Current Work in Support of Section III Division 3 of the ASME Boiler and Pressure Vessel Code

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Oct. 6, 2011

*Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste

- This is the part of the ASME Code that is most relevant to the design of radioactive material transportation packages

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Topics for Discussion

- NRC review/acceptance of the Code
- Sub-section WD
- Strain-based acceptance criteria
- Special Working Group on Computational Modeling for Explicit Dynamics

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NRC Review/Acceptance of the Code

Office of Defense Programs

- The Division of Spent Fuel Storage and Transportation has initiated a formal review of Section III Division 3 of the Code
- A team of senior technical experts is nearly finished with this review
- Comments are expected to be sent to ASME before the February Code Week meeting
- This is the first step toward having the NRC recognize the Code – ASME resolution of comments may be needed for full recognition

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Section WD

Office of Defense Programs

- The Code already has rules for transportation packages (Section WB) and storage casks (Section WC)
- Section WD is being written for internal support structures (baskets)
- Most sub-parts of this section are finished and are going through the approval process
- When all sub-parts are approved, the entire section will be added to the Code

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Strain-Based Acceptance Criteria

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- The ASME Code has traditionally relied upon stress-based acceptance criteria

- For severe energy-limited events a strain-based approach provides a more consistent margin of safety (the current rules were originally requested to provide guidance for airplane impact analyses)

- Rules for inelastic analyses using strain-based acceptance criteria have been developed and are going through the approval process

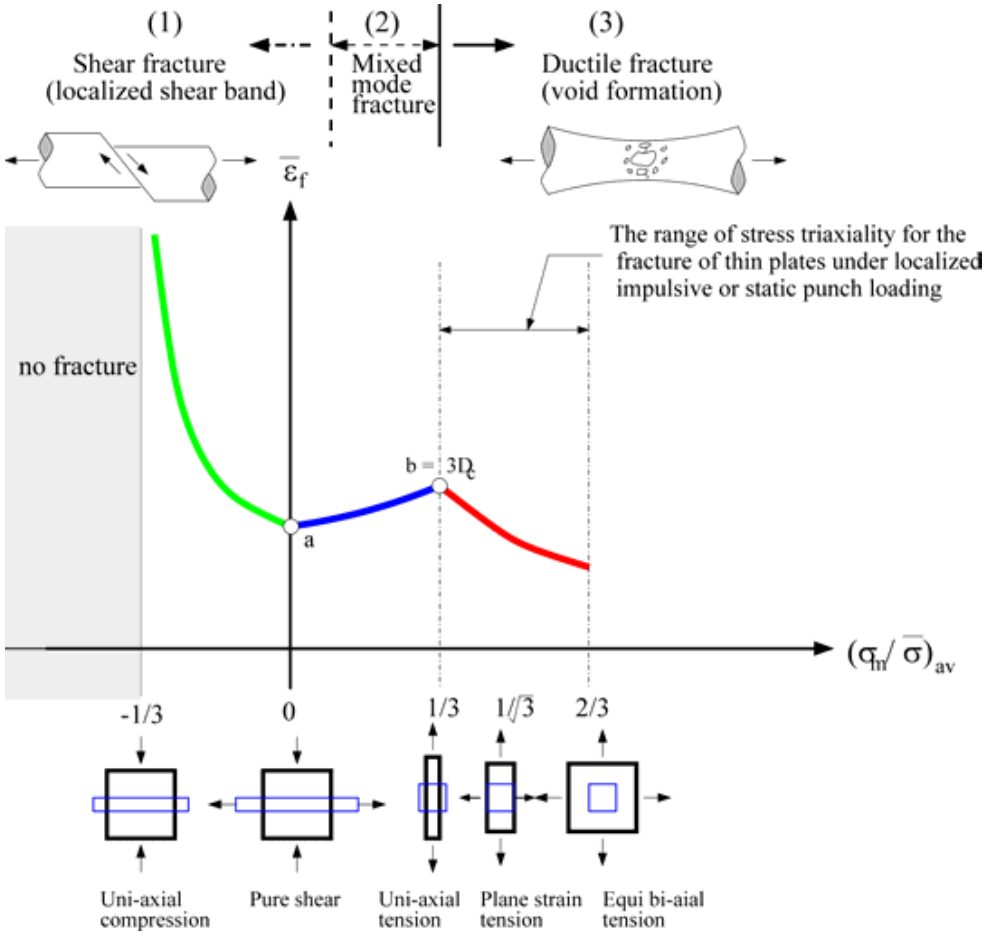
Strain-Based Acceptance Criteria (cont.)

- Limited to energy-limited events (such as impact)
- Intended for events that are not moderated by impact limiters, such as puncture or airplane impact
- Currently limited to 304/304L and 316/316L steel
- Requires detailed knowledge of the stress-strain curve
- Requires tracking of individual heats of material
- Recognizes that failure strain is a function of stress state (stress triaxiality)
- Stress triaxiality varies with both time and location
- Use requires “Quality Models”

Triaxiality Factor

- ASME definition is first stress invariant (sum of the principal stresses) divided by the deviatoric stress (von Mises stress) – uniaxial tension is 1

- Many finite element theory manuals define it is the mean stress divided by the deviatoric stress – uniaxial tension is 1/3



Strain-Based Acceptance Criteria (concl.)

- At regions away from a discontinuity:
  - Average through the cross-section:

$$[(TF)(\varepsilon^p_{eq})]_{avg} \leq (\mathbf{0.67}\ \varepsilon_{uniform})$$

  - Maximum location (may not be on the surface):

$$[(TF)(\varepsilon^p_{eq})]_{max} \leq [\varepsilon_{uniform} + 0.25\ (\varepsilon_{fracture} - \varepsilon_{uniform})]$$

- At the location of a discontinuity:
  - Average through the cross-section:

$$[(TF)(\varepsilon^p_{eq})]_{avg} \leq (\mathbf{0.85}\ \varepsilon_{uniform})$$

  - Maximum location (may not be on the surface):

$$[(TF)(\varepsilon^p_{eq})]_{max} \leq [\varepsilon_{uniform} + 0.25\ (\varepsilon_{fracture} - \varepsilon_{uniform})]$$

- These inequalities must be satisfied at all time increments

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Special Working Group on Computational Modeling for Explicit Dynamics

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- This group is tasked with defining “Quality Models”, which the NRC will require for either stress-based analyses or strain-based analyses

- The output of their efforts will be a guidance document which is expected to become an ASME Code Appendix

- Many of the items in this guidance document will be incorporated into NRC guidance, either through an ISG or revision to Reg. Guide 7.6

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SWG on Computational Modeling Guidance Document

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- Choosing a suitable finite element code
- Input to the finite element analysis
  - Geometry
  - Mesh/element selection
  - Contact/friction/interfaces
  - Material models/properties
  - Boundary conditions
  - Initial conditions
- Analysis control and formulation
  - Time increment
  - Mass scaling
  - Hourglass control and shear locking
  - Damping

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SWG on Computational Modeling Guidance Document (cont.)

- Other considerations
  - Residual stresses/strains
  - Additive damage from sequential events
  - Thermal stresses due to differential thermal expansion
  - Modeling of welded connections
  - Modeling of components that buckle
  - Modeling of bolted connections
  - Gaps
- Modeling examples including mesh convergence studies
- Analysis checking
- Results/reporting