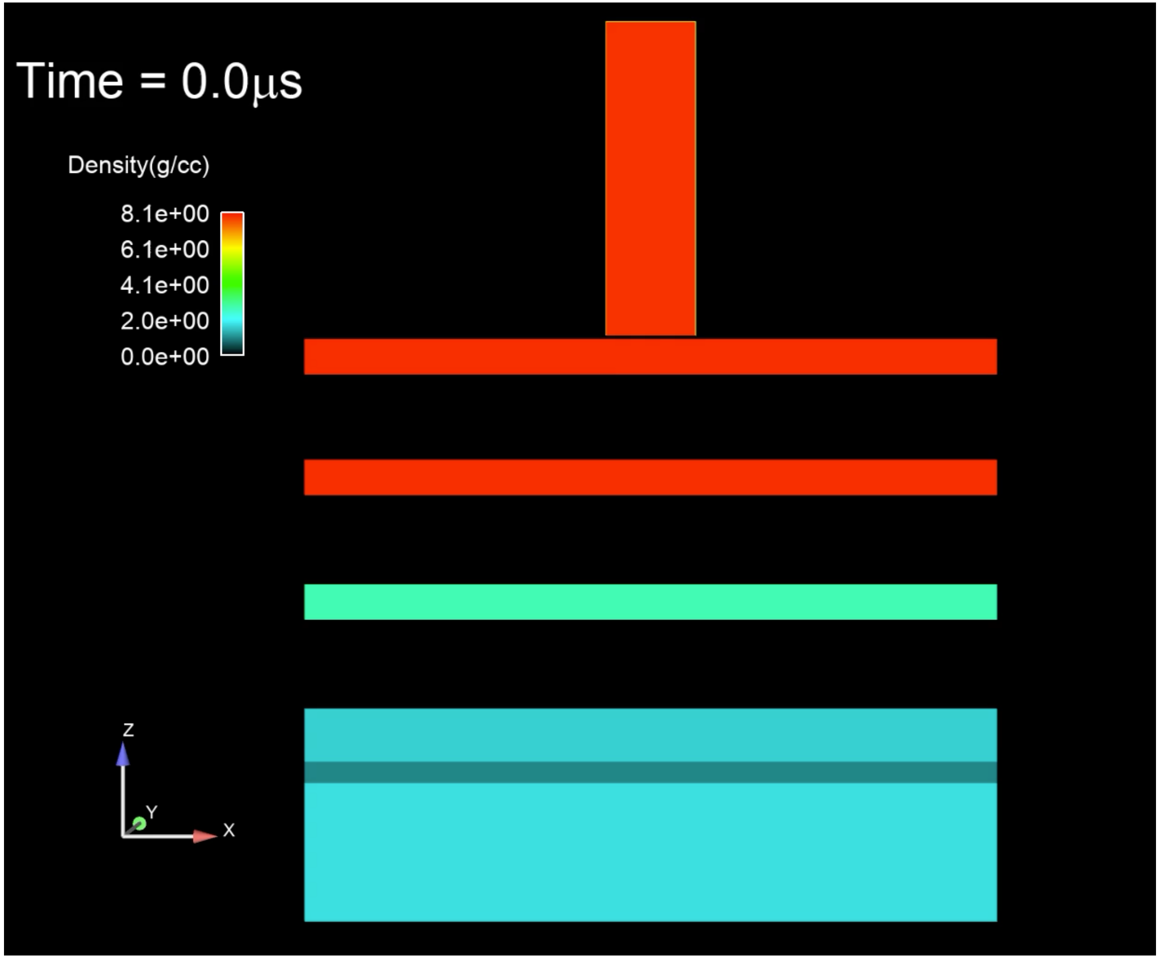
Time = 200.0μs

Time = 400.0μs

Time = 600.0μs



Stack Up Result for 350g Fragment Video



Concluding Remarks

- More details on Aramid will improve model
- Use MATCH or other burn model to predict HTPB response
- Experiments for model verification have been completed and we will work on validation efforts