Blast Mitigation Effort

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Introduction

Blast Mitigation

Dampening of Blast Overpressure

Water-Mist
Designed Barriers
…

Absorption and Reflection of Energy

Soft Matter
Composite Materials
Sandwich Structures
Functional Graded Materials
Coated Materials
…

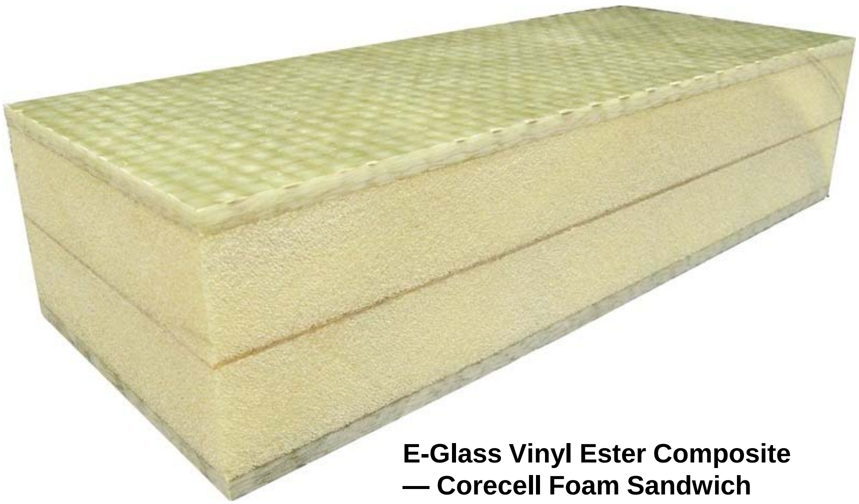
Post Blast Performance

Fire and Structural Collapse
Self Healing Materials
…

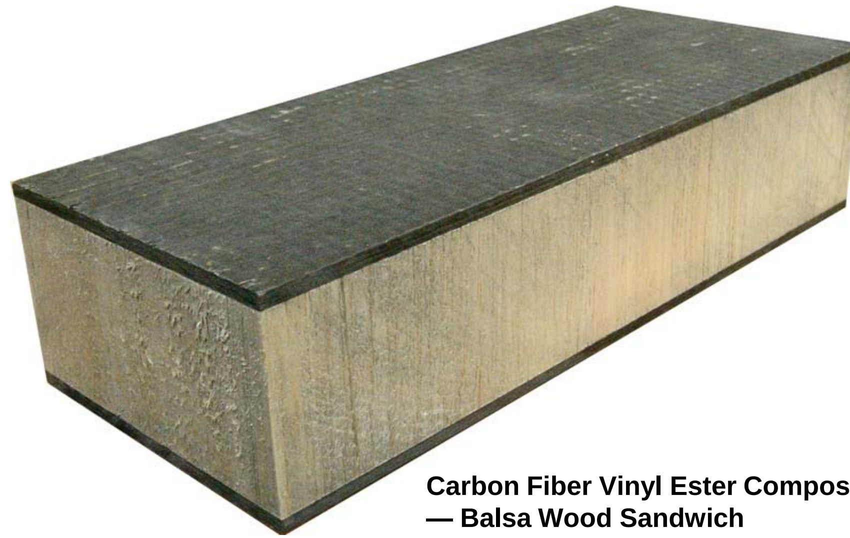
Response of Sandwich Composite Panels to Shock Loading

Sandwich Composites

These are materials consisting of two face sheets sandwiching a core material.



E-Glass Vinyl Ester Composite — Corecell Foam Sandwich



Carbon Fiber Vinyl Ester Composite — Balsa Wood Sandwich

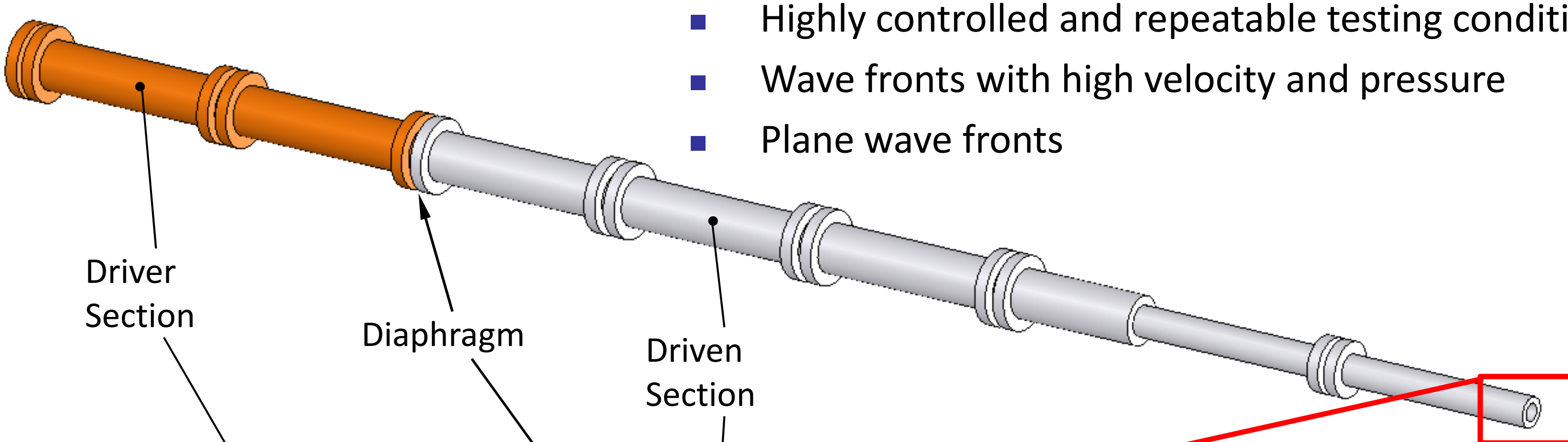
Advantages:

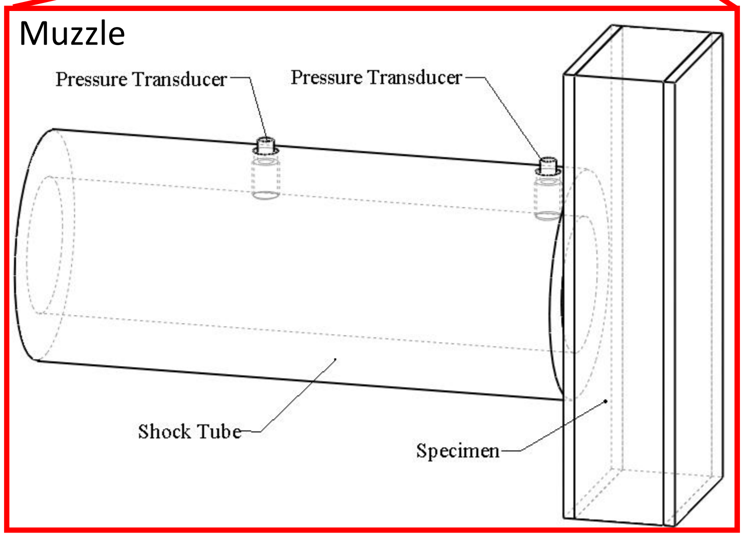
- *High strength and stiffness per unit weight*
- *Good thermal insulation*
- *High energy absorption*

Shock Tube

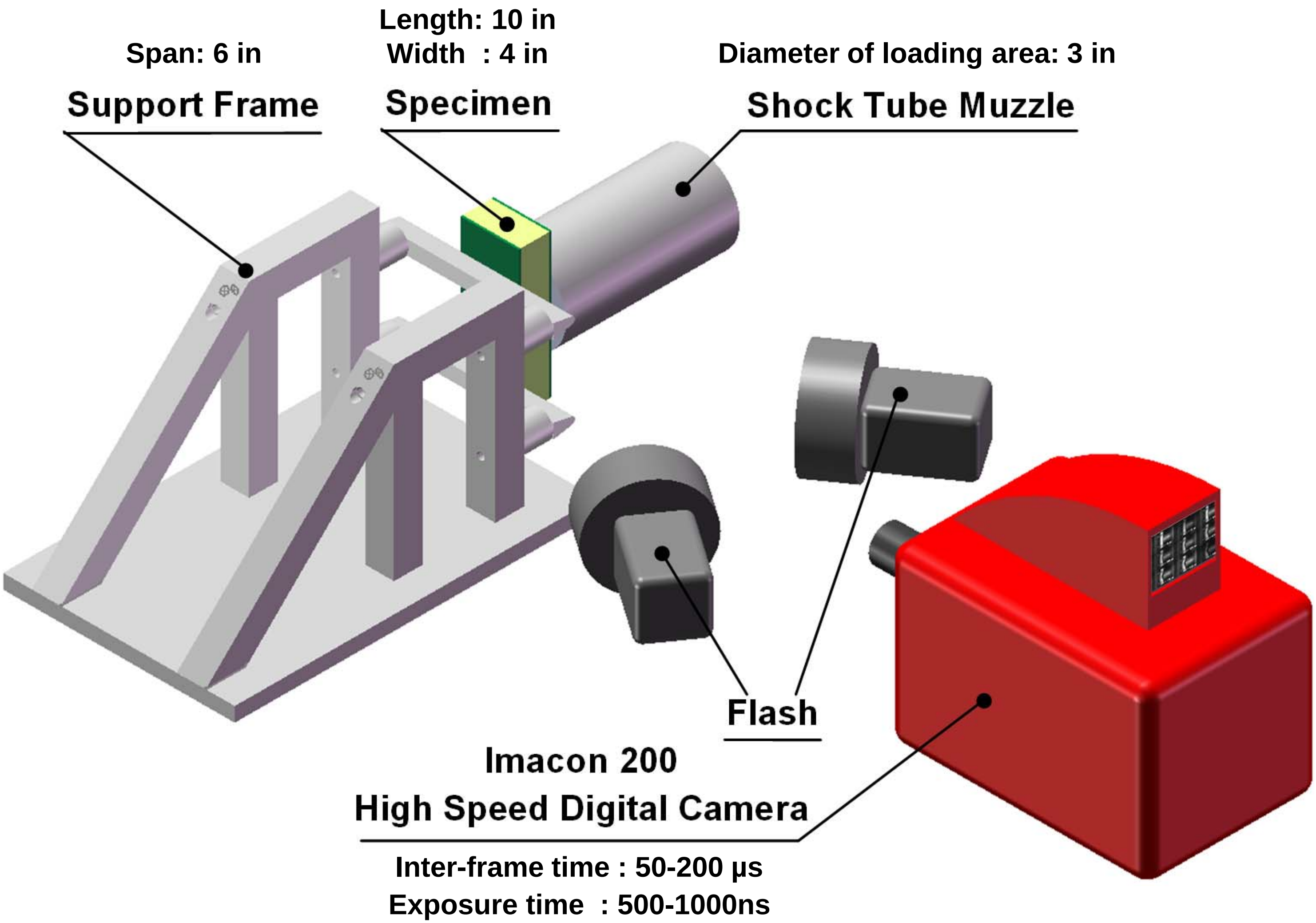
Advantages

- Highly controlled and repeatable testing conditions
- Wave fronts with high velocity and pressure
- Plane wave fronts

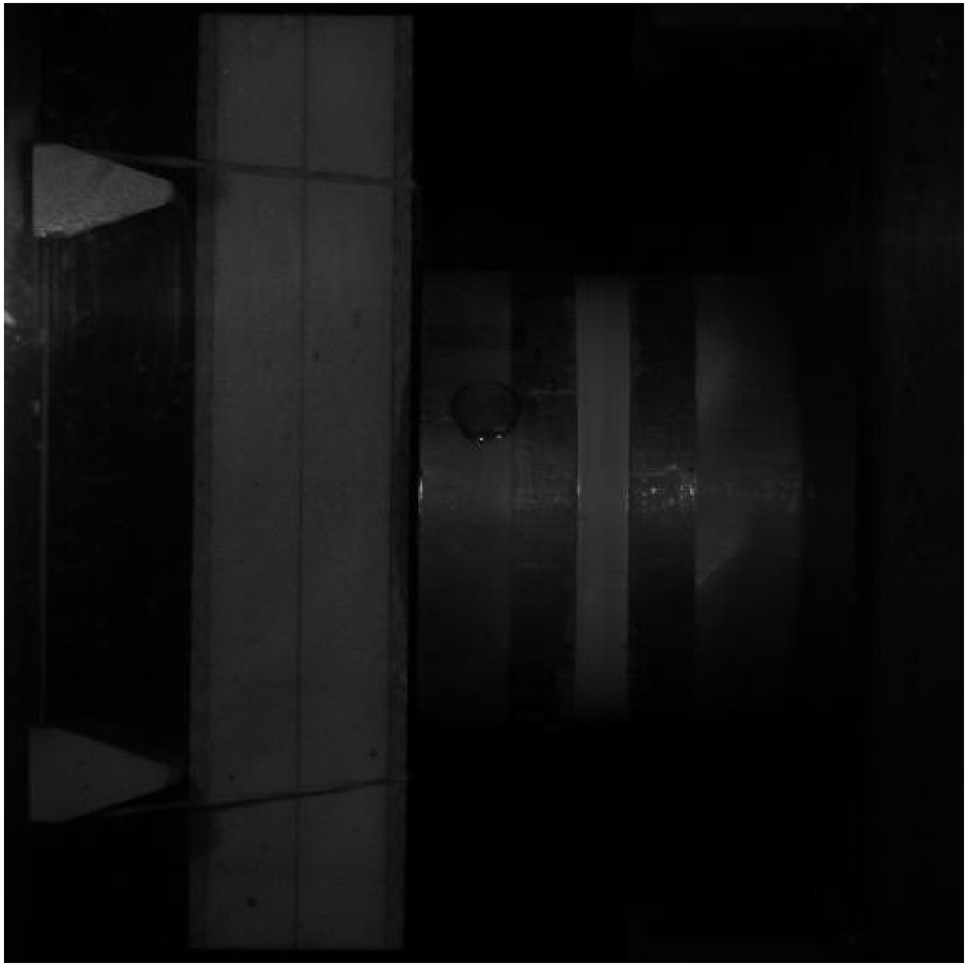




Experimental Setup

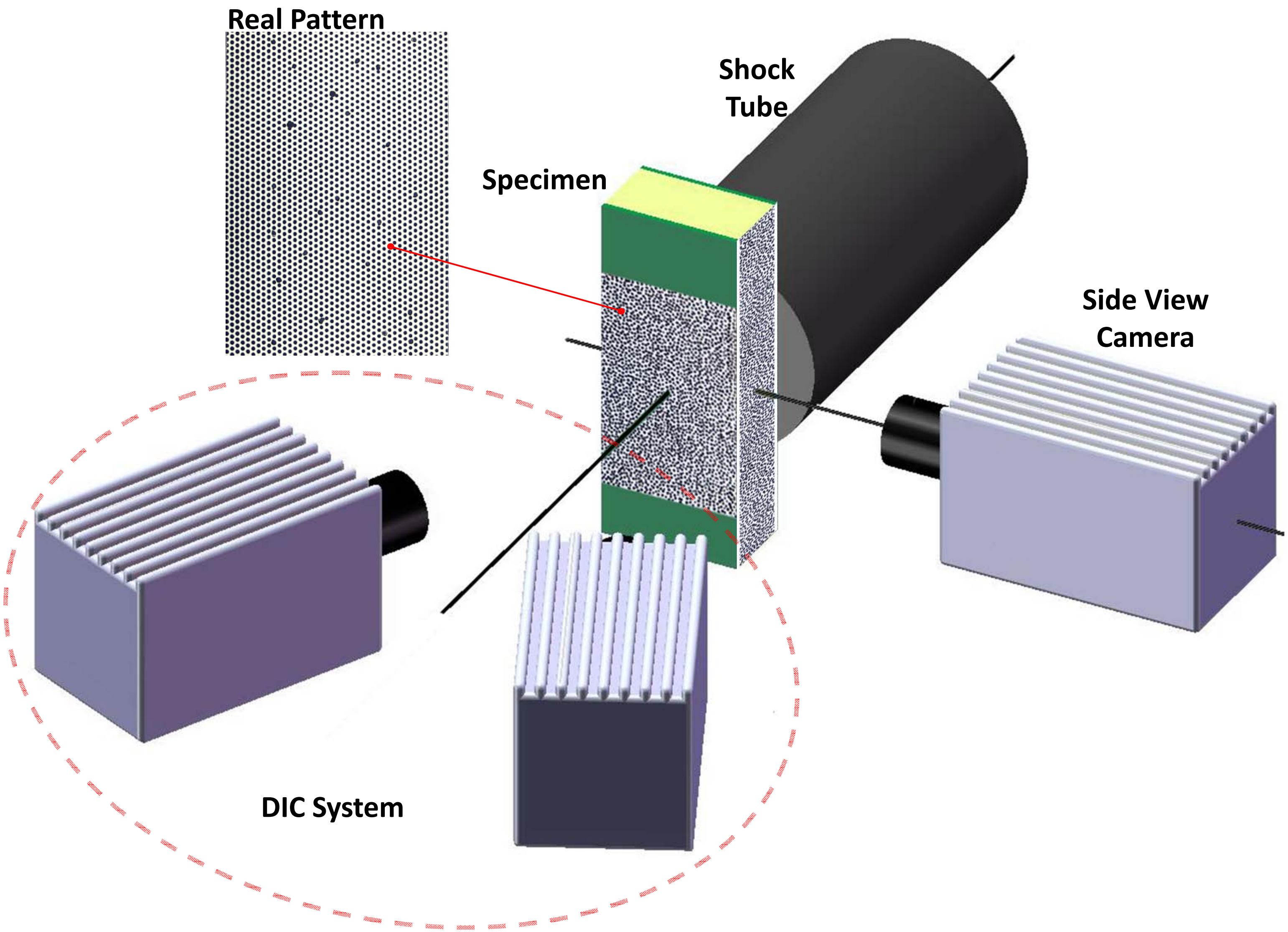


Real Time Observation

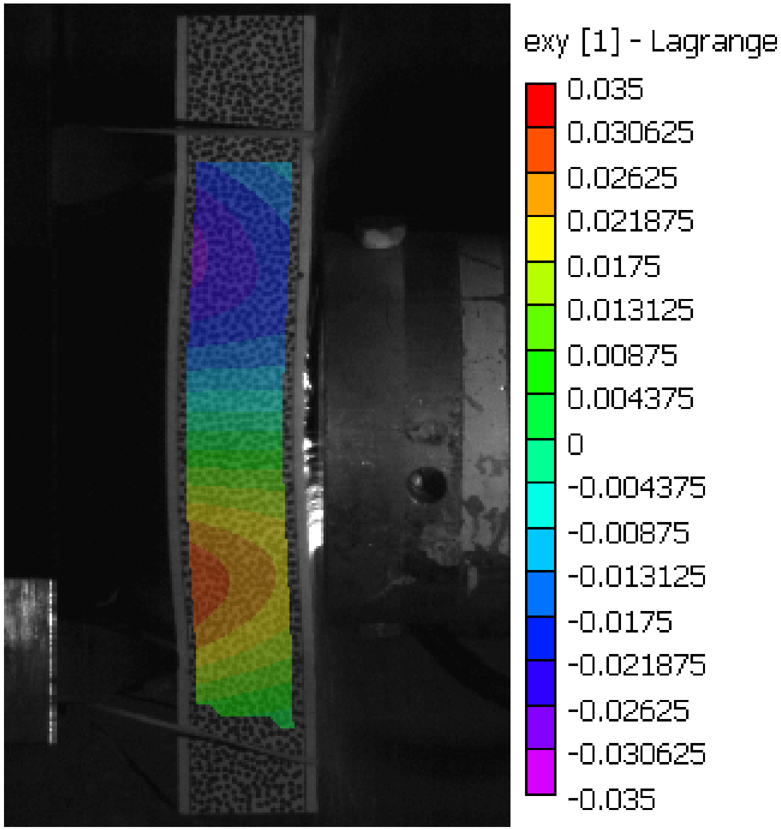


E-Glass Vinyl Ester Composite — Corecell Foam Sandwich under blast load

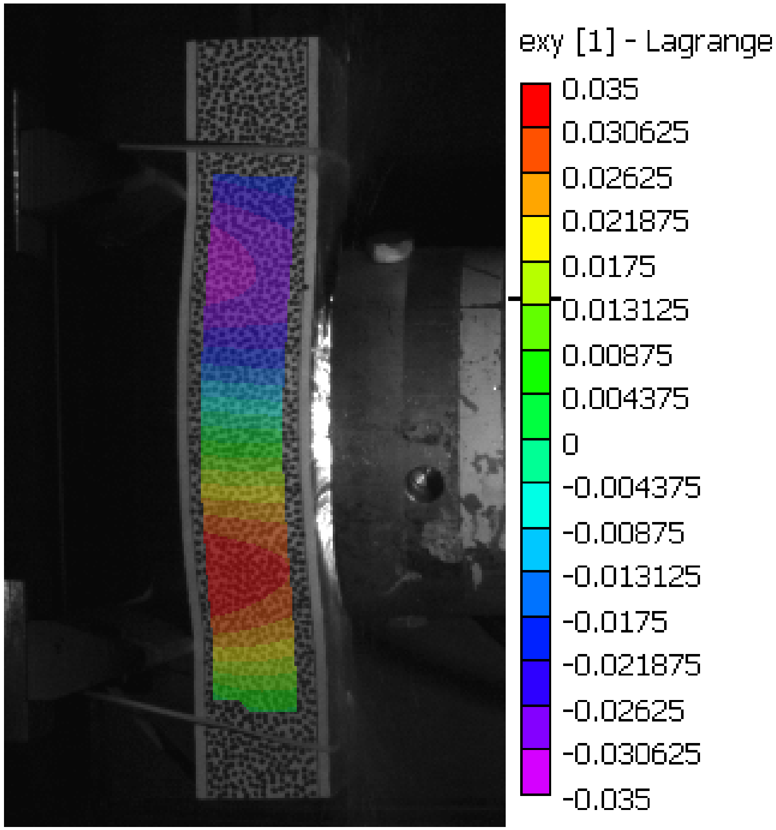
DIC Experimental Setup



Shear Strains in the Core 2-D and 3-D DIC System



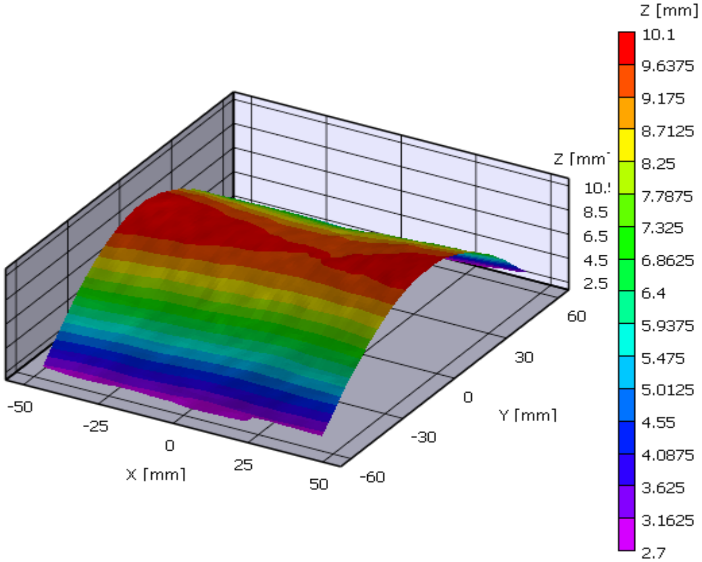
2-D DIC

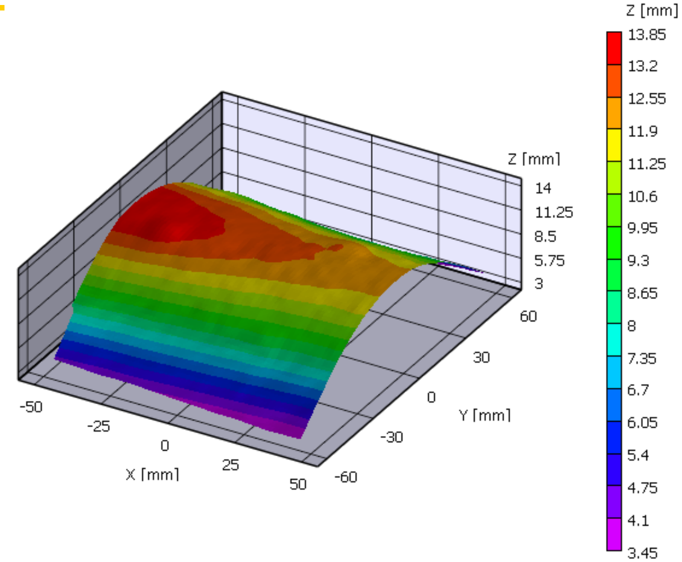


3-D DIC

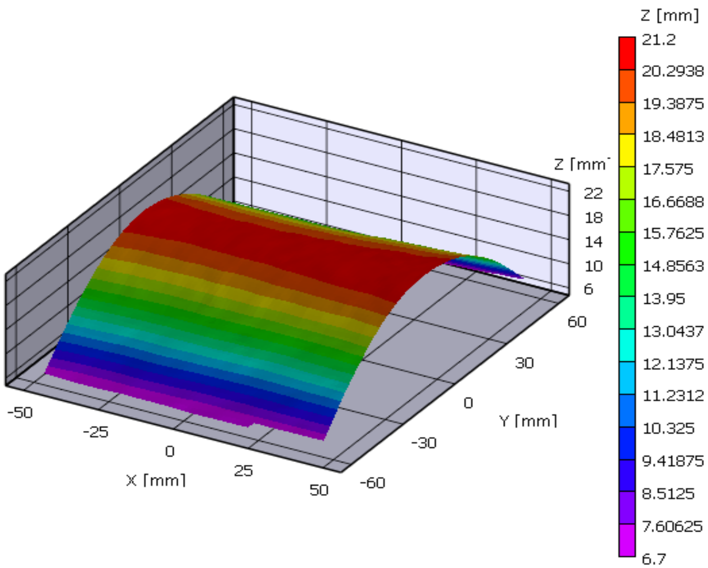
3D-Deflections

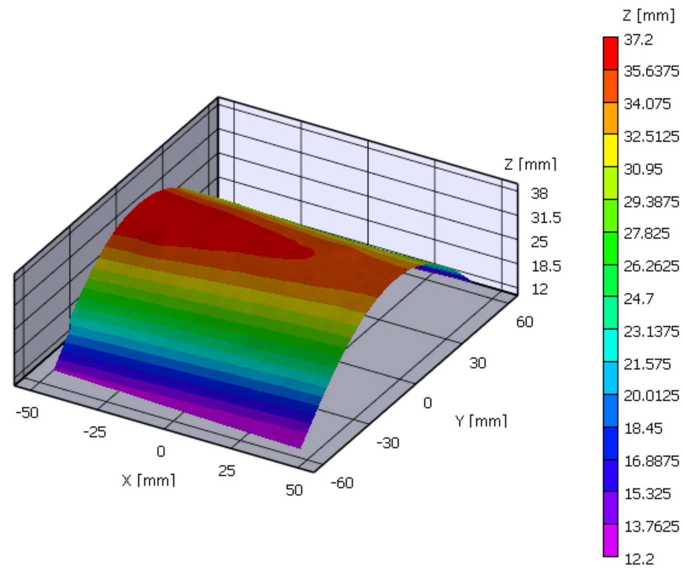
600 microseconds





1800 microseconds



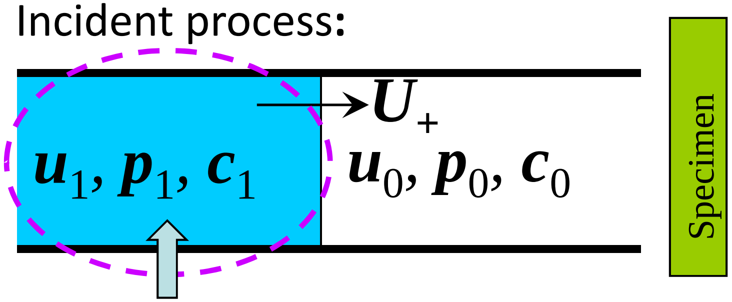


PU Back | **PU Front**

Energy Calculation

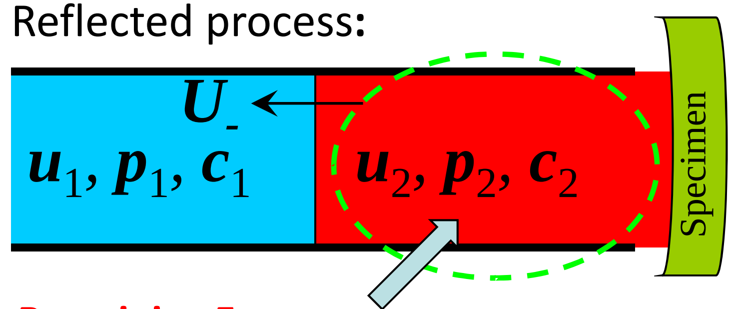
Incident and Remaining Energy Calculations:

Incident process:



Incident Energy:
energy stored in the impinging gas

Reflected process:



Remaining Energy:
energy stored in the gas located behind the reflected shock front

$$\frac{p_2}{p_1} = \left(1+\mu^2\right)\left(\frac{u_1+U_+}{c_1}\right)^2 - \mu^2$$

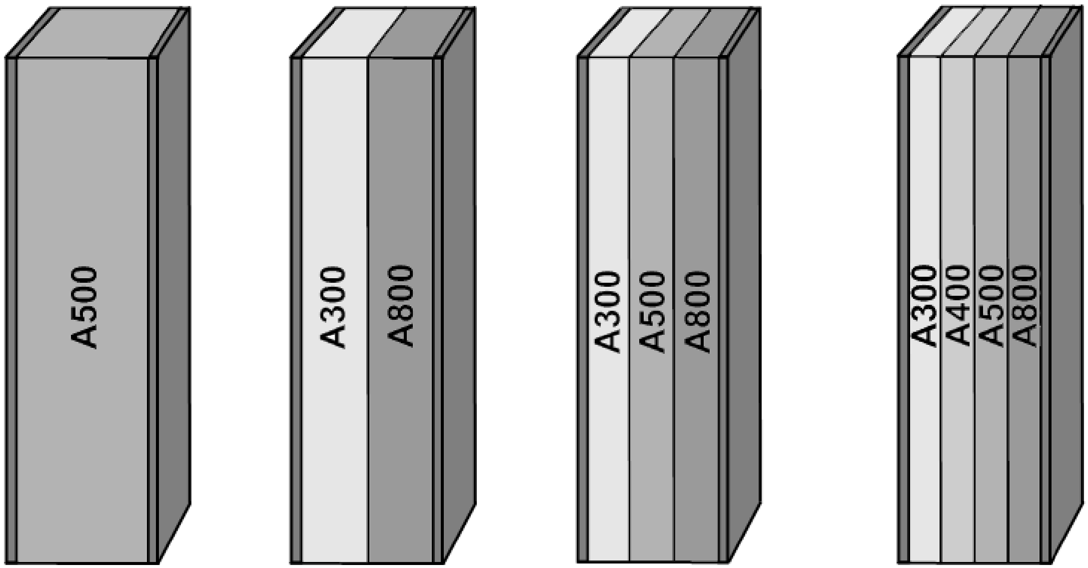
$$\left(1-\mu^2\right)\left(U_+-u_0\right)^2 - \left(u_1-u_0\right)\left(U_+-u_0\right) = \left(1-\mu^2\right)c_0^2$$

$$\left(1-\mu^2\right)\left(U_-+u_1\right)^2 - \left(u_1-u_2\right)\left(U_-+u_1\right) = \left(1-\mu^2\right)c_1^2$$

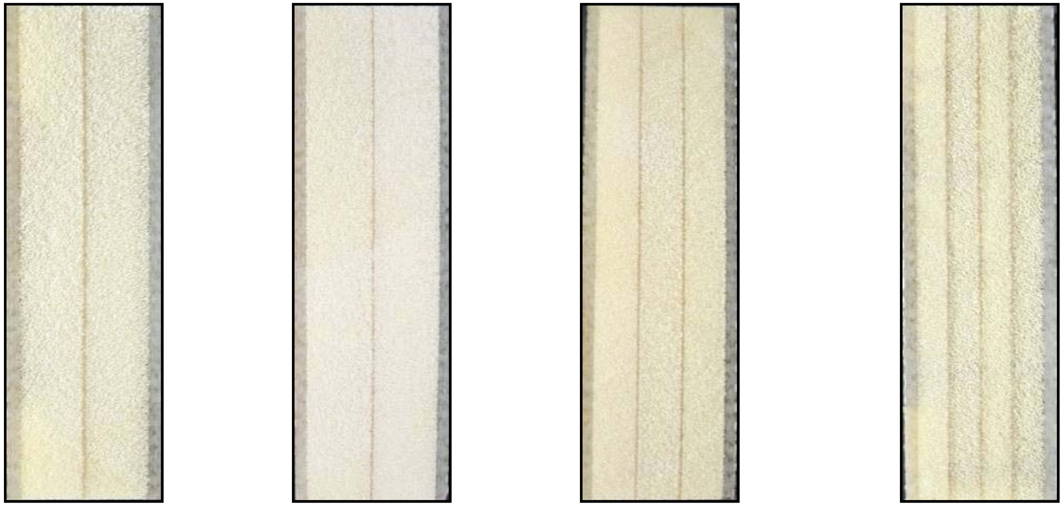
$$E = \int\left[\left(\text{pressure}\right)\times\left(\begin{array}{c}\text{cross-section}\\ \text{area}\end{array}\right)\times\left(\begin{array}{c}\text{gas particle}\\ \text{speed}\end{array}\right)\right]dt$$

Specimen Configurations (Monotonically Increasing Wave Impedance)

Configurations



Specimens



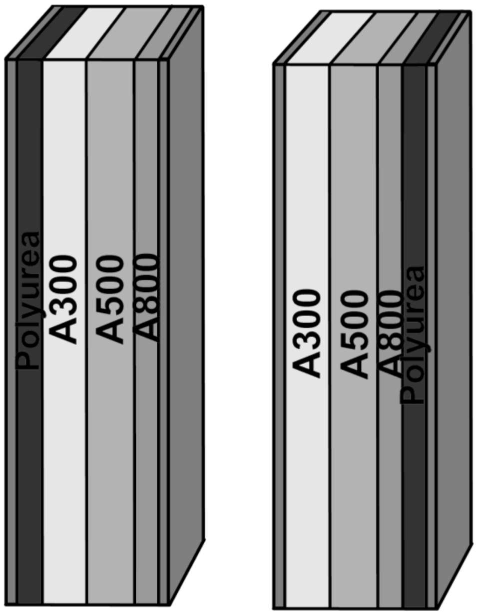
Specimen Dimensions:

- **Total length:**
  254 mm (10 in)
- **Total width:**
  101.6 mm (4 in)
- **Total thickness:**
  48 mm (1.9 in)
- **Face sheet thickness:**
  5 mm (0.2 in)

Gradation	Average Areal Density (kg/m^2)
1 Layer	19.12
2 Layer	18.43
3 Layer	19.02
4 Layer	20.07

Specimens and Configurations

Configurations



Specimens

PU Front PU Back

Average Areal Density: 26 kg/m^2

Dragonshield HT Properties

DRY PROPERTIES @ 34 MILS (0.8 mm)		
Tensile Strength	ASTM D-638	4219 psi (29.3 mpa)
Elongation @ 77ºF (25ºC)	—	619%
Hardness (Shore D)	ASTM D-2240	52-44
100% Modulus	ASTM D-412	1280 psi (8.9 mps) $\pm$ 100
300% Modulus	ASTM D-412	2137 psi (14.9 mpa) $\pm$ 100

High Speed Video

PU Front (Sample 3)

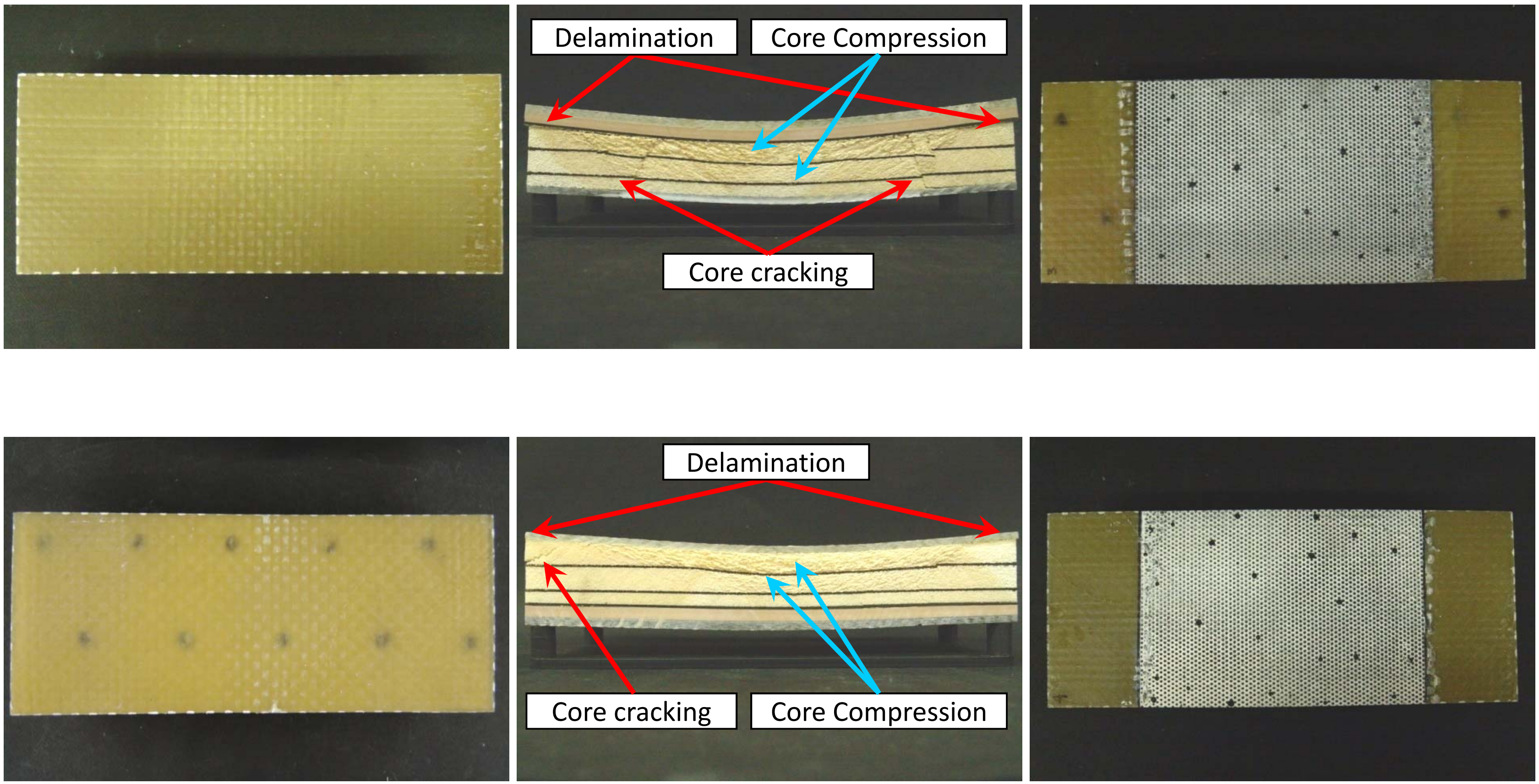
PU Back (Sample 4)

Post-Mortem Images

Front face sheet (blast side) | **Foam core** | **Back face sheet**

PU Front

PU Back



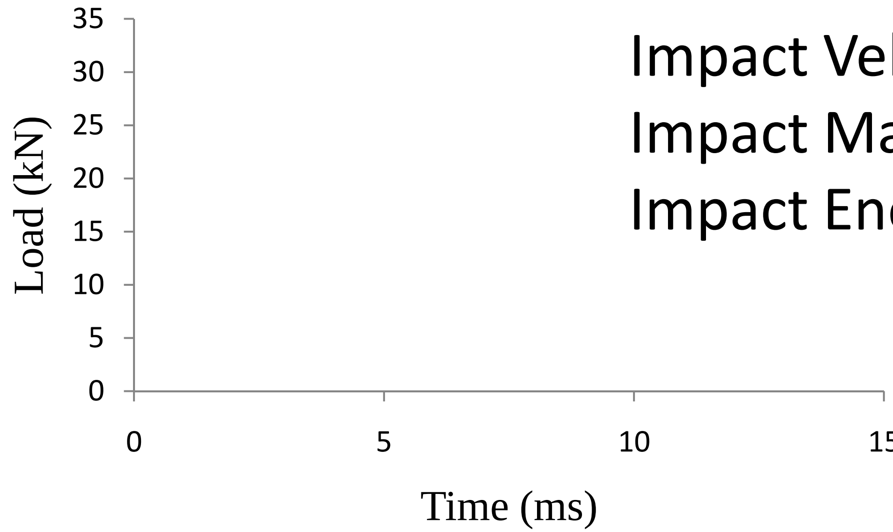
High Speed Video (10 plys)

PU Back(Sample 1)

PU Front (Sample 3)

The Effect of Low and High Velocity Impact Damage on Blast Performance

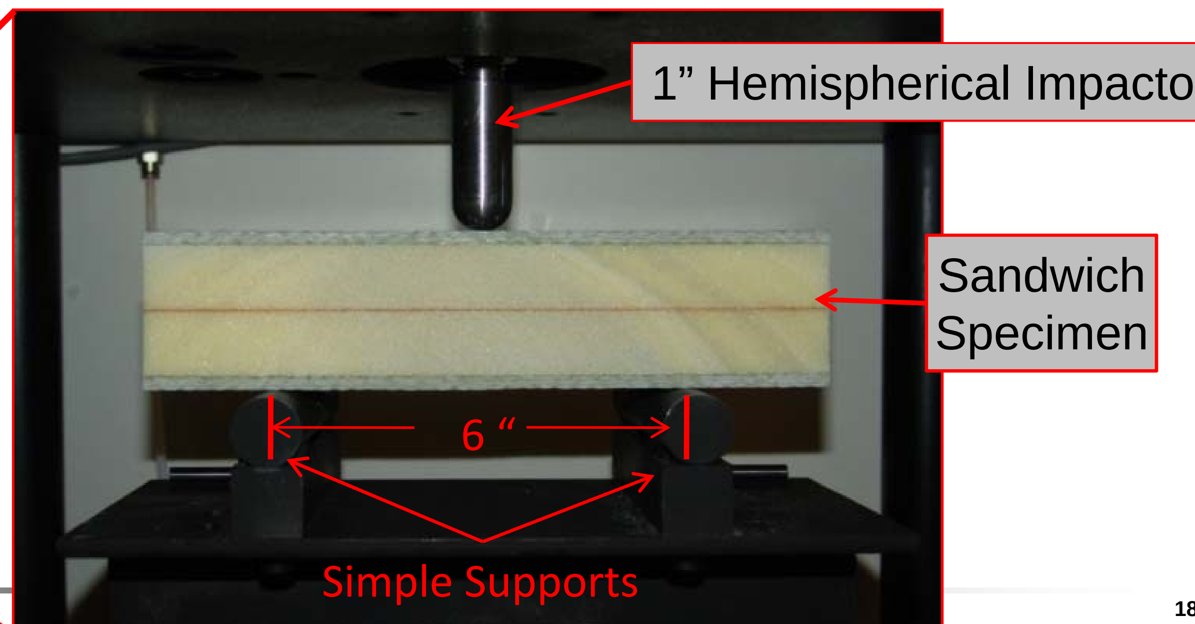
Low Velocity Impact Experiment



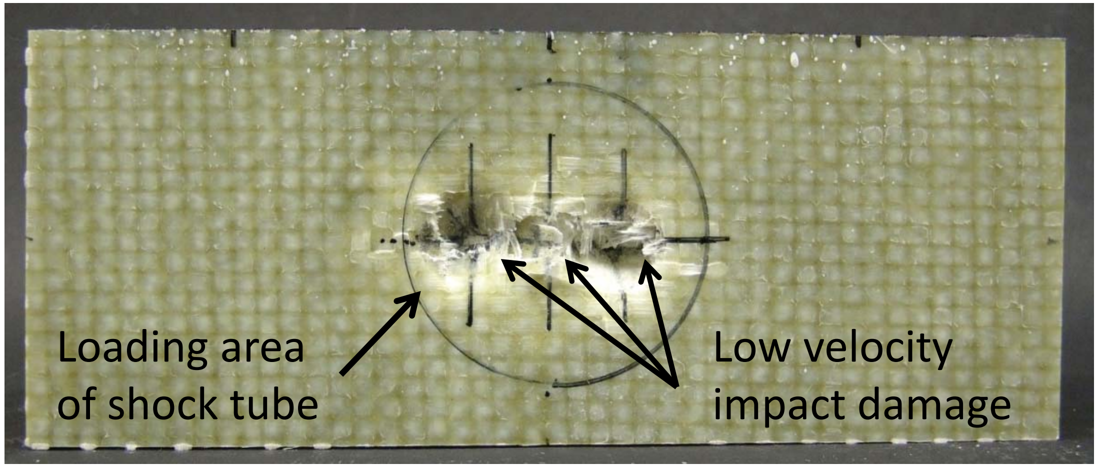
Impact Velocity ≈ 4.7 m/s

Impact Mass ≈ 26.1 kg

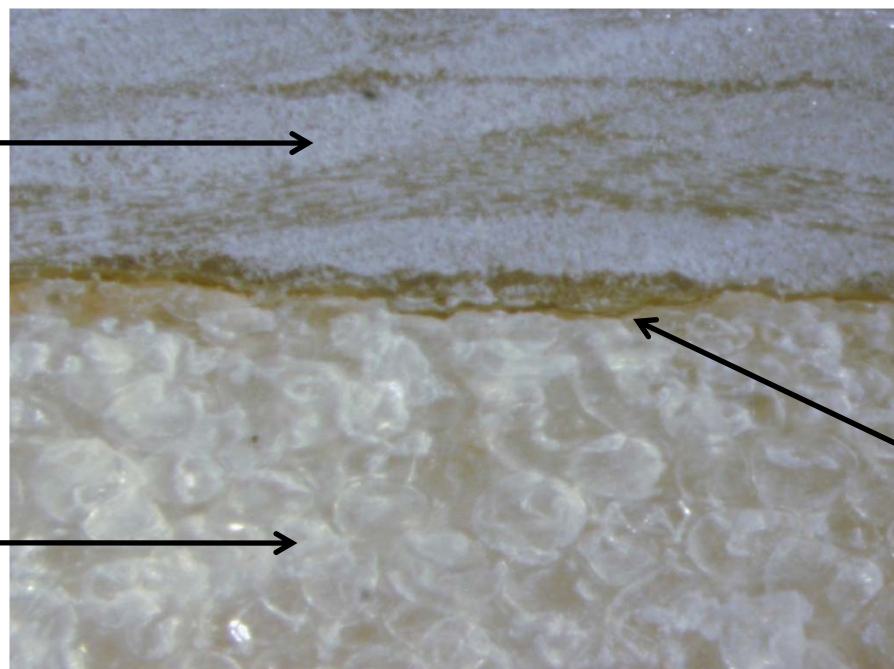
Impact Energy ≈ 300 J



Typical Low Velocity Impact Damage



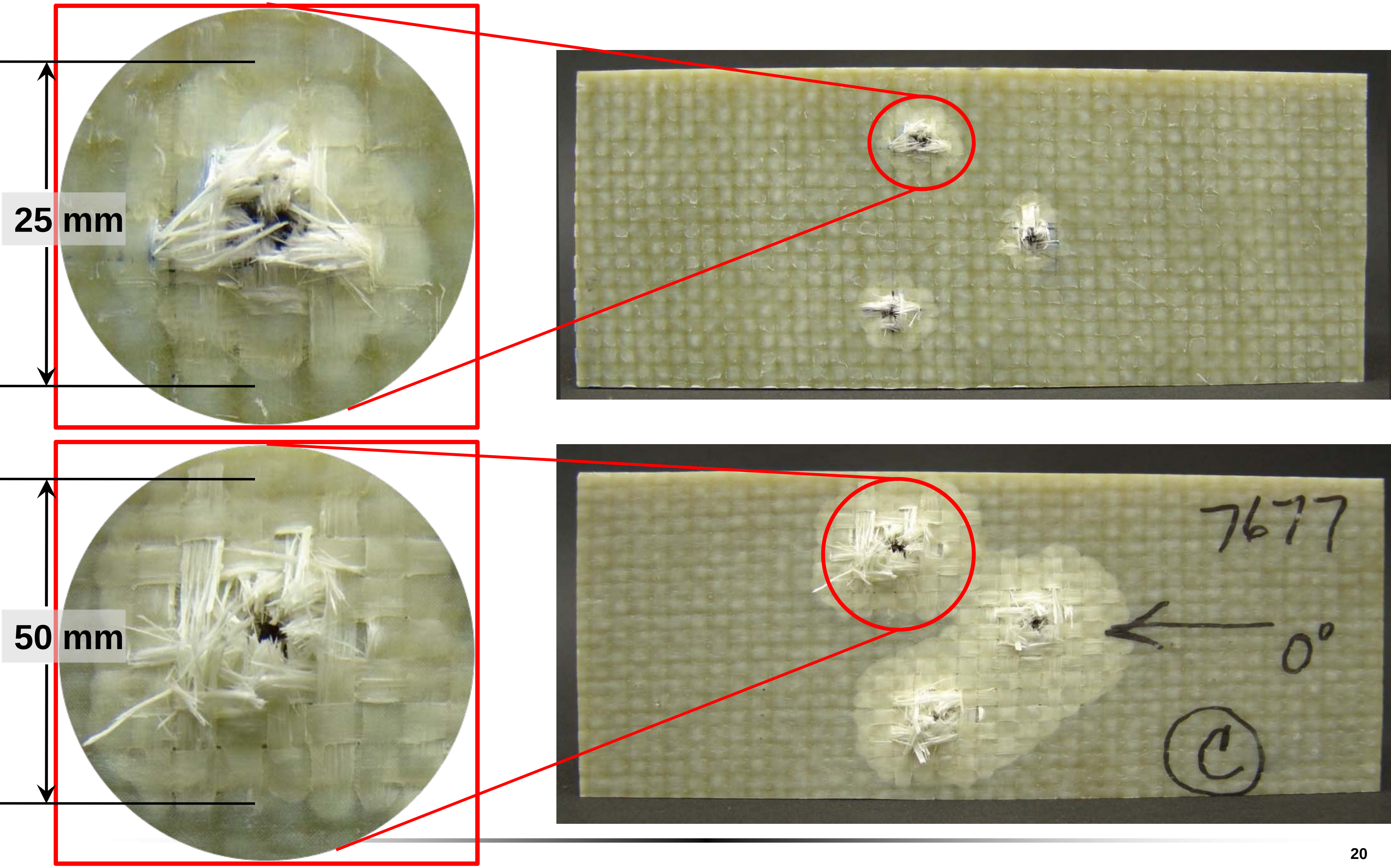
Face sheet



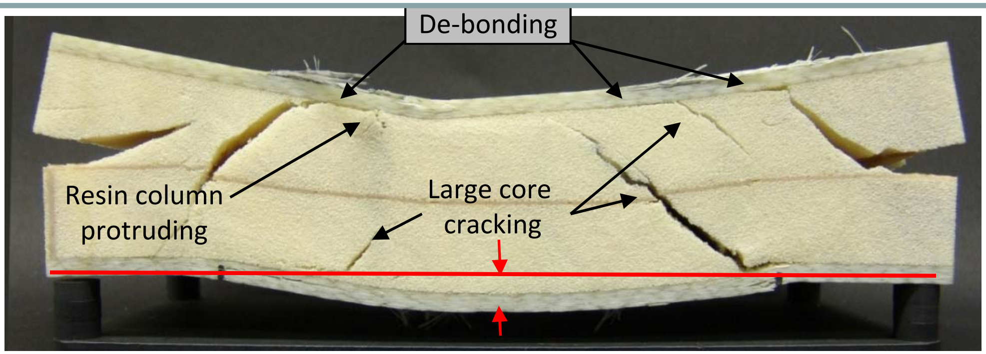
Face sheet/Core De-bonding

Core

Typical High Velocity Impact Damage



Post Blast Images of Pre Damaged Sandwich Composites

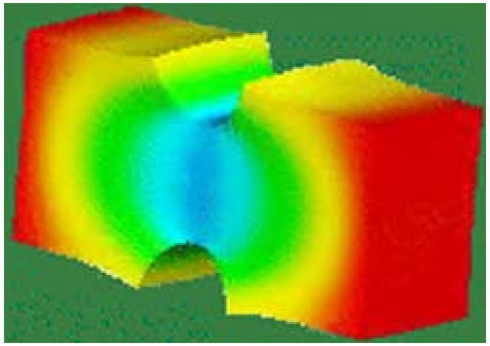


Specimen with High Velocity Impact Damage

Impact Type: High Velocity (920 m/s)
Number of Impacts: 5
Impact Mass : 0.01Kg
Total impact Energy Absorbed: ≈ 2108J

Specimen with Low Velocity Impact Damage

Impact Type: Low Velocity (4.7 m/s)
Number of Impacts: 3
Impact Mass : 26.21 kg
Total impact Energy Absorbed: ≈ 760J



IMPLAST 2010

Renaissance Providence Hotel

12-14 October 2010

Workshop on Blast Mitigation

Keynote Speakers

Dr. Gerald Nurick, University of Capetown, South Africa

Dr. Mary Ellen Hynes, Department of Homeland Security, USA

Dr. Ravinder Chona, Air Force Research Laboratories, USA

Dr. William G. Proud, Cavendish Laboratories, Cambridge, UK

Dr. Yapa D.S. Rajapakse, Office of Naval Research, USA