OPTIMUM MATERIAL PROPERTIES OF COMPOSITES SANDWICH STRUCTRES FOR ENERGY ABSORPTION

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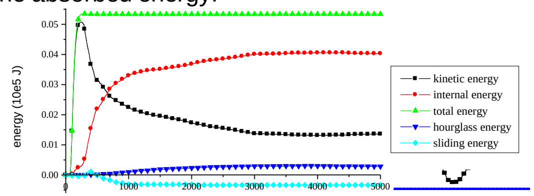
INTRODUCTION

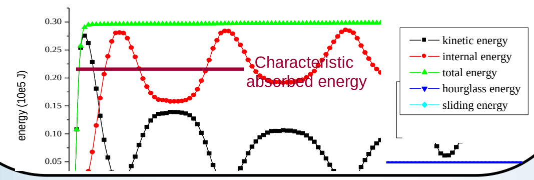
- This work is part of a larger project focused on the optimization of composite sandwich structures for blast mitigation purposes.
- Maximizing energy absorption is key.
- Thus, the influence of material properties on the energy absorption characteristics of composite sandwich structures is examined.
- Primary tasks:
  - Establish criteria for evaluating energy absorption,
  - Parametric study varying material properties of a single composite face sheet, and
  - Parametric study varying material properties of a sandwich structure.

DETERMINING ABSORBED ENERGY

- Internal energy has a plateau: the plateau value is the absorbed energy.



- Internal energy does not have a plateau: the first minimum internal energy is defined as characteristic absorbed energy.



ENERGY ABSORPTION CRITERION

- The absorbed energy, E_a, should not be solely used as the criterion.
  - Total energy is different.
  - Absorbed energy is dependent on total energy.

Table 1. Energy responses of 1mx1m panel with different thicknesses under identical blast loading situations.

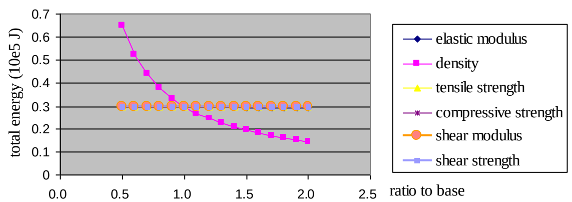
Structure	Blast loading		Energy response	
Panel thickness (cm)	TNT weight (g)	Distance (cm)	Total energy (10e5 J)	Characteristic absorbed energy (10e5 J)
0.5	1000	50	0.084292	0.070787
1.0	1000	50	0.040945	0.027453

- Use E_a/E_T as the criterion.
  - This is a non-dimensional factor that reflects the capability of the material to dissipate energy without transferring kinetic energy .

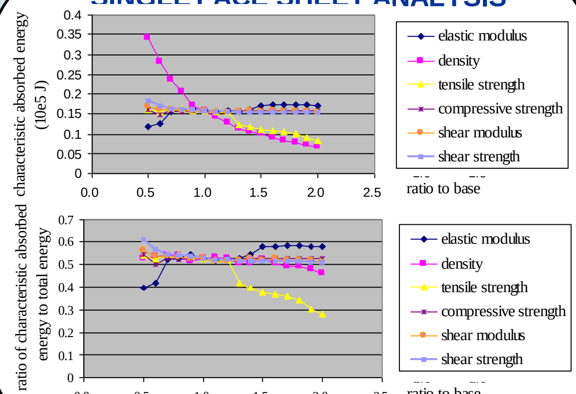
$$\frac{E_a}{E_T} = \frac{E_a}{E_a + E_k} = \frac{1}{1 + \frac{E_k}{E_a}}$$

SINGLE FACE SHEET ANALYSIS

- 100cmx100cmx1cm panel with 1.0 kg of TNT 0.5 m away is analyzed. A set of "base" material properties are selected. These base values are then varied as an independent variable in the analysis, between 50 and 200% of the original value. The resulting energy as a result of these variations is plotted.

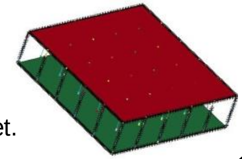


SINGLE FACE SHEET ANALYSIS



SANDWICH STRUCTURE ANALYSIS: MODEL DESCRIPTION

- Geometry:
  - 22.86 cm by 22.86 cm by 5.76cm (¼ geometry model);
  - Front face sheet 0.5 cm thick; back face sheet 2 cm thick;
  - Circular bars with a diameter of 0.2 cm and spaced at 4.572 cm are used to idealize the middle core of the composite sandwich structure.
- Blast load :
  - 518g TNT;
  - 26.13cm away from the center of front face sheet.



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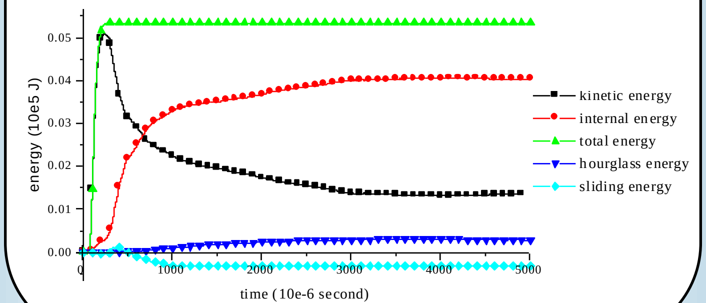
(Continued)

SANDWICH STRUCTURE ANALYSIS: MODEL DESCRIPTION

- Boundary conditions:
  - The edges of the back face sheet are fixed;
  - Symmetrical boundary conditions.
- Material Model:
  - MAT 58 was used to simulate the face sheets;
  - MAT3 was employed for bar elements.
- Element formulation:
  - Belystschko-Tsay shell for both face sheets;
  - Beam element for the middle core.
- Contact type:
  - CONTACT_ERODING NODES TO SURFACE between the middle core and the face sheets;
  - CONTACT_AUTOMATIC SURFACE TO SURFACE between the front and back face sheets.
- Hourglass energy control:
  - Type 4 hourglass viscosity type;
  - Hourglass coefficient is 0.1.

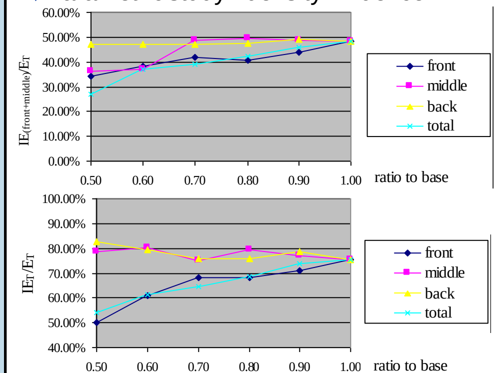
SANDWICH STRUCTURE ANALYSIS: MODEL DESCRIPTION & RESULTS

- Rigid body constraint to avoid initial penetration.
- Contact energy control:
  - Contact energy remains less than 10% of the total energy;
  - Time step scale factor 0.1;
  - Penalty stiffness scale factor 0.8.
- Energy response:



SANDWICH STRUCTURE ANALYSIS: RESULTS

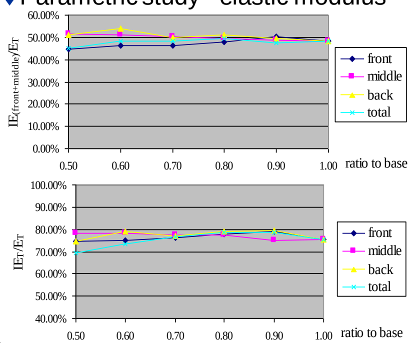
- Parametric study –density influence



Notes: $IE_{(FRONT+MIDDLE)}/E_T$ is the sum of absorbed internal energy in front panel and middle core over total energy; IE_T/E_T is the total absorbed internal energy over total energy.

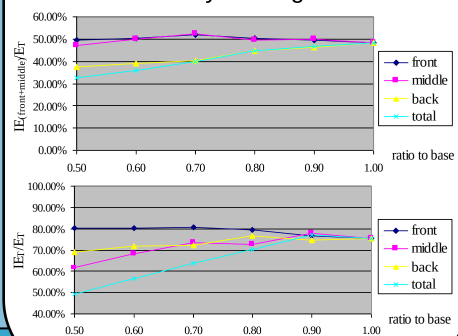
SANDWICH STRUCTURE ANALYSIS: RESULTS

- Parametric study –elastic modulus



SANDWICH STRUCTURE ANALYSIS: RESULTS

- Parametric study –strength



CONCLUSIONS

- In order to compare the energy absorption characteristics of different structures, a non-dimensional parameter that reflects the capability of the material to dissipate energy without transferring kinetic energy is introduced.
- In the single face sheet analyses, density, elastic modulus, and tensile strength show stronger influence than the other material property parameters.
- In composite sandwich structure analysis, the results show that increasing the density of front panel and increasing the total strength will efficiently increase the capability for energy absorption.

FUTURE WORK

- Current work has investigated unidirectional composite panels. Other fiber orientations are to be considered.
- Select actual composites that best represent targeted properties.
- Investigate geometries for the core of the sandwich structure that will consume the energy absorbed by the face sheet from blast loading.

ACKNOWLEDGEMENTS

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