Composites Crashworthiness

Energy Absorption

Or the long and winding road
toward Standardization

Prof. Paolo Feraboli
Aeronautics & Astronautics
University of Washington
206.543.2170
feraboli@aa.washington.edu
Ground and Air vehicles alike
What is Crashworthiness?

Reasons for accident fatality:
- Contusion against objects.
- Excessive decelerations.
- Fire.

Conditions for survivability:
1. maintaining sufficient occupant space
2. providing adequate occupant restraint
3. employing energy-absorbing devices
4. and allowing for a safe post-crash egress from the craft.
A systems approach

Restraint system
Star Mazda RIMP

- Design of the Rear IMPact structure (RIMP)
- Certification as per Formula 3 FIA guidelines
- Crash test against rigid barrier at 22.4 mph
**Passenger cars**

- *Front Crumple zone.*
- *Tubular mentality.*
Measuring Energy Absorption:

- Specific Energy Absorption (SEA) is the Absorbed Energy per unit mass of crushed structure,

- Absorbed Energy is the total area under the Load-Displacement diagram

\[
SEA = \frac{EA}{\rho \cdot A \cdot \delta} = \frac{\int_0^\delta F \cdot dl}{\rho \cdot A \cdot \delta}
\]
SEA:

- In general composites have a greater SEA potential
- but need to be carefully studied and understood.

- a. \([0]_n\)
- b. \([90]_n\)
- c. \([0/90]_n\)
- d. \([\pm 45]_n\)
Failure modes:

- Metal structures collapse by plastic folding/ hinging.
- Buckling is only danger.
Fragmentation/ splaying:

- fracture and bending of the lamina bundles, and interlaminar crack growth
Rotorcraft subfloor
Commuter Aircraft cargo floor supports
Superluxury car
Or not....
CMH-17 Crashworthiness Working Group

- **Numerical standardization**
  - Current FE modeling strategies are not predictive
  - Round Robin is beginning, and it involves major FE explicit dynamic codes to validate existing material models and modeling strategies
  - Goal is to develop guidelines for “plug-and-play” capabilities

- **Experimental Standardization**
  - No existing test standard to determine SEA
  - No way to screen material systems/forms/lay-ups
  - Material suppliers, OEM’s and engineers need to speak one language
  - Proposed corrugated specimen to be compared with flat channels and tubular specimens
Numerical Standardization:

- Use for crash applications is still not mainstream due to difficulty in predictability.
- Predicting failure is very difficult in composites (see SIFT presentation)
- Crashworthiness modeling requires explicit, dynamic, non-linear (post-failure) modeling
Experimental Standardization:
- Self-stabilizing: no fixture necessary
- No autoclave or mandrel necessary
- **Less complexity, cost and uncertainty than tubular specimen**
Corrugated Specimen:

- 0/90 Tough Semicircle Slow
- 0/90 Tough Sinusoid Fast
- Aluminum Short
Corrugated Specimen:
- Specimen after testing, and Load, SEA, Total energy vs. stroke

TOP

BOTTOM

Graph: SEA, Load, Energy vs. Stroke [cm]
Acknowledgments:

- Larry Ilcewicz and the CMH-17 community
- 30+ members of the Crashworthiness WG
- Xinran Xiao (General Motors)
- Mostafa Rassaian (Boeing Phantom Works)
- My students!
  - Tyler Cleveland, Elof Peitso, Gaetano Settineri, Mark Miller, Derek Hazen, Jared Grogan, Francesco DeLeo, Francesca Garattoni