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Test Methodologies for Determining Energy Absorbing Mechanisms in Automotive Composite Material Systems

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Objectives

- Develop experimental techniques and test methods for discerning the deformation behavior and damage mechanisms that occur during progressive crushing of composite materials.
- Provide experimental data to support the development of analytical material damage models.

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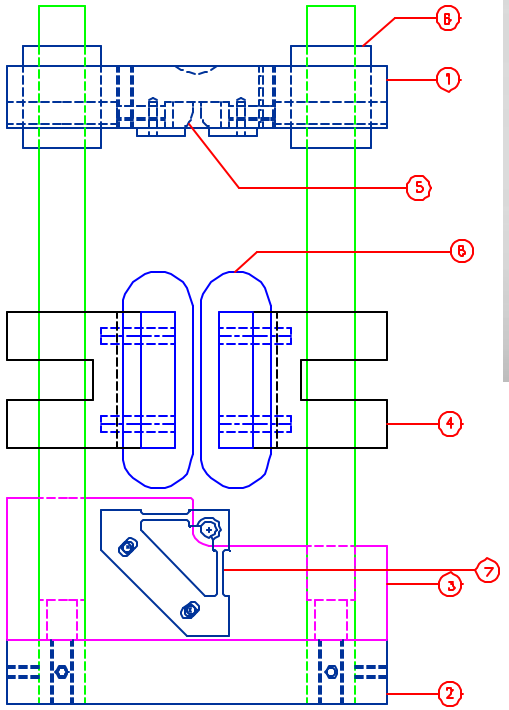
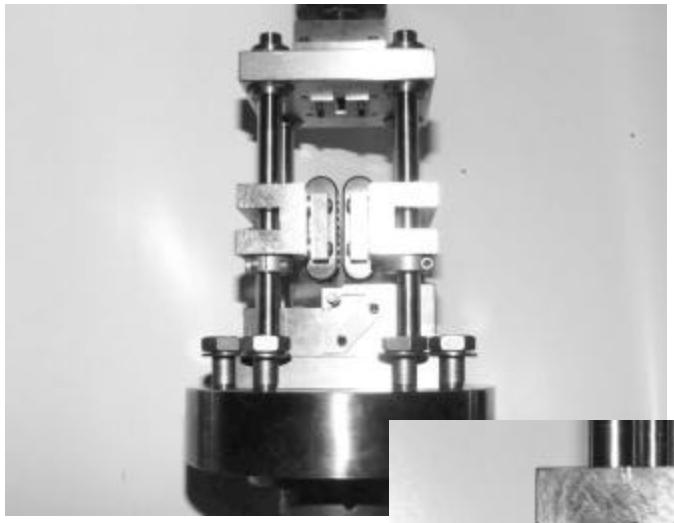
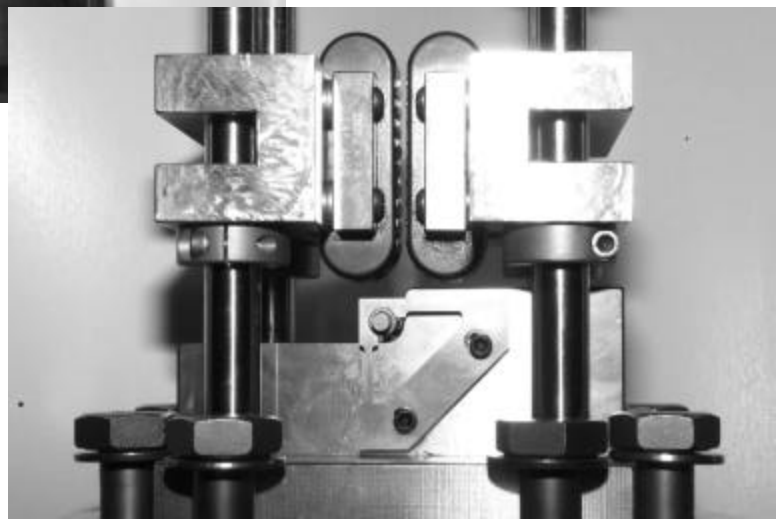
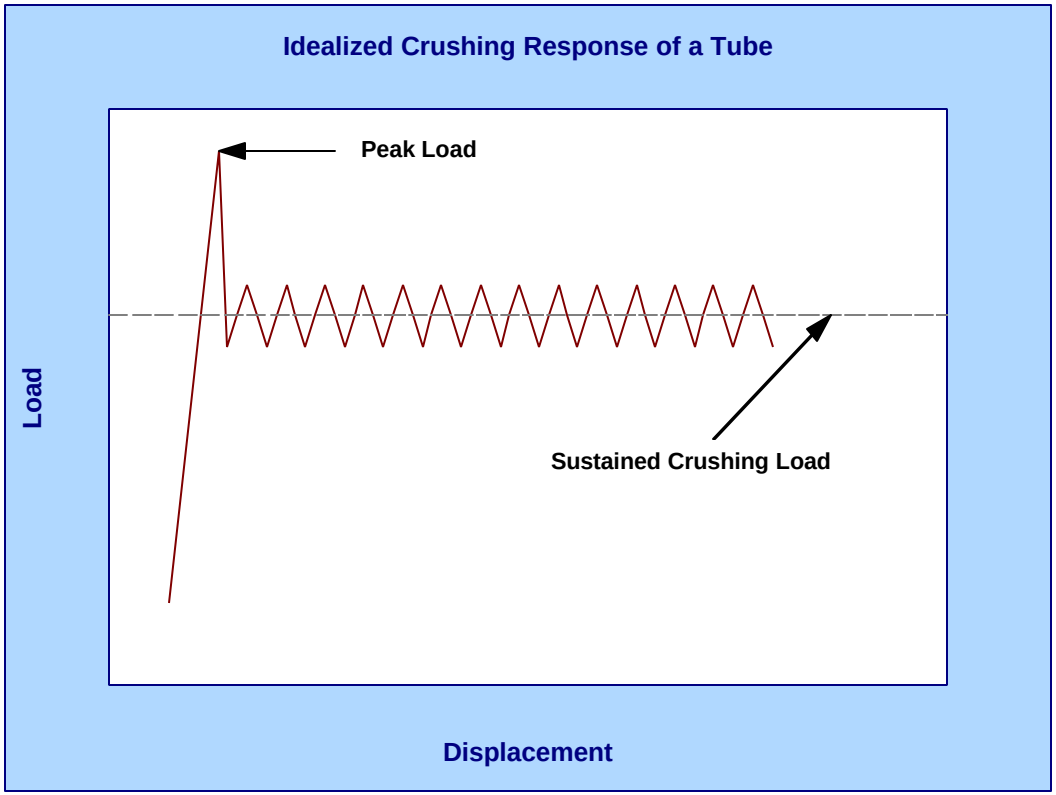
Strip Test Fixture







Idealized Response



Specific Energy Absorption

$$E_s = \frac{W}{Vr}$$

W = total energy absorption
= area under curve
V = volume of crushed material
ρ = density

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Test Fixture Validation

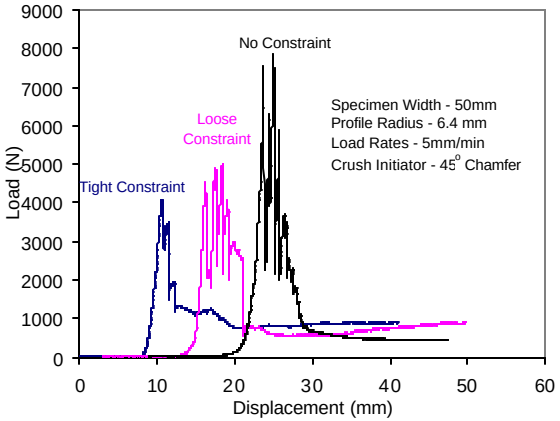
- Conducted preliminary testing on candidate automotive composite material systems
  - Graphite/Epoxy cross-ply laminates
    - Panel designations: CP1 and CP2
    - Akzo Fortafil prepreg #602 (50K tow)
  - Graphite/Epoxy triaxial braid
    - Panel designation: #10-13
    - 0/+30/-30 fiber orientations
    - Akzo #556 carbon fiber with Ashland Hetron 922 epoxy
  - Glass-reinforced continuous strand mat
    - Panel designation: CSM
    - Baydur polyurethane resin

Validation cont.

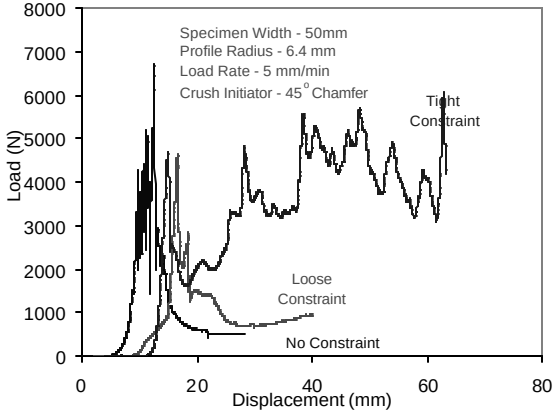
- Nominal specimen dimensions
  - length: 178 mm (7 in.)
  - width: 50 mm (2 in.)
  - thickness: 3 mm (1/8 in.)
- Crush initiator used was a 45^{o} chamfer
- Loading rate: 5.0 mm/min (0.2 in/min)
- Profile radius: 6.4 mm (0.25 in.)
- Maximum displacement was 50 mm (2 in.)

Test Results

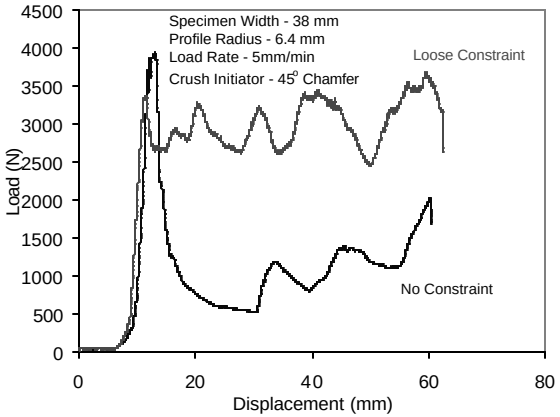
Load Displacement Traces
Akzo Prepreg #602 Cross Ply Panel # CP1



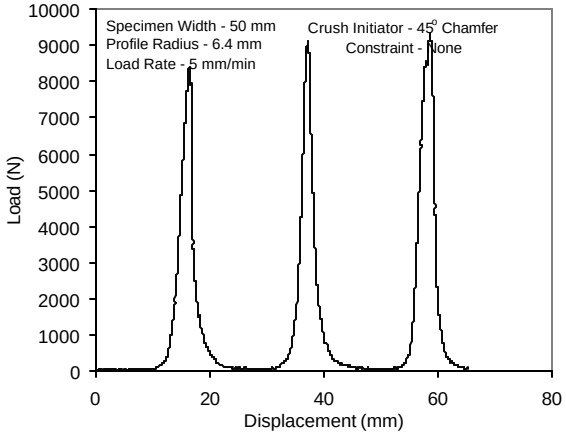
Load Displacement Traces
Akzo Prepreg #602 Cross Ply Panel # CP2



Load Displacement Traces
Akzo 556 Triaxial Braid Panel # 10-13



Load Displacement Traces
Baydur Glass Fiber CSM



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Summary of Test Fixture

- A test fixture has been developed for conducting progressive crush tests on composite plates
- Different damage mechanisms can be activated depending on the condition of the profile constraint
- Modifications to the basic specimen geometry are required when testing material systems having a low axial stiffness
- Future testing will investigate the progressive crush behavior of chopped carbon fiber composites
- Paper will be presented at the SAE/DOE 2000 Future Car Congress, April 2-6, 2000, in Arlington, Virginia

Status - Chopped Carbon Fiber

- P4 process using carbon fiber is not sufficiently mature for consideration in the current project
- Vendor identified for fabricating test specimens using compression molded chopped carbon fiber
  - YLA is the supplier of the molding compound
    - RS-35 epoxy resin
    - Toray T700 12K-tow carbon fiber
  - CCS Composites is the fabricator
  - Standard panel size: 9-3/4” x 8” x 0.125”

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Test Matrix

- Test variables
  - Profile radius: 0.25 in. and 0.50 in.
  - Load rate: 0.2 in./min.
  - Constraint: none, loose, tight
- Specimen variables
  - Width: 0.5 in., 1.0 in., 2.0 in.
  - Areal weight: 150 gsm, 300 gsm
  - F.V.: 40%, 50%
  - Fiber length: 1.0 in, 2.0 in.

Areal Weight (gsm)	V_f (%)	Fiber Length (in.)
300	50	1
300	40	1
300	50	2
300	40	2
150	50	1
150	40	1
150	50	2
150	40	2

Panel Status

- 8 different panel types were ordered January 18, 2000
- Received the 150 gsm, 1” fiber length, 40% and 50% fiber volume fraction panels
- The 300 gsm, 1” fiber length, panels are scheduled to be shipped this week
- The remaining panels are scheduled to be delivery by mid-April