

## KEYWORDS

High Strain Rate

Dynamic Mechanical Behavior

Fracture

Split-Hopkinson Pressure Bar

Confining Pressure

High-Speed Imaging

Materials Characterization

Deformation Response

Failure Mechanisms

Constitutive Model Development

Johnson-Cook Parameters

Shear Banding

The performance of materials at high strain rates is of interest for various applications (e.g., structural, military and sports). Southwest Research Institute® (SwRI®) has a long history in characterizing the high strain rate response of materials. The SwRI High Rate Test Laboratory housing the Split-Hopkinson pressure bar apparatus has been designated an ASME Historic Mechanical Engineering Landmark, based on pioneering work in the 1960s that allowed direct generation of the complete stress-strain curve for a single impact.

The SwRI High Rate Test Laboratory is equipped with instrumentation for measuring, recording and analyzing test data for strain rates approaching  $5000 \text{ s}^{-1}$ . High-speed imaging systems are available to record the high rate response. Lab capabilities include high rate testing in tension, compression, torsion and three-point bend. Microstructural characterization of tested material can be accomplished to determine deformation and failure mechanisms. The facility is staffed with experienced personnel who can adapt test conditions to meet unique requirements.

### Dynamic Test Capability

- Tension ( $\epsilon \leq 2 \times 10^3 \text{ s}^{-1}$ )
- Compression ( $\epsilon \leq 5 \times 10^3 \text{ s}^{-1}$ )
- Torsion ( $\epsilon \leq 2 \times 10^2 \text{ s}^{-1}$ )
- Fracture toughness
- Taylor impact ( $\epsilon \sim 10^5 \text{ s}^{-1}$ )

### Materials Testing Experience

- Armor materials
- Blast-resistant materials
- Metals
- Ceramics
- Glass
- Powders/granular materials
- Biological materials (tendons, ligaments, bone)
- Porous/foam materials
- Polymers
- Fiber composites
- Fabrics
- Concrete
- Rocks and soils

### Materials Characterization

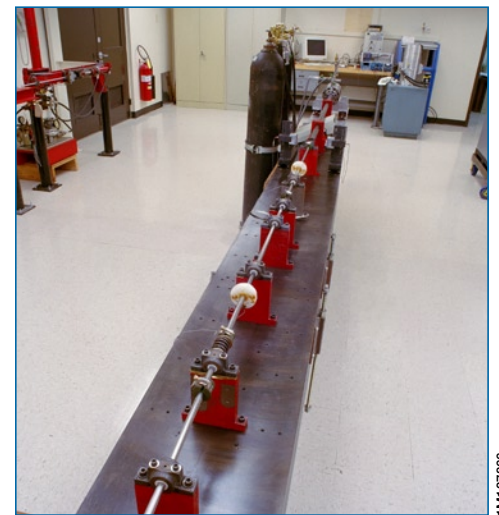
- Deformation response: stress-strain curves
- Strain rate effects
- Failure mechanism determination
- Shear and delamination testing
- Dynamic deformation and displacement measurements
- Fracture
- Constitutive model development
- Determination of Johnson-Cook model constants



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### Dynamic Test Equipment

- Split-Hopkinson pressure bar systems
  - Compression
  - Tension (direct, indirect)
  - Environments: vacuum, air, Ar, N
  - High temperature ( $\leq 1000^\circ\text{C}$ )
- High-speed torsion actuator
- High-speed data acquisition system
- High-speed imaging systems (up to  $10^6$  frames/second)
- High-speed strain gage amplifiers
- Displacement mapping system for 3-D dynamic strain measurements
- Confining pressure apparatus ( $\leq 500 \text{ MPa}$ )



SwRI High Rate Test Laboratory

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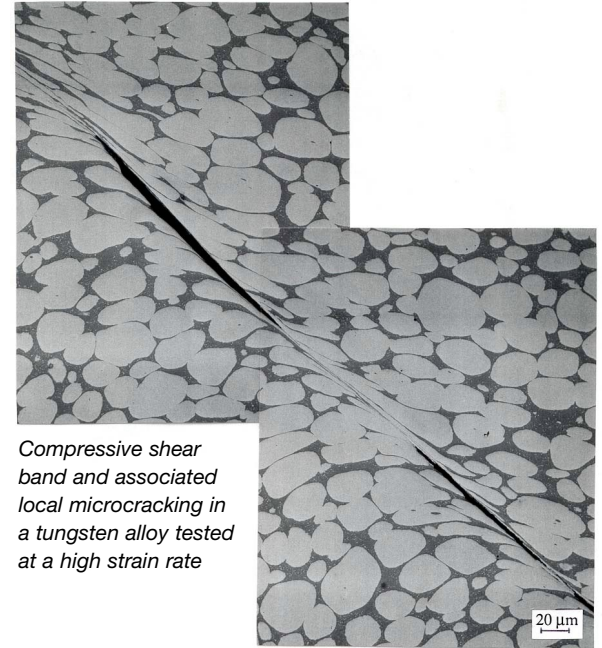


Dynamic mechanical test specimens

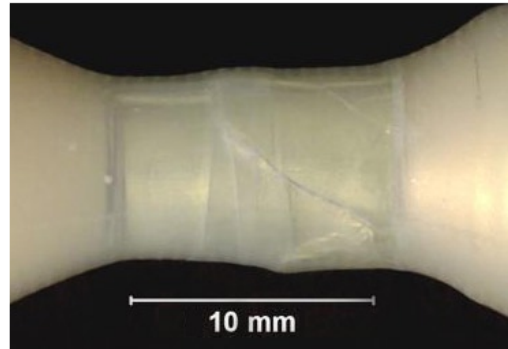
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## Support Capabilities and Facilities

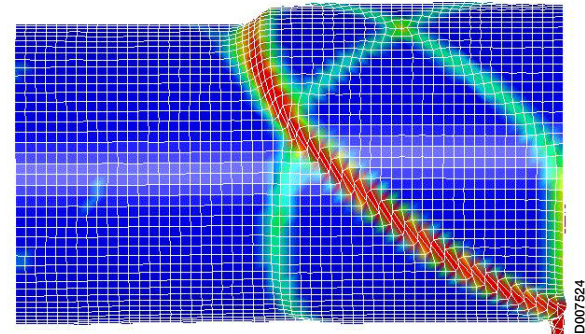
- Numerical simulations of experiments (LS-DYNA, CTH, EPIC)
- Metallurgical laboratory
  - Optical and scanning electron microscopy
  - Energy dispersive spectroscopy
  - Auger spectroscopy
  - X-ray diffraction
- Ballistics and explosives range
- Mechanical test laboratory
  - Low strain rate material characterization
  - Tri-axial compression and extension
  - High-temperature testing
  - Testing in extreme environments
  - Customized testing
- Full-service machine shop



*Compressive shear band and associated local microcracking in a tungsten alloy tested at a high strain rate*



*Shear failure in glass specimen following confined compression testing; damage profile captured with numerical simulation*



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