Novel Sandwich Composite Structures for Blast Mitigation

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Abstract

The dynamic behavior of various sandwich composites made of E-Glass Vinyl-Ester and Corecell A-series foam have been studied using a shock tube apparatus. For the polyurea investigation, the foam core was monotonically graded based on increasing wave impedance, and the influence of the polyurea location on the overall dynamic behavior was studied. For the CoreShell Rubber (CSR) vs Non-CSR toughened resin composite investigation, the core was homogeneous, and the influence of the coreshell rubber nano-particles on the overall dynamic behavior was studied. A high-speed side-view camera, along with a high-speed back-view 3-D Digital Image Correlation (DIC) system was utilized to capture the real timedeformation process as well as mechanisms of failure. Post mortem analysis was also carried out to evaluate the overall blast performance. Results will help in designing new and more efficient blast mitigating materials and structures.

Relevance

With an increased threat of damage to civilian and defense structures in the form of blast loading there has arisen a need to replace conventional structural materials with improved blast resistant material as well as generate new ideas to mitigate blast over-pressure.


Blast attack on USS Cole

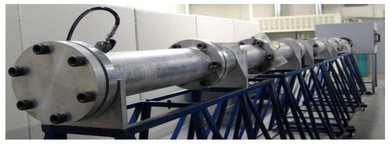

Blast loading on civilian structures

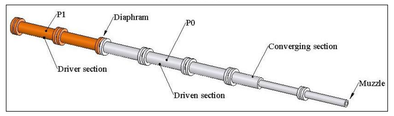

Blast attack on Army structures

Previously, the main focus of research in this area has been on the numerical and theoretical behavior of functionally graded materials. Experimental work on the dynamic response of composites with polyurea, as well as steel plates with polyurea has been investigated, but there has been no research regarding the dynamic response of sandwich composites with polyurea interlayer. Also, the addition of core shell rubber (CSR) to sandwich structures and their influence on blast loading is a relativley new application and investigation. Previously, only the impact response of core shell rubber (CSR) toughened composites has been studied.

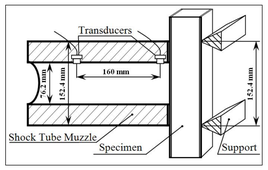
Technical Approach

Experimental Set-up and Procedure:

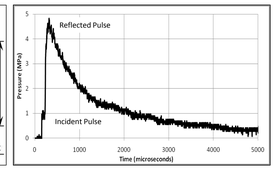

The Shock Tube



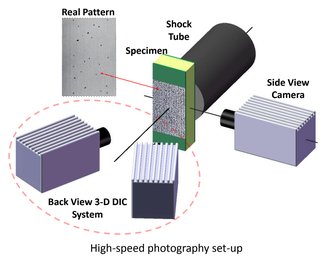
Schematic of Shock Tube



Detailed Dimensions of the Muzzle

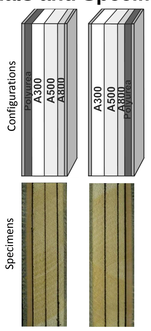


Incident and Reflected pressure profiles



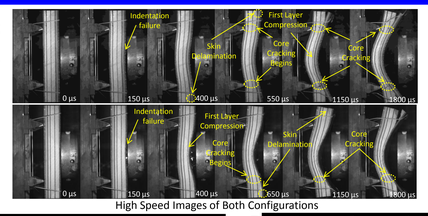
High-speed photography set-up

Materials and Specimens:

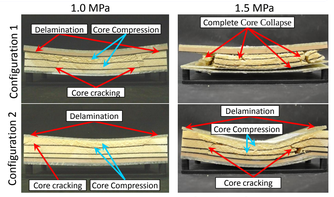


Configuration 1 Configuration 2

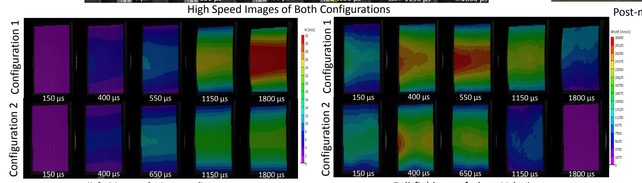
Results:



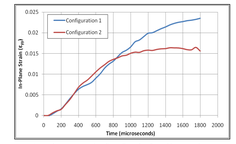
High Speed Images of Both Configurations



Post-mortem Images of Both Configurations



Full-field out-of-plane Deflection

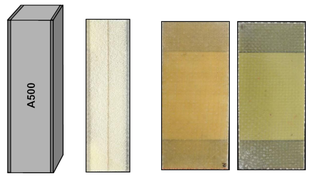


In-plane strain for Both Configurations

Full-field out-of-plane Velocity

Polyurea Investigation

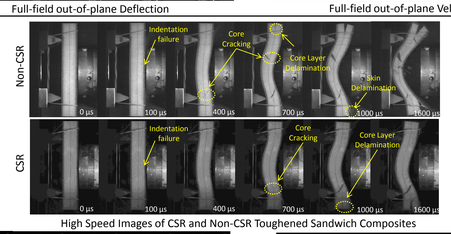
CSR vs Non-CSR Toughened Composite Investigation



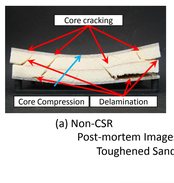
(a) Schematic Specimen Configuration (b) Real Secimen Configuration (a) Non-CSR Facehseet of Sandwich Structure (b) CSR Facehseet of Sandwich Structure

Microscopic View of Coreshell Rubber [www.kaneka.com]

Core:
Co-Polymer I designed for impact resistance
Shell:
Co-Polymer II designed to be compatible with thermosetting resins



High Speed Images of CSR and Non-CSR Toughened Sandwich Composites



(a) Non-CSR (b) CSR
Post-mortem Images of CSR and Non-CSR Toughened Sandwich Composites

Full-field out-of-plane Deflection

Full-field in-plane Strain

Out-of-plane velocity of CSR and Non-CSR Toughened Sandwich Composites

Accomplishments Through Current Year

A comprehensive series of shock tube experiments were conducted on sandwich panels consisting of composite facesheets and energy absorbing core materials in order to evaluate the overall blast response and mitigation capabilities

Major Results

1. **Polyurea Investigation:** The application of polyurea behind foam core and in front of back facesheet (configuration 2) allows for stepwise compresison of core, reducing deflections, in-plane strains, back face velocities and overall damage
2. **CSR vs Non-CSR Toughened Composite Investigation:** The addition of nano-scale Coreshell Rubber (CSR) particles to the resin system of the sandwich structures, aids in dispersing the initial impulse of the shock wave, thus reducing deflections, in-plane strains, and back face velocites and overall damage

Future Work

1. The effect of equivalent core layer mass vs. equivalent core layer thickness in the blast response of sandwich structures

Opportunities for Transition to Customer

Consulting with Industry:

1. TPI Composites, Warren, RI
2. Specialty Products Inc.(SPI), Lakewood, Washington
3. Gurit SP Technology, Quebec, Canada

New types of sandwich structures were designed and fabricated to withstand blast loadings and mitigate blast overpressures. Technical collaboration with TPI Composites, Specialty Products Inc., and Gurit SP Technology will help in fascilitating sample preparation. This effort also aligns with the mission of DHS to transition technology and allow for a unified effort to protect our homeland.

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Publications Acknowledging DHS Support

- N. Gardner, E. Wang, P. Kumar and A. Shukla, "Blast Mitigation in a Sandwich Composite using Graded Core with Polyurea interlayer" Experimental Mechanics, Accepted for Publication (2011)
- E. Wang, N Gardner and A. Shukla, "The blast resistance of sandwich composites with stepwise graded cores", International Journal of Solid and Structures, 46, 3492-3502, 2009.
- E. Wang, N. Gardner and A. Shukla, "Experimental study on the performance of sandwich composites with stepwise graded cores subjected to a shock wave loading", SEM Annual Conference and Exposition on Experimental and Applied Mechanics, Albuquerque, New Mexico , June 1-4, 2009.
- N. Gardner, "Blast performance of sandwich composites with discretely layered core", SEM Annual Conference and Exposition on Experimental and Applied Mechanics, Student Paper Competition, Albuquerque, New Mexico , June 1-4, 2009.
- N. Gardner and A. Shukla, "The Blast Response of Sandwich Composites with a Functionally Graded Core", SEM Annual Conference and Exposition, Indianapolis, Indiana, June 7-10, 2010.
- N. Gardner and A. Shukla, "The Blast Response of Sandwich Composites With a Functionally Graded Core and Polyurea Interlayer", SEM Annual Conference and Exposition, Indianapolis, Indiana, June 7-10, 2010.
- N. Gardner and A. Shukla, "The Blast Resistance of Sandwich Composites with a Functionally Graded Core and Polyurea Interlayer", IMPLAST 2010, SEM Fall Conference, Providence, October 12-14, 2010.

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