Integrated Approach for Material Modeling

Phase Transformation, Stress and Failure

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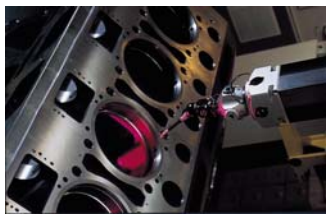
Outline

- Material challenges and Integrated Approach
- Material modeling of manufacturing process and performance at microstructure level
- Applications of those modeling
- Future needs

Material Challenges

- New emission regulations
- Demanding of higher reliability and lower cost
- New applications and new environments
- Increasing new design and production volume

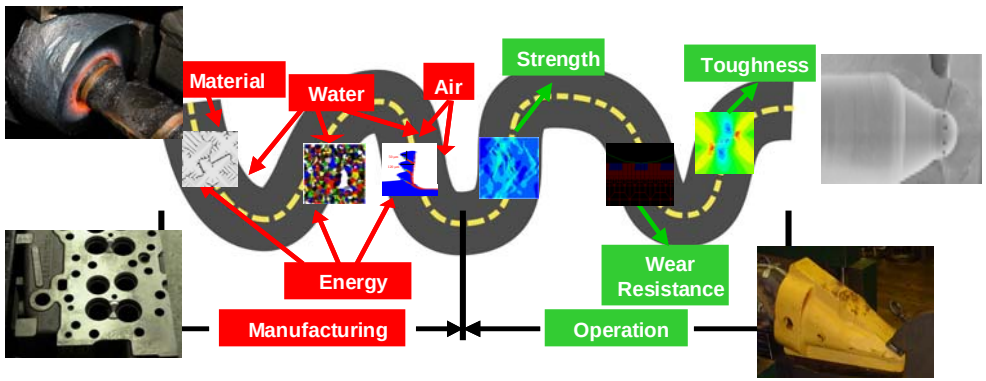
→ Cost effectively produce parts with high strength, longer fatigue life, and better wear and corrosion resistance


Material Design and Process

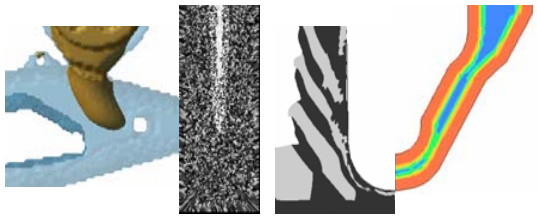
- Understand impact of manufacturing process towards material behaviors
- Maximize material performance with proper process flow and parameters
- Develop and utilize modeling tools to improve design

- ***Integrated approach for manufacturing process and material performance***

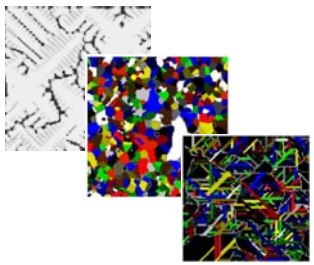


Phase Transformation, Residual Stress and Failure

Manufacturing Process



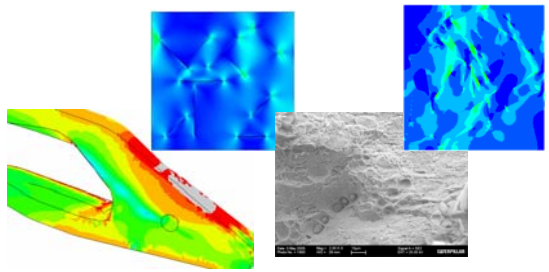
Casting; Heat treat,
Forging; Machining



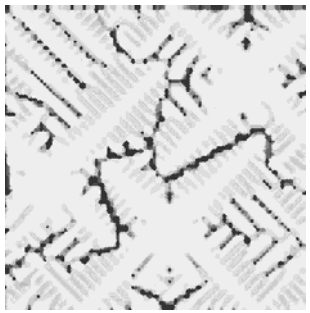
Microstructure;
Residual stress;
Defects

Fracture; Fatigue; Wear

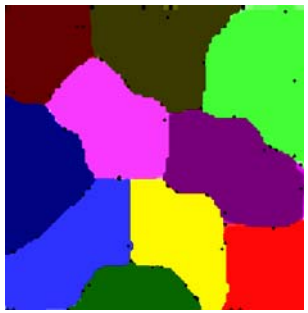
Material Performance



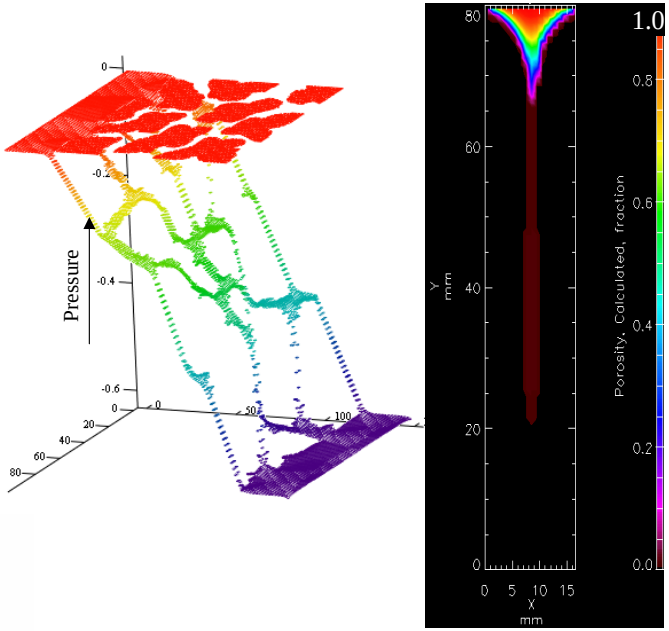
Casting Microstructure and Defects Model

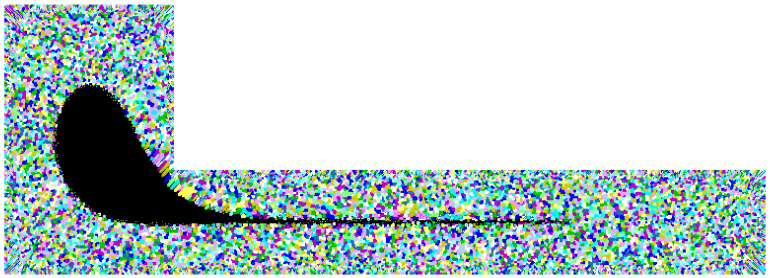


Carbon segregation



MnS inclusions





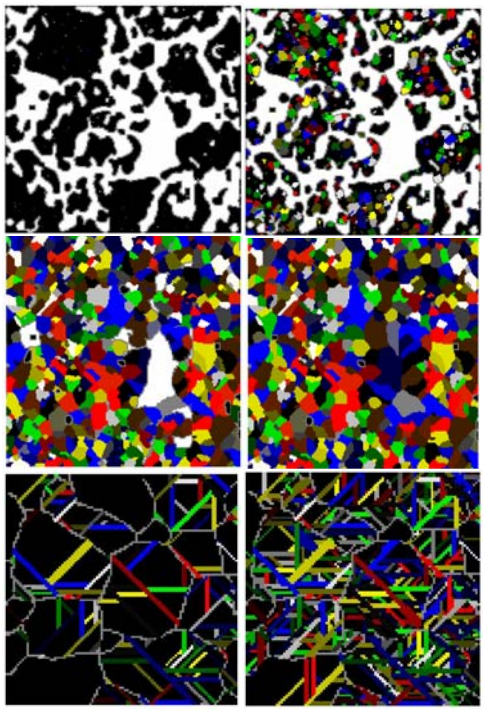
Shrinkage/gas porosities

Microstructure, segregations, residual stress → Following process

Inclusions, porosities → Performance

A. Catalina

Microstructure Evolution During Heat Treat



Austenization, grain growth, martensitic transformation

Material Properties:

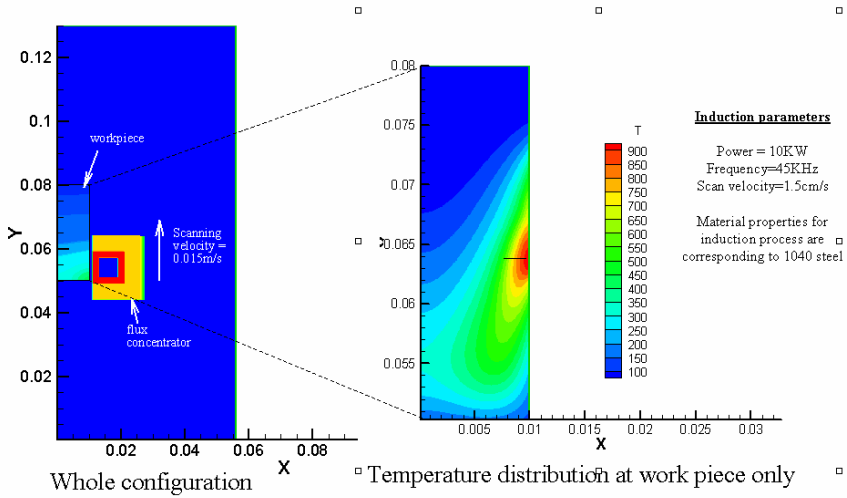
Phase; phase distribution(spacing/lath/plate size); segregation; grain size; precipitation; inclusions; other defects

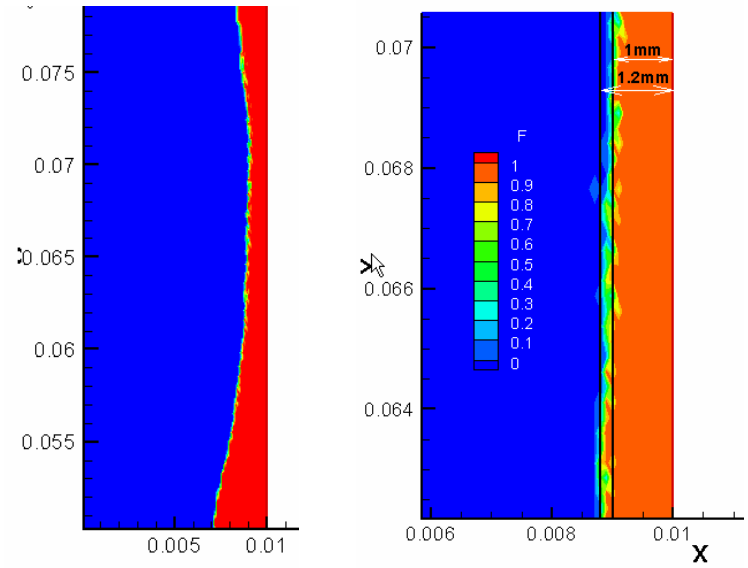
Material states:

Residual stress; accumulated plastic strain(dislocation slip); internal damage(micro cracks, voids)

B.J. Yang

Residual Stress at Macro and Micro Level





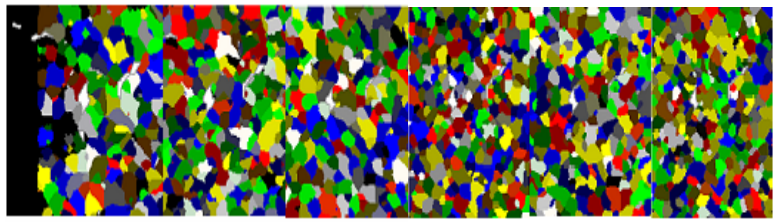
Induction temperature

Material state: residual stress and accumulated plastic strain

→ Temperature history

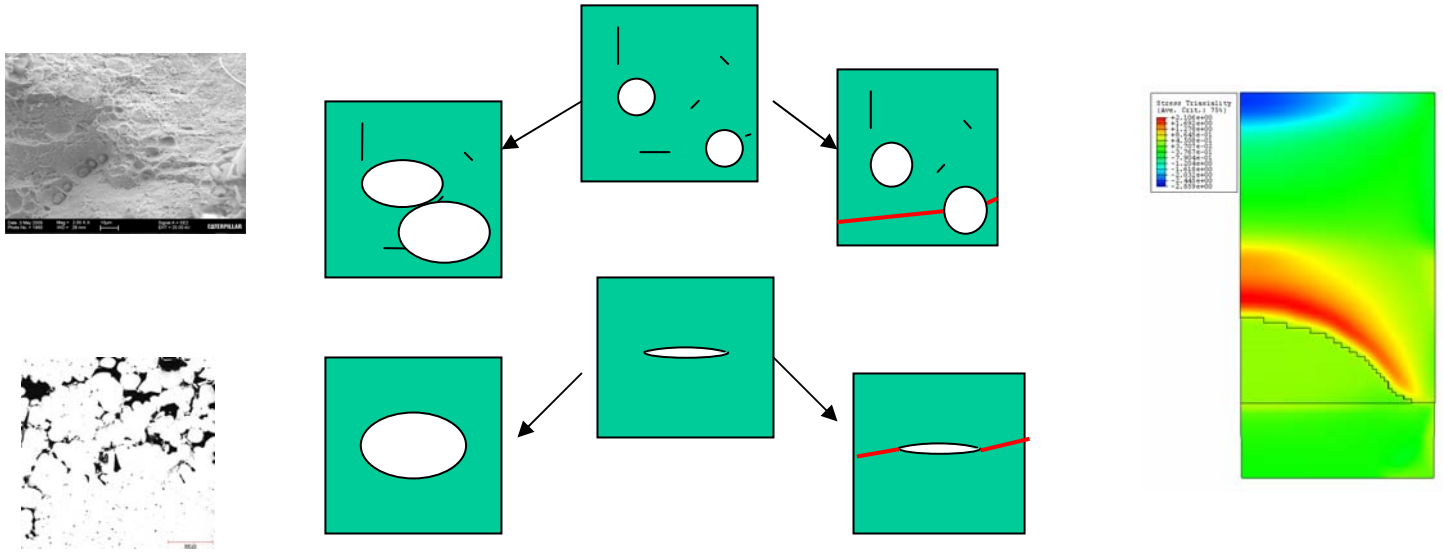
→ Microstructure evolution or constitutive

→ Material data



Induction hardness and grain size distribution

Fracture of Steel

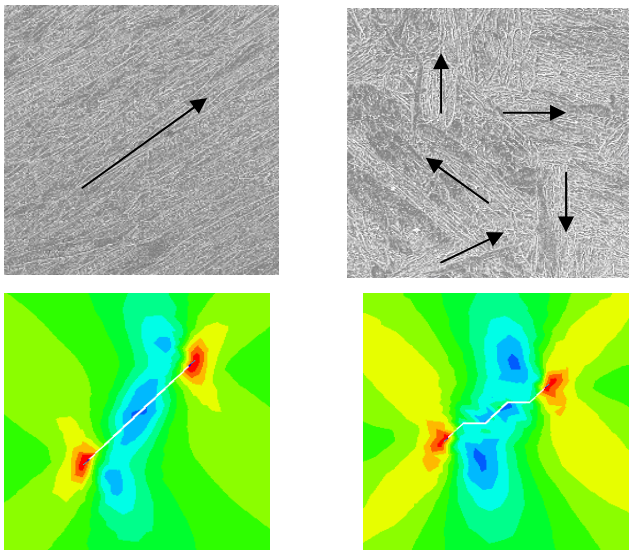


Void growth and micro propagation failure mechanism

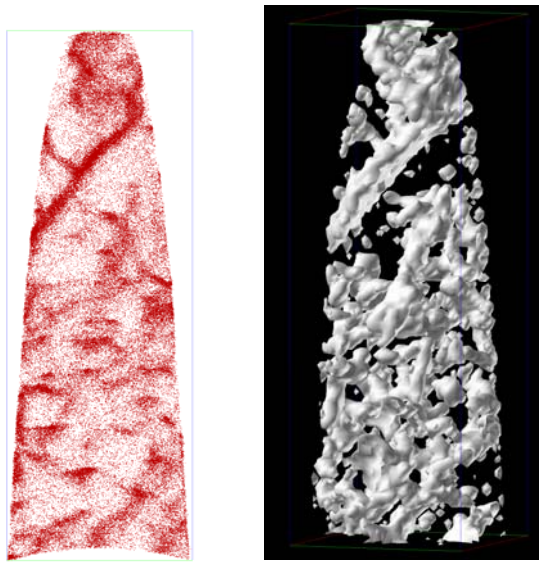
Defects like porosity, inclusion, precipitates act as failure initiation sites

Material constitutive is based on void growth/coalescence and brittle fast crack propagation

Microstructure and Toughness



Martensite lath effects on crack propagation

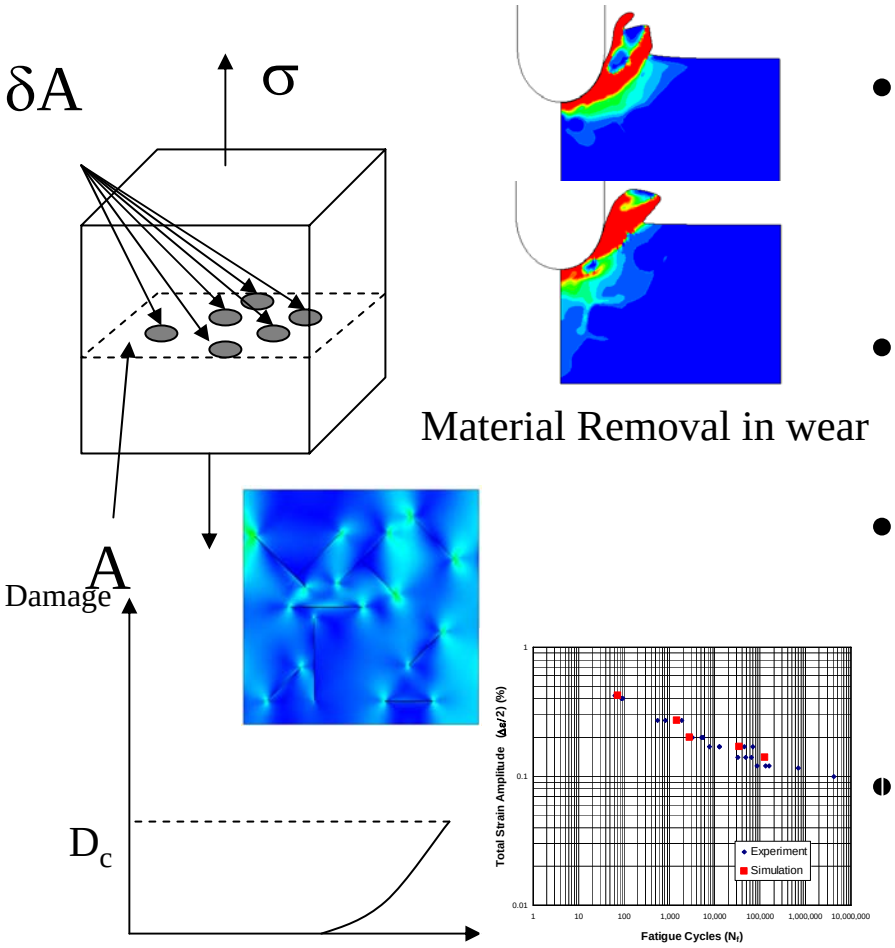


Carbon distribution

Different material characterization methods help us understand microstructure impact on steel toughness

D. Sherman

Damage, Fatigue and Wear Resistance

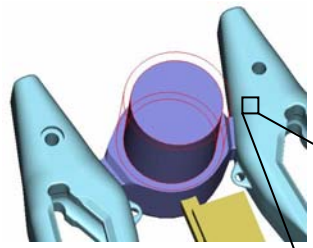


Material Removal in wear

Continuum damage model for fatigue

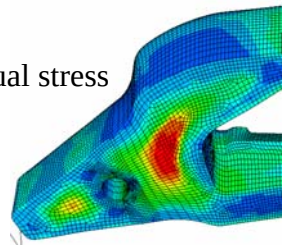
- Initial damage distribution based on defects
- Implicit continuum damage evolution model
- Wear modeling to treat material removal as machining process
- Phase information were built into the material removal simulation

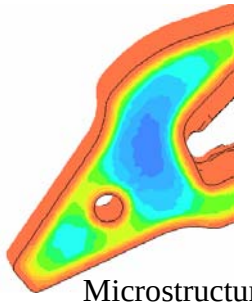
Large Casting Part Failure Analysis



Grain size, Segregation

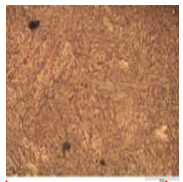
Residual stress



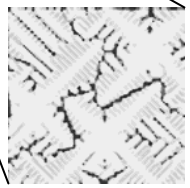


Microstructure

Martensite



M+B



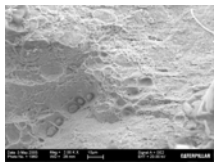
ML casting simulation

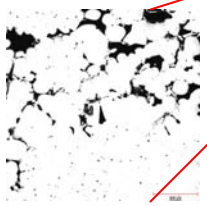
ML heat treatment simulation

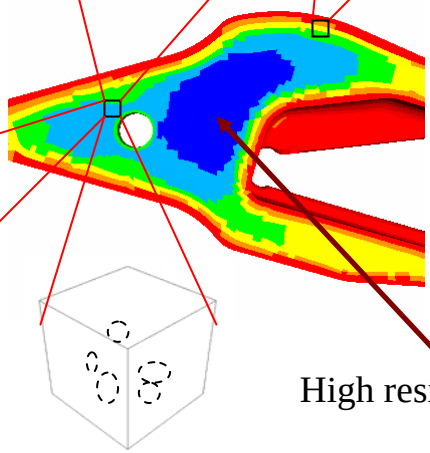
Microstructure

Material property
Residual stress

Inclusions, Porosity

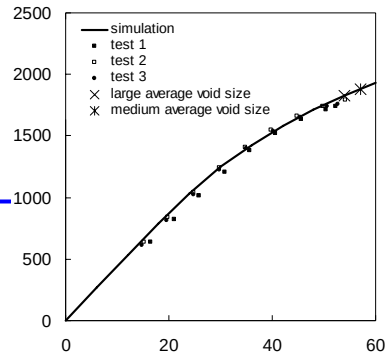




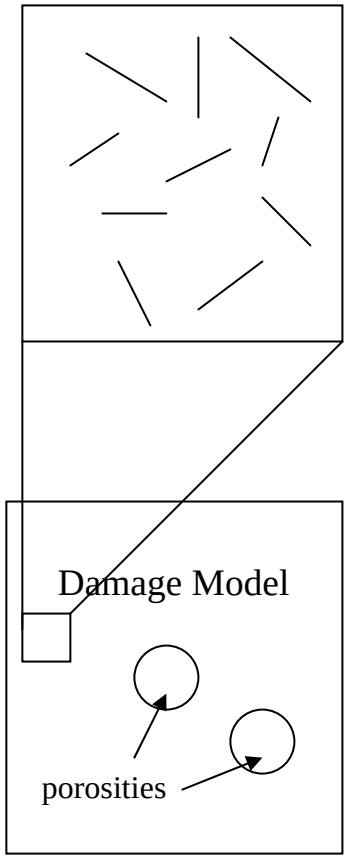


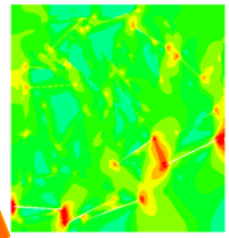
High residual stress

Loading

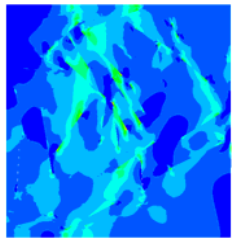


Modeling of Grey Iron Part Fatigue Life

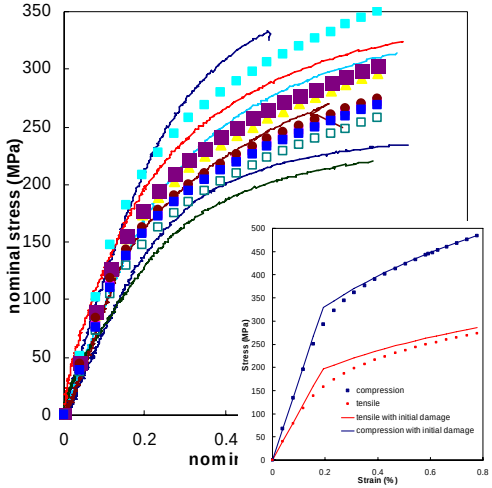


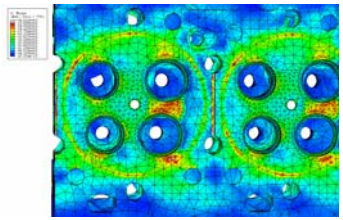


Tensile

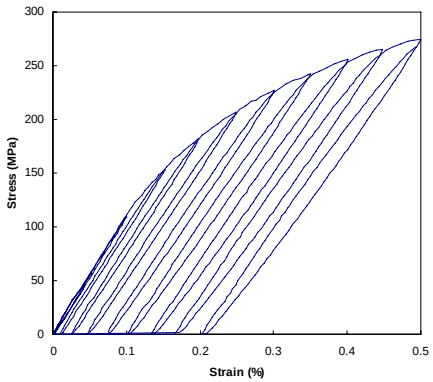


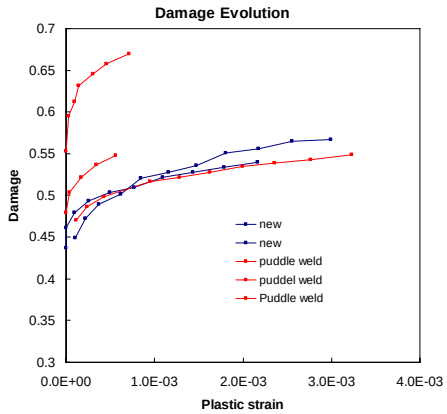
Compression





Validation





Summary

- New challenges for material require all new approach for design, material selection and analysis prediction – an integrated approach based on microstructure to look at component whole life cycle.
- Deeper understanding and advanced capabilities of testing and modeling material behavior, especially their microstructure, residual stress and failure are essential for integrated approach.

Thank You!