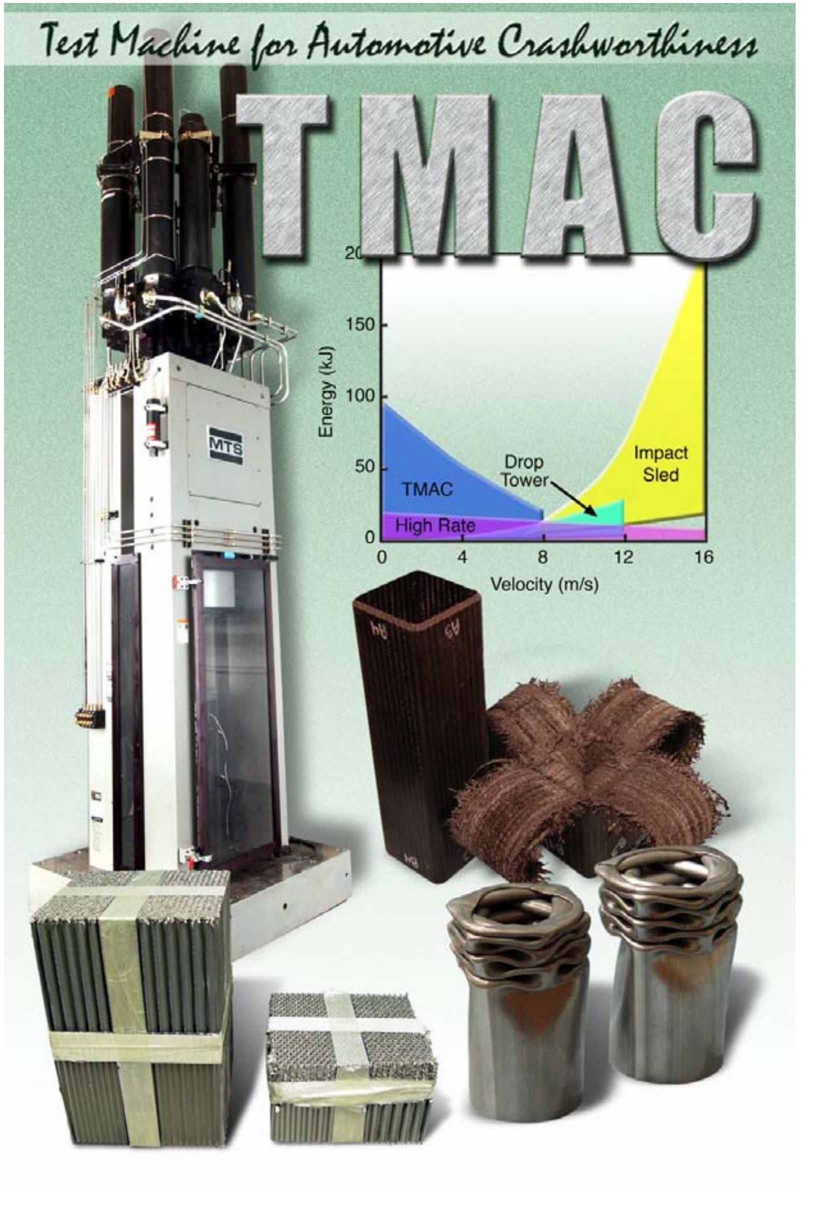
Crashworthiness Testing of Advanced Materials

C. David (Dave) Warren

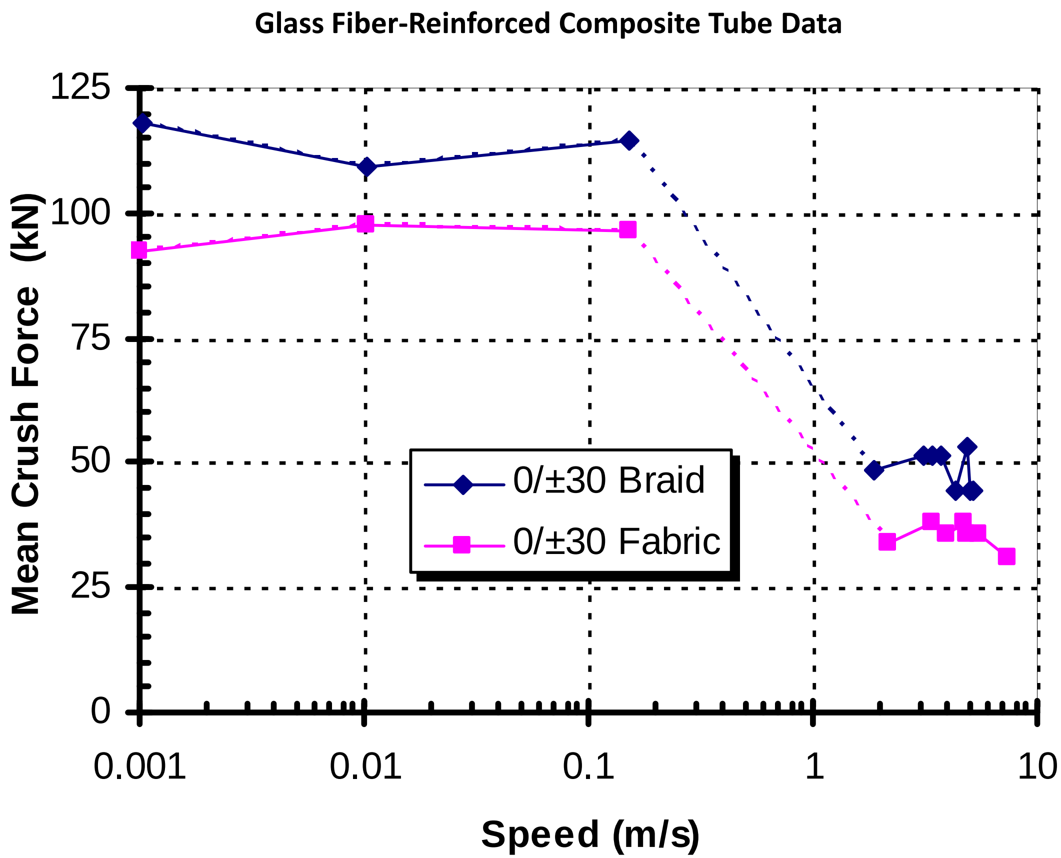
Field Technical Manager
Transportation Composite Materials Research

Oak Ridge National Laboratory
P.O. Box 2009, M/S 8050
Oak Ridge, Tennessee 37831-8050
Phone: 865-574-9693 Fax: 865-574-0740
Email: WarrenCD@ORNL.GOV

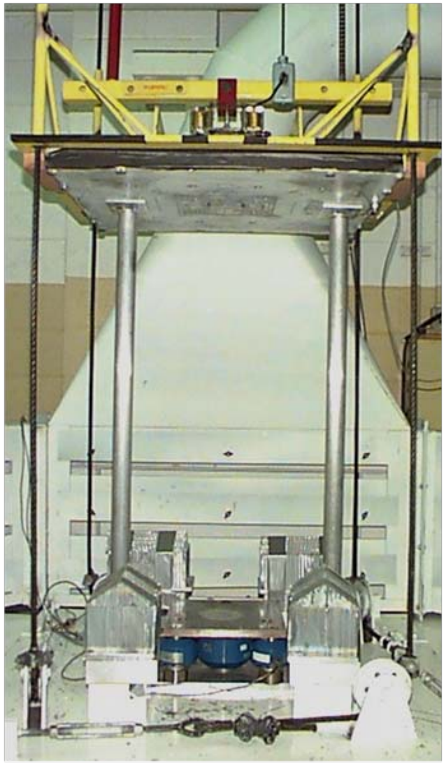


Material Behavior Depends on Strain Rate

- **Materials may respond differently when subjected to different rates of loading (e.g., impact velocity)**
- **Transition between quasi-static and high rates not understood**
- **Data is needed to develop reliable analytical models for predicting material response and structural performance during crash events**



Typical Dynamic Structural Tests



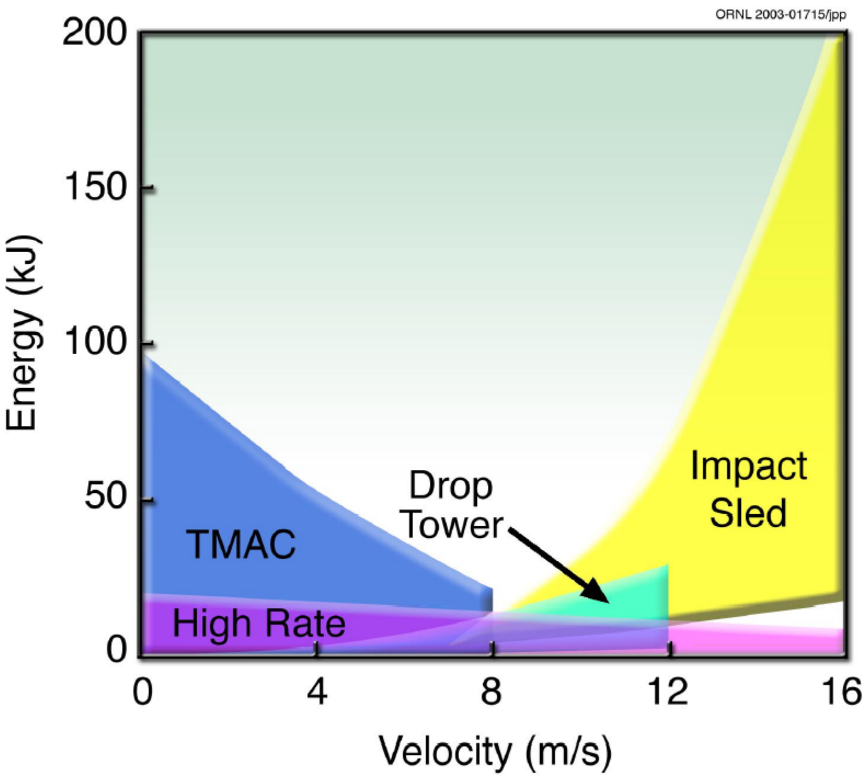
General Motors drop tower

Ford impact sled with mounted test specimen

- **Drop tower and sled tests do not give constant velocity especially at lower velocities**
- **Can approximate constant velocity if mass is large enough – not practical**
- ***Example: to maintain 0.7 m/s crush velocity to within 10% over 125 mm crush requires 8600 kg***

TMAC

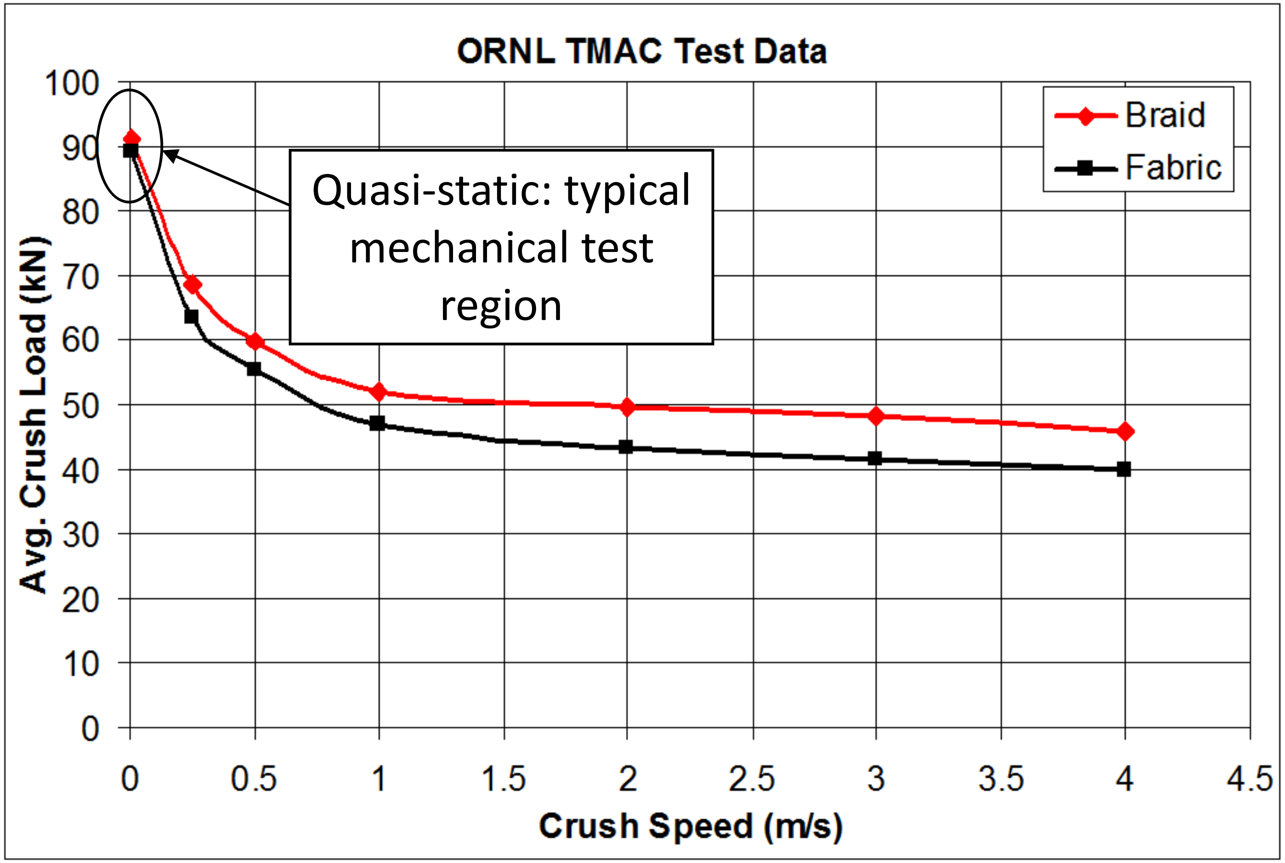
- **Test Machine for Automotive Crashworthiness (TMAC)**
  - Tube crushing or tension at 100's of kN
  - Constant velocity to 8 m/s (18 mph) thru 25 cm stroke
- **High speed – small load test machine**
  - Coupon tensile testing at loads to 22 kN
  - Constant velocity to 18 m/s (40 mph)
  - Attachable 450 kg mass for peak forc and to mitigate specimen variations
- **Planned capability additions**
  - Full field strain measurement



TMAC Specifications

- **Physical**
  - **1 m daylight**
  - **490 kN actuator capacity (static)**
  - **250 mm stroke**
  - **> 490 kN side-load capacity**
  - **Attachable 450 kg mass**
  - **4340 steel (Rc 40) impact plate w/ 16 RMS finish**
- **Operating**
  - **No load: 230 mm travel at 8 m/s**
  - **113 kN: 230 mm travel at > 6 m/s**
  - **267 kN: 115 mm travel at 6 m/s**
  - **Target velocity constant within ± 10% for 115 mm**

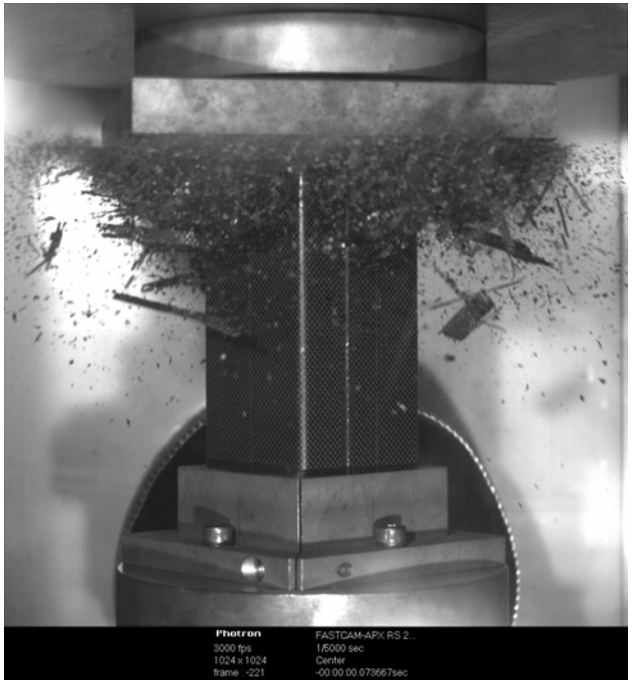
Example of Rate Dependent Data



Average crush load versus speed for glass-fiber reinforced composite tubes

We need good strain rate dependent material behavior data in order to properly model structural behavior during crash events

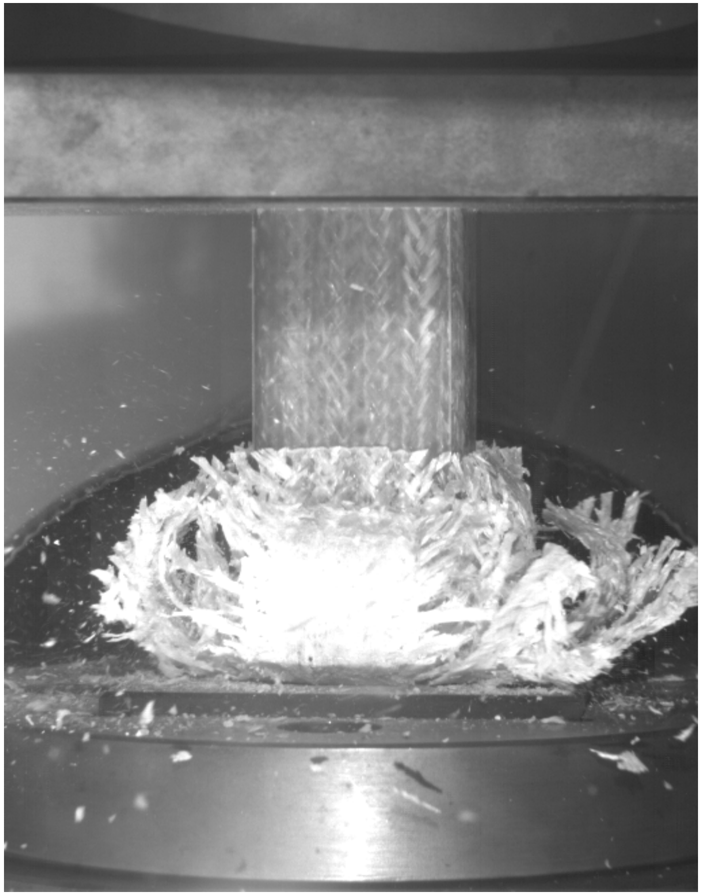
Example TMAC Test Results



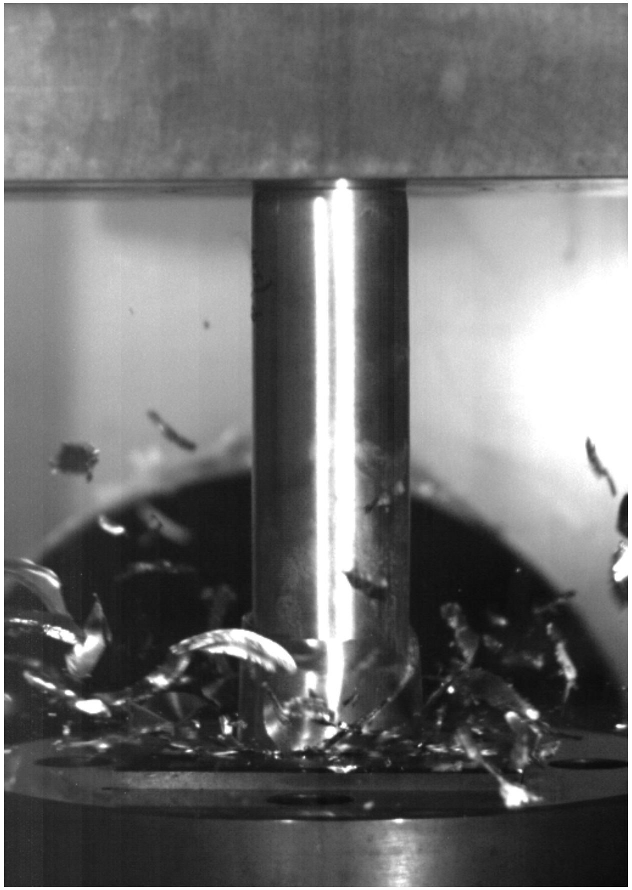
Snapshot of carbon fiber tube during a 4 m/sec crush test

Residue of a carbon fiber tube crush test

Example TMAC Test Results



Glass-fiber braided composite tube during 0.5 m/sec crush test



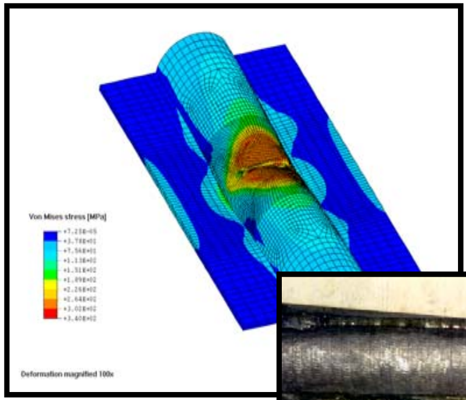
Magnesium tube during 0.5 m/sec crush test

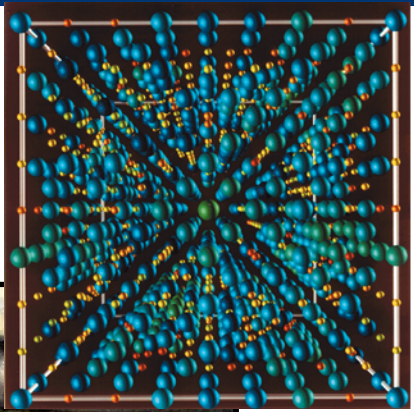
ORNL User Program

- Provides external users *free* access to dynamic testing capabilities for nonproprietary work with results published in the open literature
- Proprietary work can be conducted on a cost recovery basis, with no publication requirement
- ORNL staff and users conduct the project together
  - ORNL provides the equipment, facilities, and operational support
  - User plans the experiment, provides test specimens and fixtures, conducts data analysis, and writes the paper; ORNL will assist with some or all of these tasks
  - Typical project requires about one person-week of ORNL staff support
  - Paper submitted to ORNL co-author(s) for review within three months, and presented or published within one year, after test completion
- Proposal form found at www.ntrc.gov, user should work with ORNL technical contact to prepare proposal

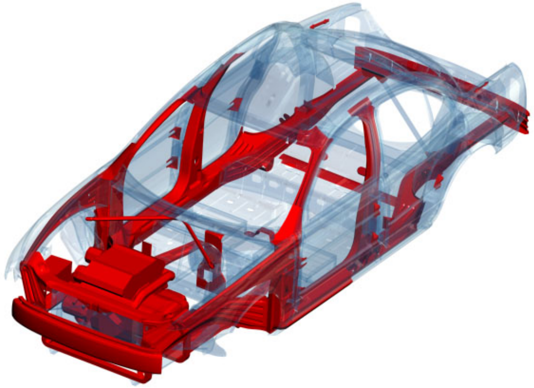
Modeling and Simulation

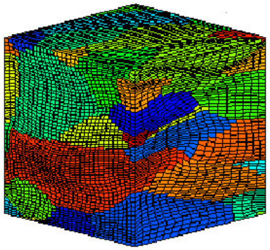
- **State-of-the-art modeling**
  - **Materials**
  - **Materials processing**
  - **High rate deformation**
  - **Strain induced transformation**
  - **Melting and solidification**

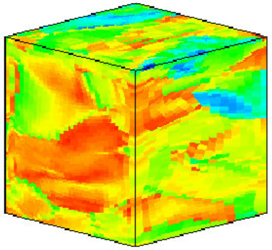




❑ Broad Industrial Collaborations







BES, OAAT, AIM, ONR, DOT, Weyerhaeuser, AISI, A/SP, NCMS, NTSB, GM, Ford, DaimlerChrysler

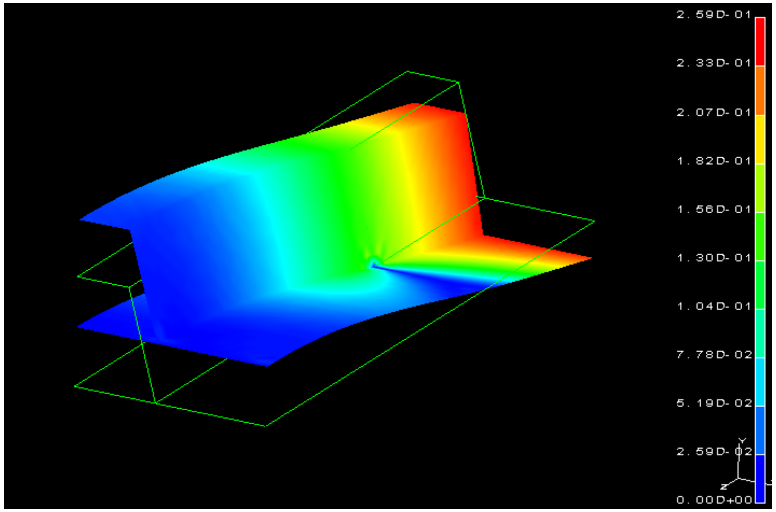
Joining of Composites

Accomplishment

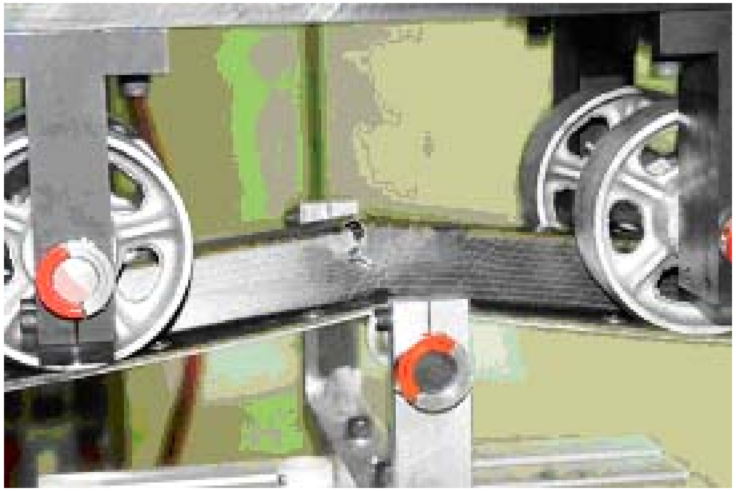
- Developed technologies to quantify the integrity of hybrid joints (joints between composites and traditional structural materials, for example, steel)
- Key issues associated with joint performance addressed
  - Creep, fatigue, environmental exposure, damage evolution leading to catastrophic failure

Benefits

- Basic rules for joint design and predictive models for automotive design using composites
- Enables increased use of composites in vehicles, leading to weight savings and increased fuel efficiency
- Increases hybrid joint reliability



Hybrid joint rail model results



Hybrid joint rail test