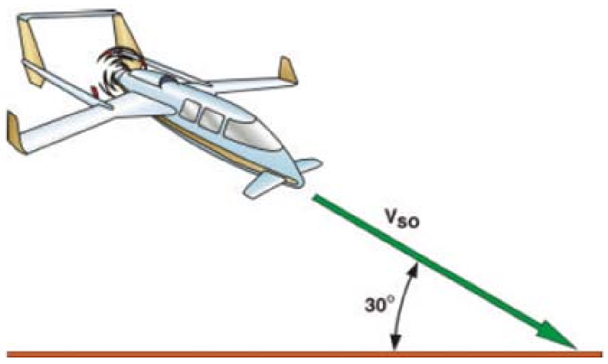
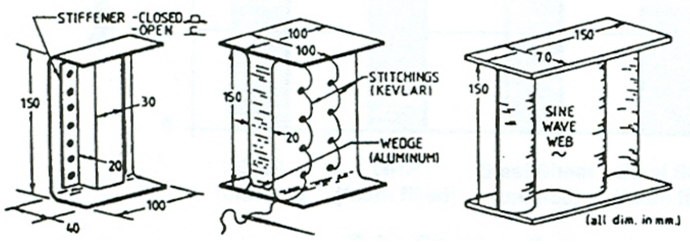
CRASHWORTHINESS OF COMPOSITE FUSELAGE STRUCTURES

MATERIAL DYNAMIC PROPERTIES

The Joint Advanced Materials and Structures Center of Excellence

- Motivation and Key Issues
  - Increasing use of composite materials in airframes
    - Energy absorption due to controlled failure modes
  - Contradictory observations related to rate sensitivity reported in literature[1]
    - Observations biased by choice of material systems, structural configurations, and loading modes
    - Strain rate seldom reported; stroke rate not necessarily proportional to strain rate
- Objective
  - Investigate strain-rate sensitivity of composite material systems and energy absorption devices/representative structural configurations

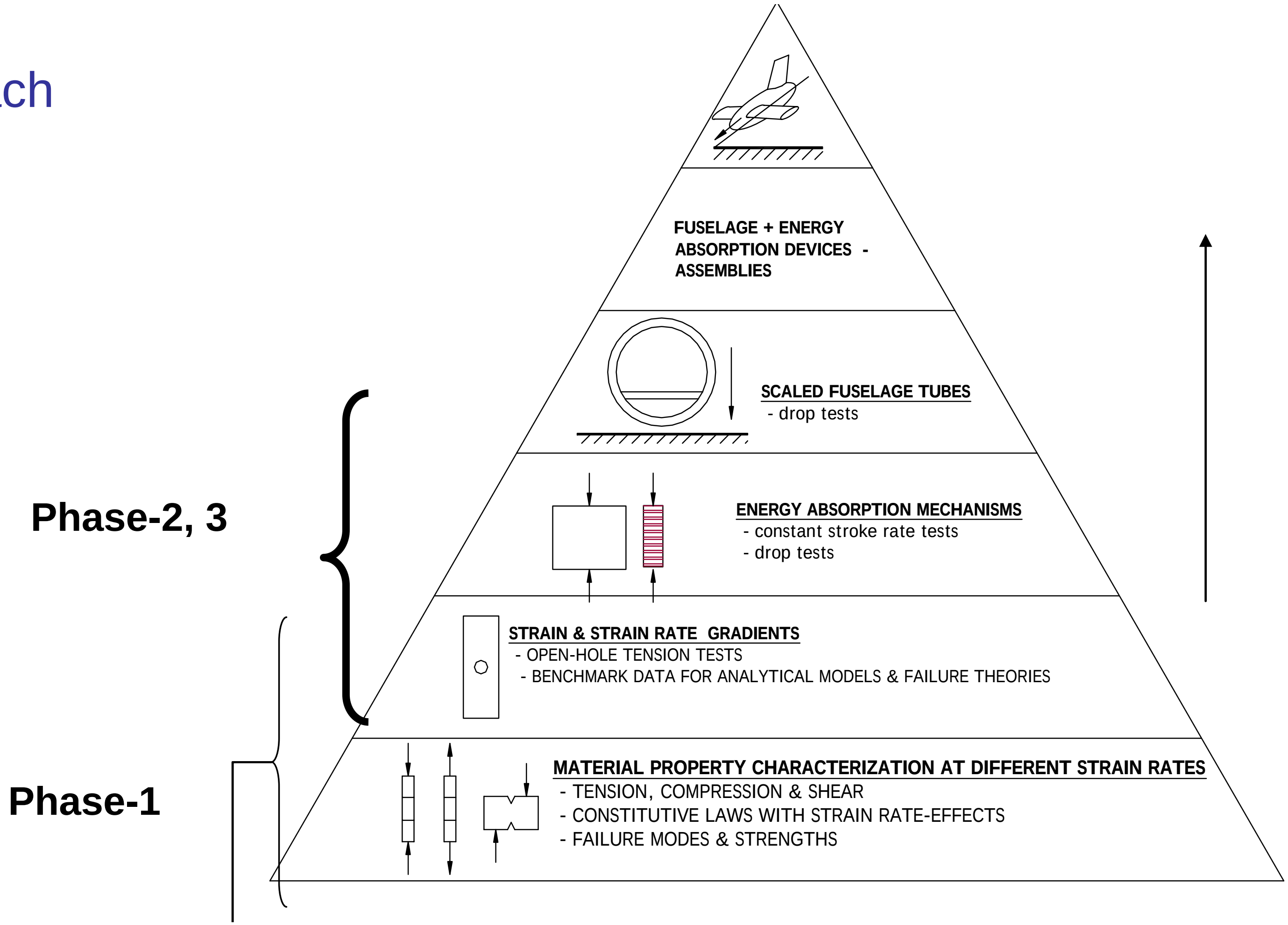




1.Carruthers, Kettle & Robinson (1998) Appl Mech Rev, 51.

CRASHWORTHINESS OF COMPOSITE FUSELAGE STRUCTURES – MATERIAL DYNAMIC PROPERTIES

- Approach



FAA Sponsored Project Information

- Principal Investigators & Researchers
  - K.S. Raju
  - GRA - J.F.Acosta, M. Ghimire, M. Thotakuri
- FAA Technical Monitor
  - Allan Abramowitz
- Other FAA Personnel Involved
  - Curtis Davis
- Industry Participation
  - Spirit Aerosystems
  - Raytheon
  - Cessna
  - Sikorsky
  - Bell Helicopter

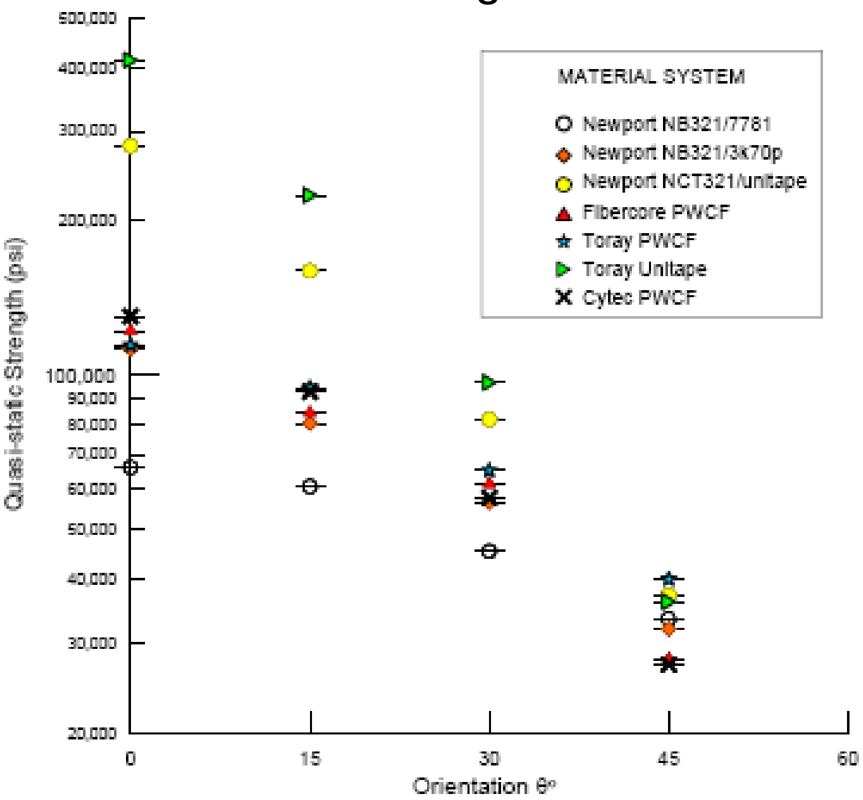
MATERIAL CHARACTERIZATION :PHASE-1

- Material Systems
  - Newport NB321/3k70P
  - Newport NB321/7781 Fiberglass*
  - Newport NCT321/G150 Unitape
  - Toray T800S/3900-2B[P2352W-19] BMS8-276 Rev-H- Unitape*
  - Toray T700G-12K-50C/3900-2 Plain Weave Carbon Fabric*
  - Fibercote E-765/PW Carbon Fabric /Epoxy
  - Cytec PWC T300 3KNT Plain Weave Carbon Fabric*
  - Plascore Nomex Honeycomb core PN2-3/16-3.0
- Material Properties
  - In-Plane Tensile Properties (Strength & Modulus) :$[0°]_n$, $[\pm 15°]_{ns}$,$[\pm 30°]_{ns}$, $[\pm 45°]_{ns}$
  - In-Plane Compressive Properties (Strength & Modulus): $[0°]_n$, $[\pm 15°]_{ns}$,$[\pm 30°]_{ns}$, $[\pm 45°]_{ns}$
  - In-Plane Shear Properties (Strength & Modulus): $[0°/90°]_{ns}$

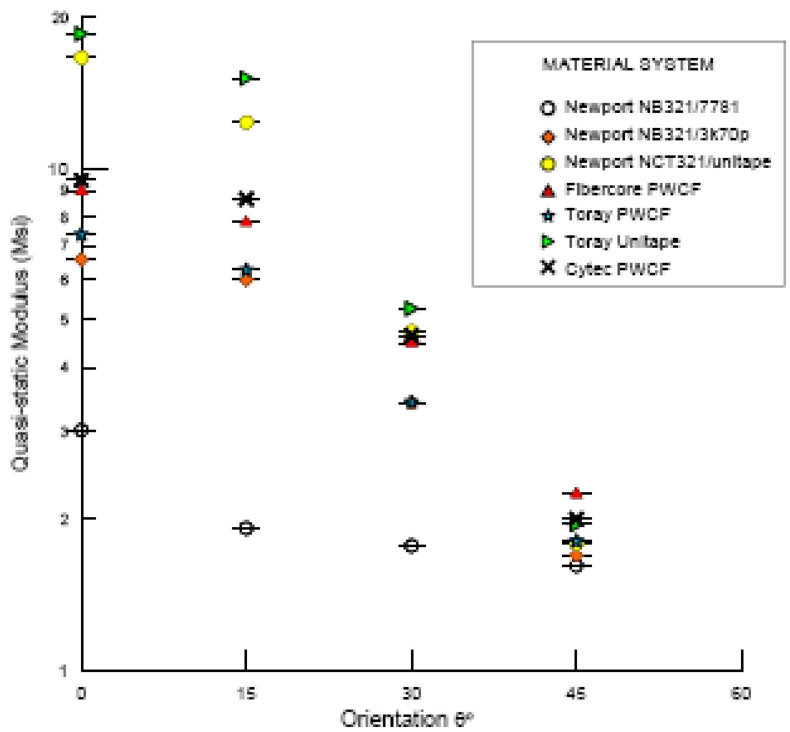
** Funded by State of Kansas (NIS program)*

MATERIAL CHARACTERIZATION :PHASE-1

Strength

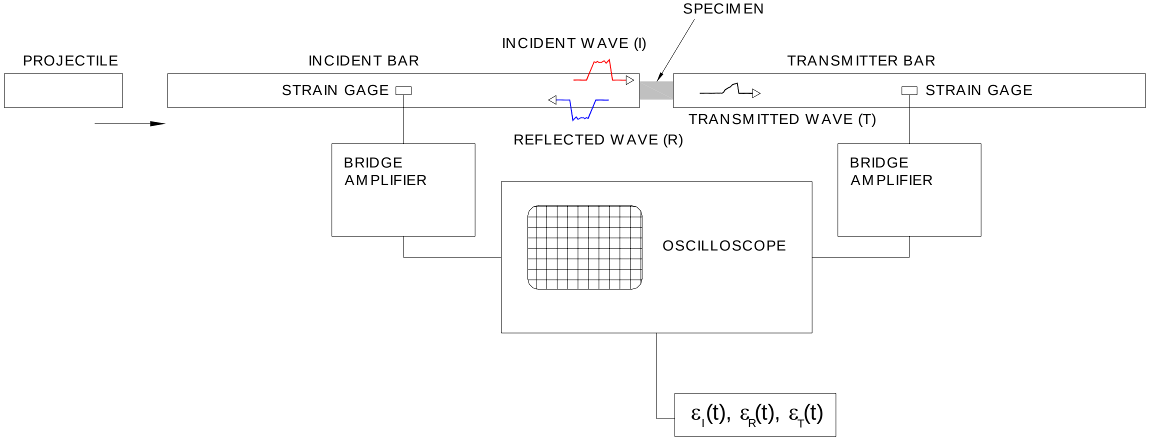


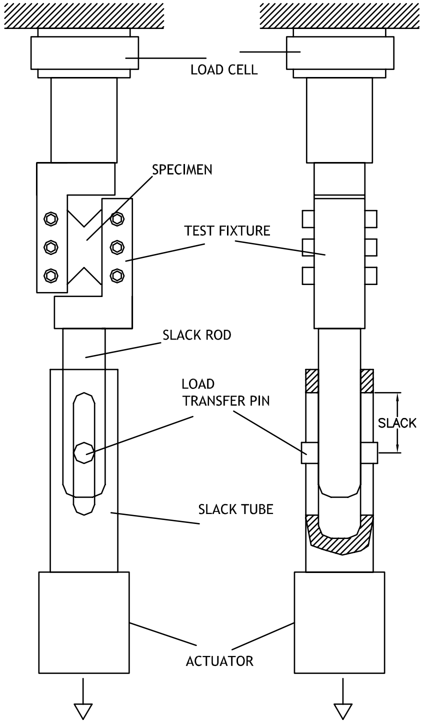
Modulus



MATERIAL CHARACTERIZATION :PHASE-1

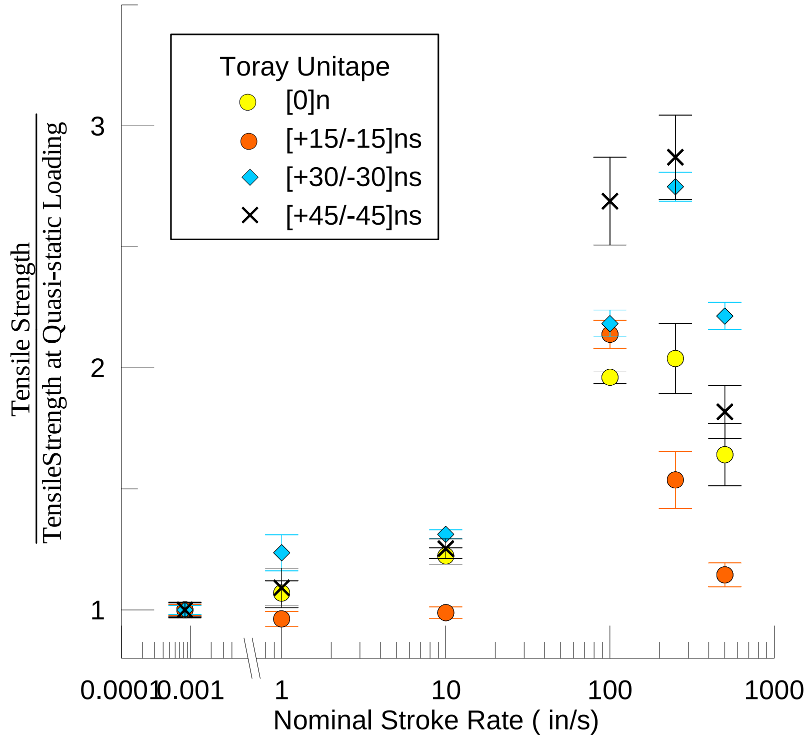
- Test Apparatus
  - TENSION MODE TESING
    - MTS servo hydraulic testing machine
      - Tension, shear and flexure tests
  - COMPRESSION MODE TESTING
    - Split-Hopkinson Pressure Bar (SHPB)
      - Compression tests





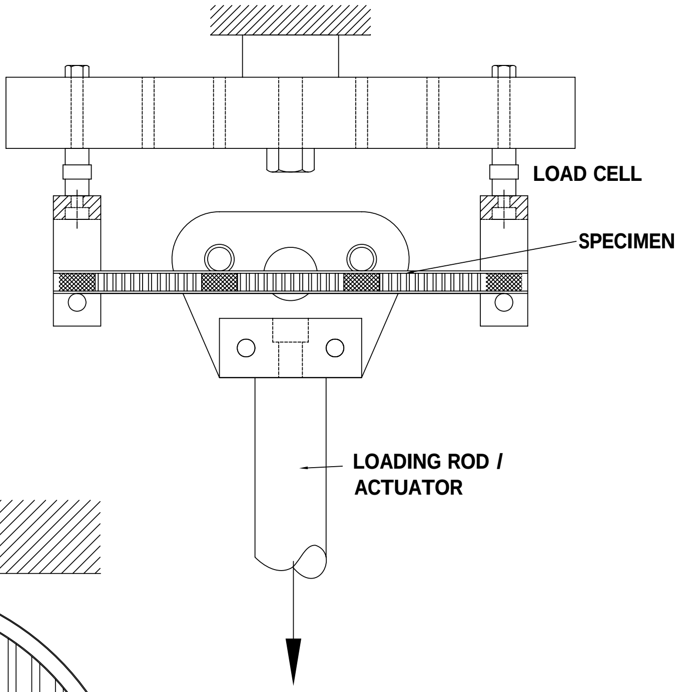
MATERIAL CHARACTERIZATION :PHASE-1

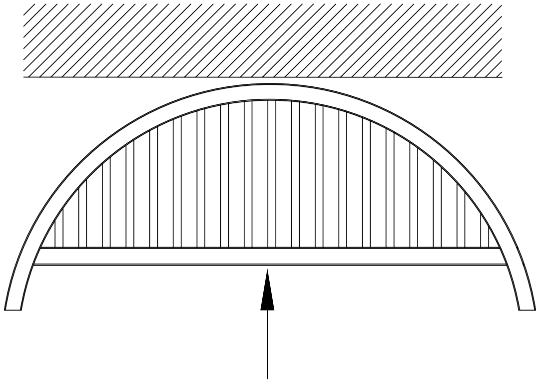
- Key Observations
  - Material strengths more sensitive to loading rates under tension and in-plane shear loading when compared to compression loading.
  - Strength increase higher for off-axis specimens (tension & compression)
- Status
  - Testing & documentation completed. Revision of document under progress (submission of revised document 7/30/07)



Crashworthiness of Composite Fuselage Structures : Phase 2

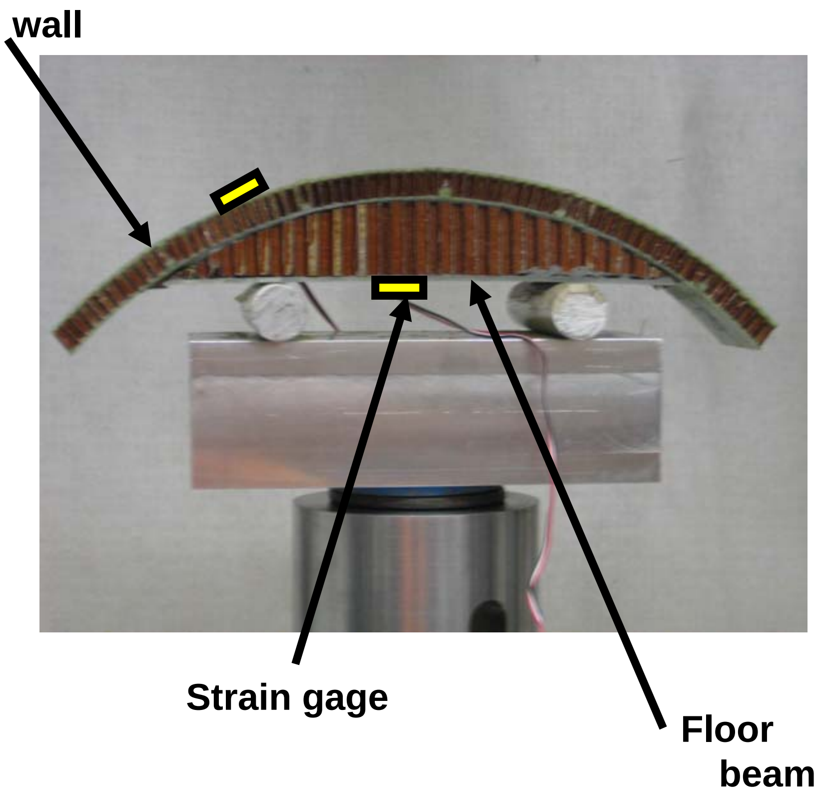
- Tasks
  - Pin Bearing
  - Open-hole tension
  - Interlaminar Shear strength
  - Flexure
  - Scaled fuselage section



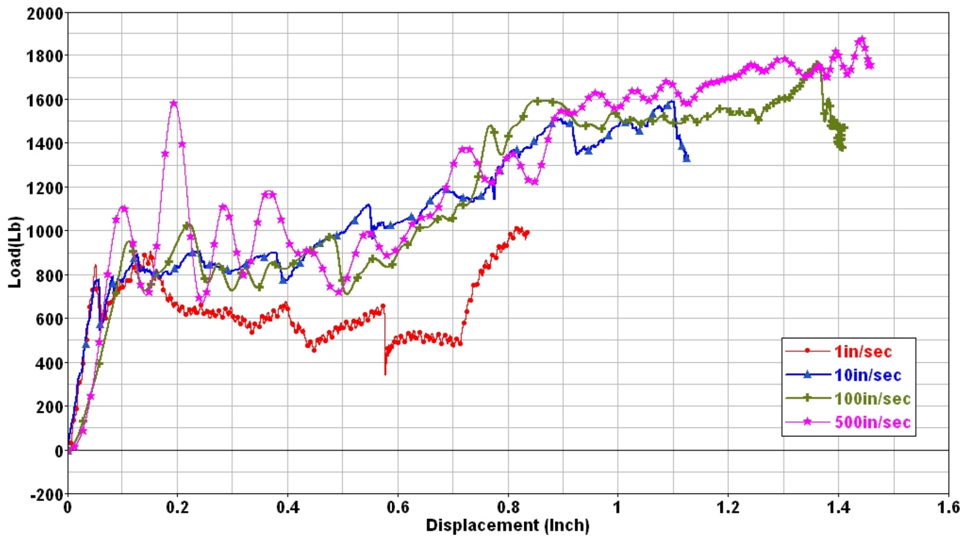


PHASE 2 : TESTS ON SCALED FUSELAGE SECTION

- Features of test article
  - Cylindrical panel construction
    - Nominal Radius ~ 6 inches
    - Sandwich (2 ply – core – 2 ply)
    - Floor beam – 10 ply fiberglass laminate
    - Energy Absorption by crushing of honeycomb core
  - Loading
    - Loading at two points using 0.75in diameter cylindrical rollers.
  - Strain gages
    - Gages mounted on floor and cylindrical wall to monitor strain rates.



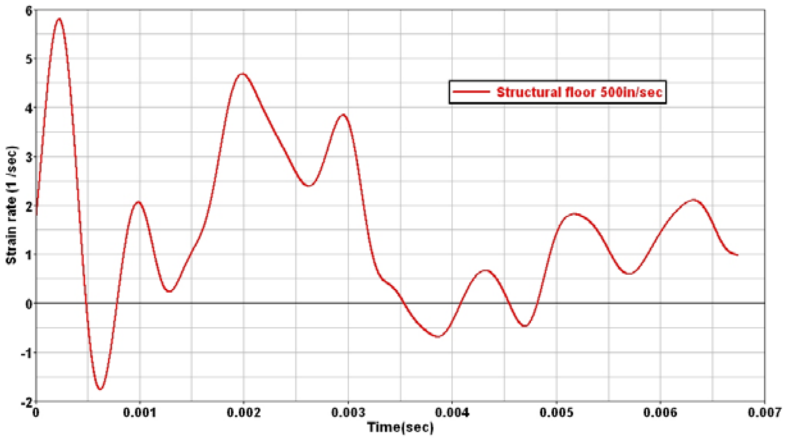
PHASE 2 : TESTS ON SCALED FUSELAGE SECTION



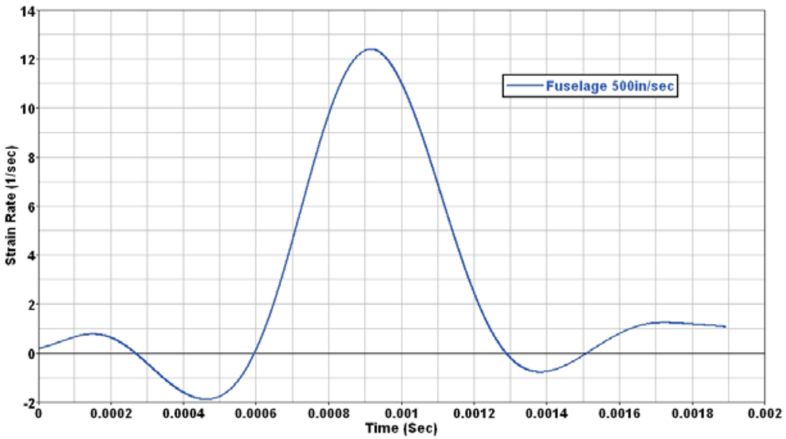
- Load-displacement response
  - No significant differences during initial loading prior to failure initiation.
  - Higher peaks observed with increasing loading rates
  - Final failure of floor beam delayed with increasing test speeds (consistent with observations of strain rate effect on material properties)
    - Floor beam snaps underneath the rollers at rate of 1 in/sec.

PHASE 2 : TESTS ON SCALED FUSELAGE SECTION

- Strain Rates
  - Maximum strain rates experienced at locations of gages were on the order of 10 s^{-1} at the highest test rates
  - No correlation observed between stroke and strain rates

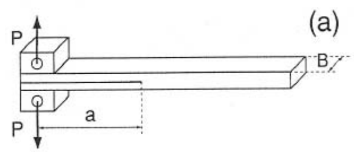


- Status of Phase-2
  - Testing completed
  - Documentation under progress. Report to be submitted 11/07

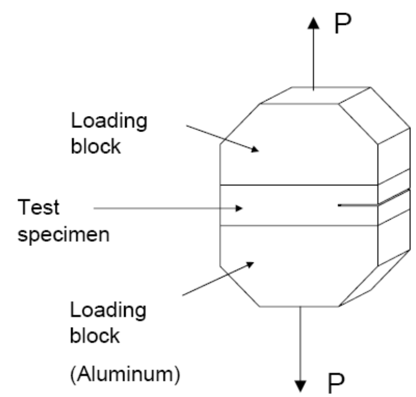


CRASHWORTHINESS OF COMPOSITE FUSELAGE STRUCTURES : PHASE 3

- Investigate rate effects on the fracture toughness of composite material systems
  - Literature review
  - Specimen & Fixture design
    - Minimize inertial effects associated with traditional ENF, DCB specimens
  - Testing & documentation



- STATUS
  - Experiments under progress



A Look Forward

- Benefit to Aviation
  - Understanding of contribution of material rate sensitivity to responses of composite structures under dynamic/crash loading.
  - Database of material properties and benchmark tests to calibrate analytical tools
- Future needs
  - Scaling studies
  - Validation of material models
  - Focused studies using other geometric configurations