PUNCH SHEAR BEHAVIOR OF THICK SECTION COMPOSITE MATERIALS

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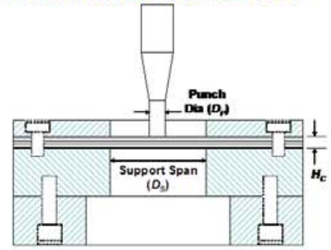
OBJECTIVES

- **Study the Punch Shear Behavior of Thick-Section Composites**
- **Quantify the Energy Absorbed During Punch Shear as a Function of Damage Mechanisms**

MATERIALS

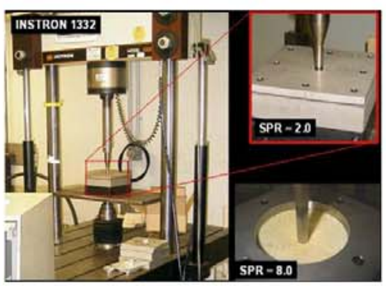
- **Fabric:** PW (15 x 15) S-2 Glass Fabric; Areal-Weight 11.5 oz/yd^2
- **Resin:** SC79, Part A - 100%, Part B - 40 %
- **Cure:** Room Temperature cure for 36 hours under vacuum
- **Post Cure:** Ramp to at the rate of 2^0F/min, hold at for 8 hours and cool down to room temperature at a rate of 2^0F/min.
- **No. of Layers:** 30
- **Thickness:** H_c = 0.74 in = 18.67 mm
- **Density:** ASTM D 792-98, ρ = 1.83 gm/cm^3 = 0.066 lbs/in^3
- **Fiber Volume Fraction:** ASTM D 2584-85, 51.72%
- **Areal Density:** AD = ρH_c = 7.02 psf = 34.26 kg/m^2
- Specimens of nominal dimension 5-in x 5-in are machined using a wet saw, and four holes are core drilled for bolting the specimens in the fixture.

EXPERIMENTAL SET-UP

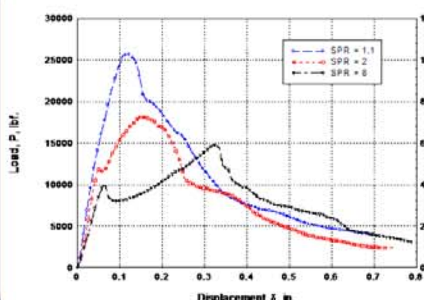


- Square support-plate (50.80-mm thick) with a circular hole at the center.
- Cover-plate (12.70-mm thick) with central hole.
- A 0.5-in diameter cylindrical punch.
- Composite plate specimens can be bolted between the support and the cover.
- Instron 1332 loading frame with a 222-kN (50 kips) load cell.
- Displacement control tests at a cross-head displacement rate of 0.05-in/min.

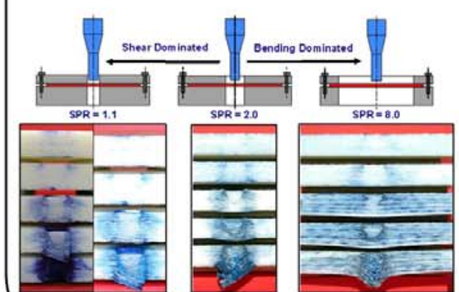
EXPERIMENTAL SET-UP



LOAD-DISPLACEMENT BEHAVIOR



DAMAGE AS A FUNCTION OF SUPPORT SPAN



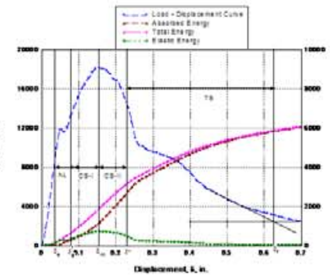
LOAD-DISPLACEMENT BEHAVIOR

- Maximum load at failure decreases as a function of support to punch ratio.
- Change in damage mechanisms are reflected in load-displacement plots.

DAMAGE AS A FUNCTION OF SUPPORT SPAN

- With the increase in support span, the damage modes changes from compression-shear dominated to tension-shear dominated damage
- Matrix crack, initiation and propagation of delamination, plug formation (compression-shear), bending and fiber breakage (tension-shear), push-out of plug.

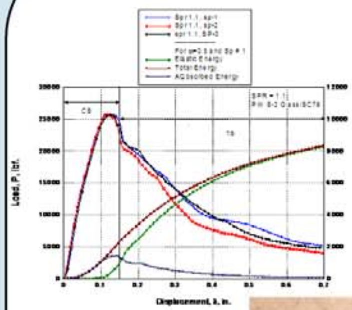
ENERGY-ABSORBING DAMAGE MECHANISMS



- **DAMAGE MODES**
  - Non-Linear Damage, $E_A^{N-L} = E_A^{\delta_e^f}$
  - Compression Shear – I, $E_A^{CS-I} = E_A^{\delta_m} - E_A^{\delta_e^f}$
  - Compression Shear – II, $E_A^{CS-II} = E_A^{\delta^*} - E_A^{\delta_m}$
  - Compression Shear, $E_A^{CS} = E_A^{CS-I} + E_A^{CS-II}$
  - Tension-Shear, $E_A^{TS} = E_A^{\delta_f} - E_A^{\delta_m v \delta^*}$
  - Total Energy, $E_A^{T} = E_A^{\delta_f}$

Elastic Energy Calculation is Performed using a Model Developed by Gama et al.

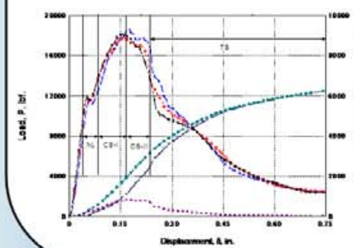
ENERGY ABSORPTION, SPR = 1.1



- **DAMAGE MODES**
  - ✧ Compression-Shear
  - ✧ Tension-Shear
- $E_A^{CS} = 17.2$ %
- $E_A^{TS} = 82.8$ %

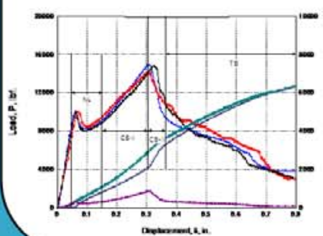
ENERGY ABSORPTION, SPR = 2.0

- **DAMAGE MODES**
  - Non-Linear Damage, $E_A^{N-L} = 3.8$ %
  - Compression Shear – I, $E_A^{CS-I} = 14.7$ %
  - Compression Shear – II, $E_A^{CS-II} = 23.7$ %
  - Compression Shear, $E_A^{CS} = 38.4$ %
  - Tension-Shear, $E_A^{TS} = 57.8$ %
  - Total Energy, $E_A^{T} = 100$ %

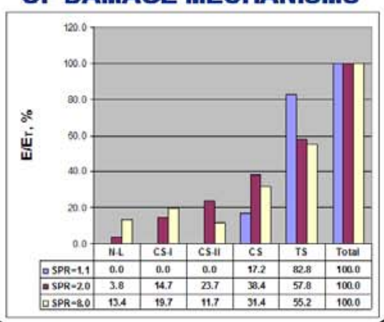


ENERGY ABSORPTION, SPR = 8.0

- **DAMAGE MODES**
  - Non-Linear Damage, $E_A^{N-L} = 13.4$ %
  - Compression Shear – I, $E_A^{CS-I} = 19.7$ %
  - Compression Shear – II, $E_A^{CS-II} = 11.7$ %
  - Compression Shear, $E_A^{CS} = 31.4$ %
  - Tension Shear, $E_A^{TS} = 55.2$ %
  - Total Energy, $E_A^{T} = 100$ %



PERCENT ENERGY ABSORBED AS A FUNCTION OF DAMAGE MECHANISMS



	N-L	CS-I	CS-II	CS	TS	Total
SPR=1.1	0.0	0.0	0.0	17.2	82.8	100.0
SPR=2.0	3.8	14.7	23.7	38.4	57.8	100.0
SPR=8.0	13.4	19.7	11.7	31.4	55.2	100.0

SUMMARY

- PST Results of S-2 Glass/SC79 Composites are Presented.
- Punch Shear Damage Mechanisms are grouped as:
  - ✧ Non-Linear Damage
  - ✧ Compression-Shear
  - ✧ Tension-Shear
- Energy absorbed in different damage mechanisms is quantified.
- The energy partitioning methodology can be used in the relative ranking of different materials.
- This knowledge of energy absorption is important in predicting the ballistic performance of composite laminates.

ACKNOWLEDGEMENTS

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