Fracture and Plasticity
Characterization of DH-36 Navy Steel

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Agenda

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- Motivation
- Background / Introduction
- Experimental Testing
- Specimens
- FE Simulations
- Calibration
Motivation

• Calibrate the fracture model for DH-36
  – Common Ship Construction Steel
  – Used for extensive testing at NSWC Dahlgren – Blast Protection
  – Need to fully understand the steel before analyzing the sandwiched plates consisting of steel backing plates coated with a thick layer of polyurea
Background – Yield vs. Fracture

Young’s Modulus, Density, and Yield Stress

Calibrated Fracture Model
Background – Fracture Models

- Polycrystalline Structure Model
- Mechanism based Model (nucleation, void growth and propagation)
- Phenomenological Physics Based Model (examples shown)
Modified Mohr Coulomb (MMC) Fracture Model

• Developed by Professor Wierzbicki and his team at the Impact and Crashworthiness Lab (ICL) at MIT

• Technology developed under the sponsorships of steel, automotive, and aerospace industries

• Proven to require less inputs parameters and result in superior accuracy

• Fracture is dependent on the state of stress (triaxiality and lode angle) and equivalent strain

\[
\bar{\varepsilon}_f = \left[ \frac{A}{c_2} \left[ c_3 + \frac{\sqrt{3}}{2 - \sqrt{3}} (1 - c_3) \left( \sec \left( \frac{\theta \pi}{6} \right) - 1 \right) \right] \cdot \left[ \frac{1 + c_1^2}{3} \cos \left( \frac{\theta \pi}{6} \right) + c_1 \left( \eta + \frac{1}{3} \sin \left( \frac{\theta \pi}{6} \right) \right) \right] \right]^{-\frac{1}{n}}
\]
Experimental Testing

- Specifically designed loading frames and specimens to achieve varying 3D stress states
Specimens

- **Dogbone**
  - Establish Stress strain
  - Test Anisotropy

- **Notched and Central Hole**

- **Punch**
Specimens, contd.

- Butterfly (ICL) (shear)

- Industry Shear
2D and 2D Digital Image Correlation (DIC)

- Accurate Strain Data
- Match Experiment to Simulation
Simulations

- FE Simulations conducted and validated (matching force - displacement) for all specimens
Find and record the exact point of the onset of fracture
Calibration

- Parameters from the surface can be used in a Abaqus (FE software) sub-routine to give element deletion (fracture).
Conclusions

• Calibration complete and successful
• Industry shear specimen gives inaccurate results
• Future Work
  – Higher Strain Rates (Impact and Explosive Loading)
  – Polyurea (Bi-axial modeling)
  – Polyurea and DH-36, optimized configuration for blast and impact protection
Questions

References

