MODELING BLAST DAMAGE OF COMPOSITE STRUCTURES

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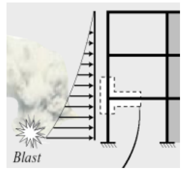
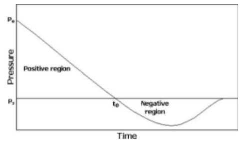
RESEARCH MOTIVATION

- Blast Affects a Multitude of People and Structures Causing Irreparable Loss to Life and Damage to Structures Worth Millions
- Blast is a Challenge Not Only to Structures, Both Civilian and Military, but Also to Scientists Who Are Trying To Model It and Come Up With a Viable Blast Resistant Solution
- In Order to Minimize the Effects of Blast Loading on Structures We Need to Understand the Way Structures Respond to Blast Loading
- Finite Element Analysis Can Provide Fundamental Understanding of the Interactions between the Structure and the Blast Loading

RESEARCH GOALS

- Understanding the response of structures under BLAST Loading
  - Idealize the “Blast Load” as a Pressure Load on Structures of Finite Duration
  - Study the Dynamics of Blast Damage
    - Energy Dissipation
    - Momentum Transfer
    - Blast Resistance Force
    - Dynamic Deflection
    - Acceleration
  - Study the Effect of Geometry and Architecture
    - Flat Plate and Cylinders
    - Plates and Sandwich



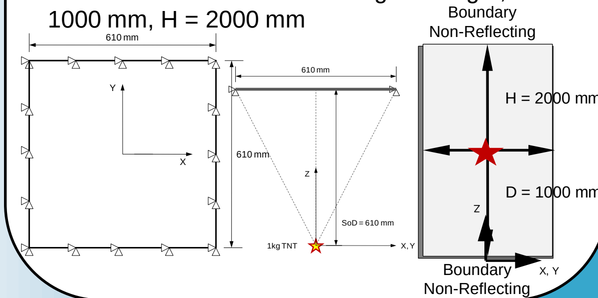


$$P(t) = P_o\left(1 - \frac{t}{t_o}\right)\exp\left(-\alpha\frac{t}{t_o}\right)$$

Blast impact response of aluminum foam sandwich composites, J MATER SCI 41 (2006) 4023–4039

LS-DYNA FINITE ELEMENT MODELING

- Plates with FIXED Boundary Conditions: Dimension = 610 mm x 610 mm, AD = 10 psf (48.8 kg/m²), 100 x 100 elements along the X and Y directions
- Cylinder with NON-Reflecting Boundary Conditions: 100 elements along the radial direction and 80 elements along the length, D = 1000 mm, H = 2000 mm



FINITE ELEMENT MODELING

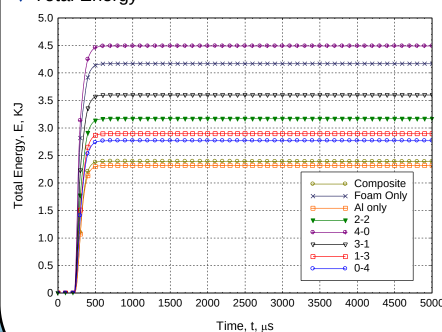
- BLAST Loading was Applied with the *LOAD_BLAST Option
- Blast on Plates: 1 KG TNT Equivalent, 610 mm

			Areal Density, AD = 48.8 kg/m²			
ID	Description	Architecture	Top Face Sheet	Core	Bottom Face Sheet	Thickness, mm
Al Only	Baseline Al		-	-	-	18.1
2-2	Al/Al-Foam/Al		12.2	24.4	12.2	43.4
1-3	Al/Al-Foam/Al		6.1	24.4	18.3	43.4
3-1	Al/Al-Foam/Al		18.3	24.4	6.1	43.4
0-4	Al/Al-Foam/Al		0	24.4	24.4	43.4
4-0	Al/Al-Foam/Al		24.4	24.4	-	43.4
Foam Only	Al-Foam		-	48.8	-	68.8
Composite	Composite		-	-	-	26.4

- **BLAST on Cylinders: 10-kg TNT Equivalent at the Center**
  - **Aluminum only**
  - **Composite**
  - **Sandwich**

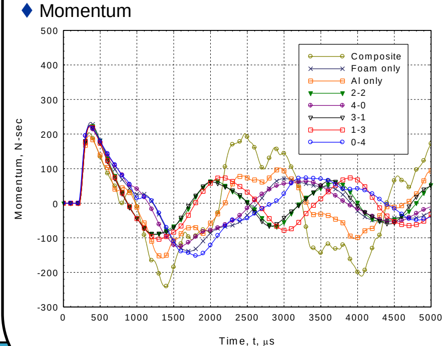
RESULTS - PLATES

- Total Energy



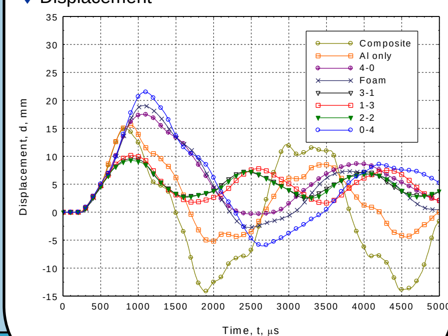
RESULTS - PLATES

- Momentum



RESULTS - PLATES

- Displacement



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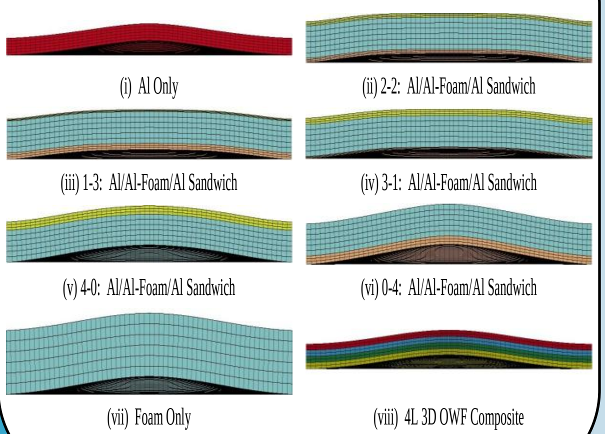
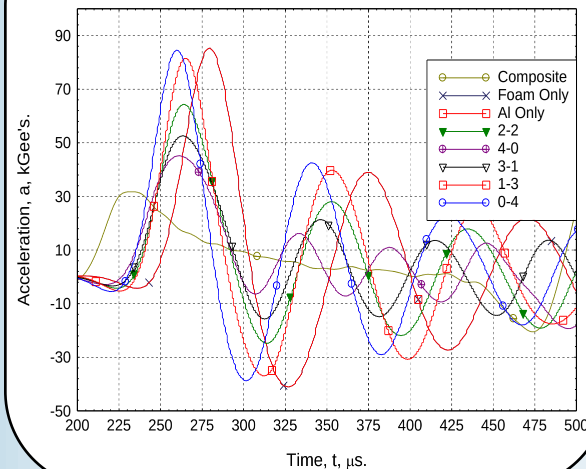
(Continued)

Results - Plates

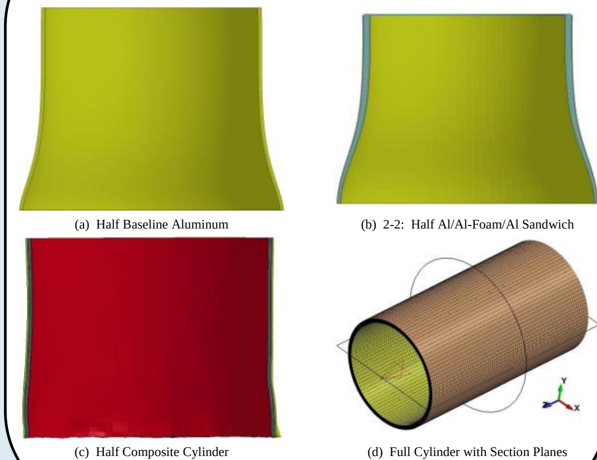

(i) Al Only
(ii) 2-2: Al/Al-Foam/Al Sandwich
(iii) 1-3: Al/Al-Foam/Al Sandwich
(iv) 3-1: Al/Al-Foam/Al Sandwich
(v) 4-0: Al/Al-Foam/Al Sandwich
(vi) 0-4: Al/Al-Foam/Al Sandwich
(vii) Foam Only
(viii) 4L 3D OWF Composite

Results - Plates

♦ Acceleration

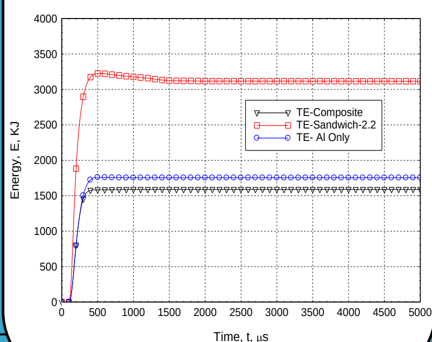


Results - Cylinders


(a) Half Baseline Aluminum
(b) 2-2: Half Al/Al-Foam/Al Sandwich
(c) Half Composite Cylinder
(d) Full Cylinder with Section Planes

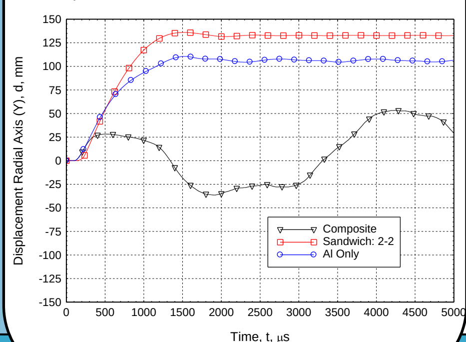
Results - Cylinders

♦ Total Energy



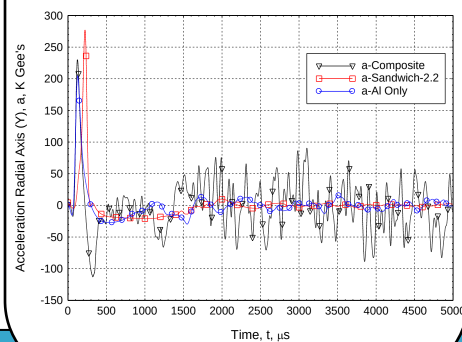
Results - Cylinders

♦ Displacement



Results - Cylinders

♦ Acceleration



Summary & Future Work

- Sandwich Structures showed Higher Energy Dissipation as Compared to Monolithic Aluminum and Composite Plates and Cylinders
- Plate and Cylinder Geometries showed similar BLAST Responses, Energy Dissipation of Sandwich and Monoliths were Different, the Momentum/Resistance Forces are Similar
- The Initial Accelerations were Found High, i.e., 30~50 kGee's for Plates (1 kg TNT) and 200+ kGee's for Cylinders (10 kg TNT)
- **What Do We Understand by BLAST Mitigation?**
  - **Reduce Acceleration and Dynamic Deflection?**
  - **Prevent Catastrophic Failure of the Structure?**
  - **What are the Competing Role of Energy Dissipation and Momentum Transfer?**

Acknowledgement

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