Void Kinematics and Tomography for Anisotropic Damage

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Problem

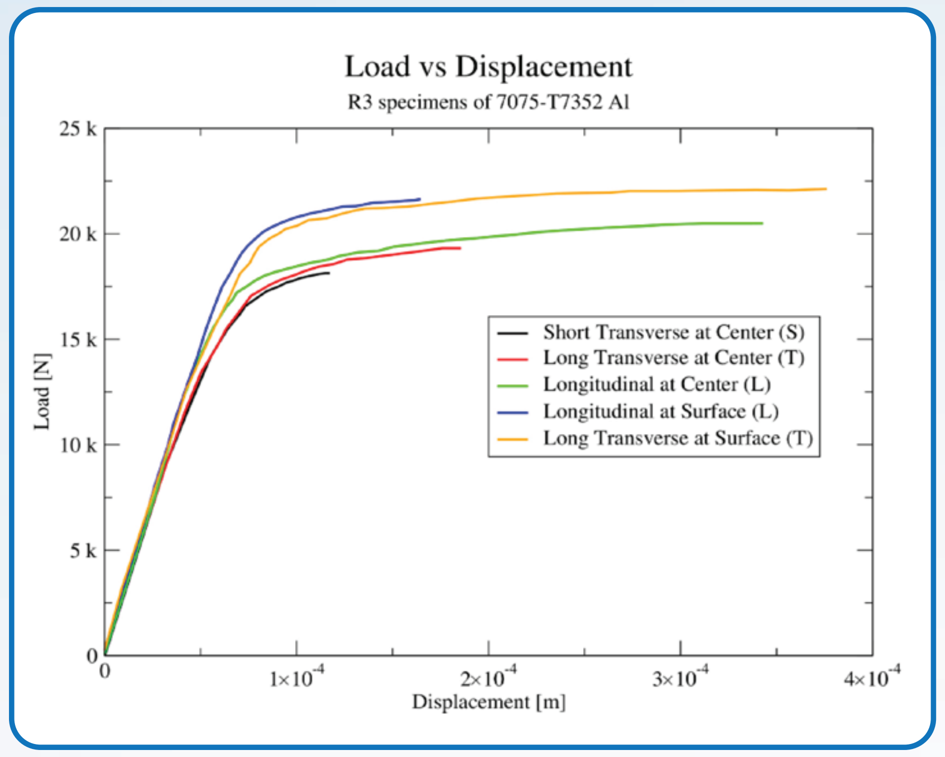
- Rolled metallic alloys used in NW components exhibit anisotropic behavior in failure
- Current models in simulation codes do not take this behavior into account

Approach

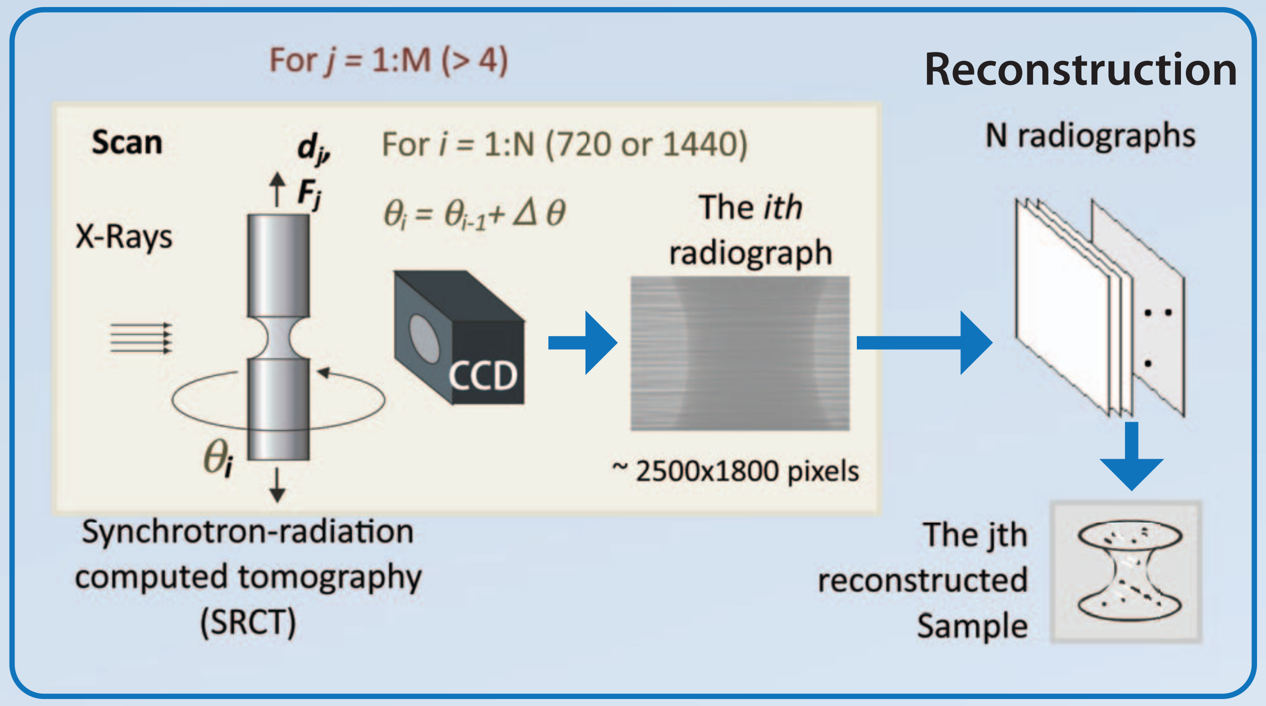
- Combined experimental and modeling program
- Experiments determine microstructure and associated anisotropic damage mechanisms
- Micromechanical model that incorporates microstructural features and kinetics of void growth and coalescence

Anisotropy

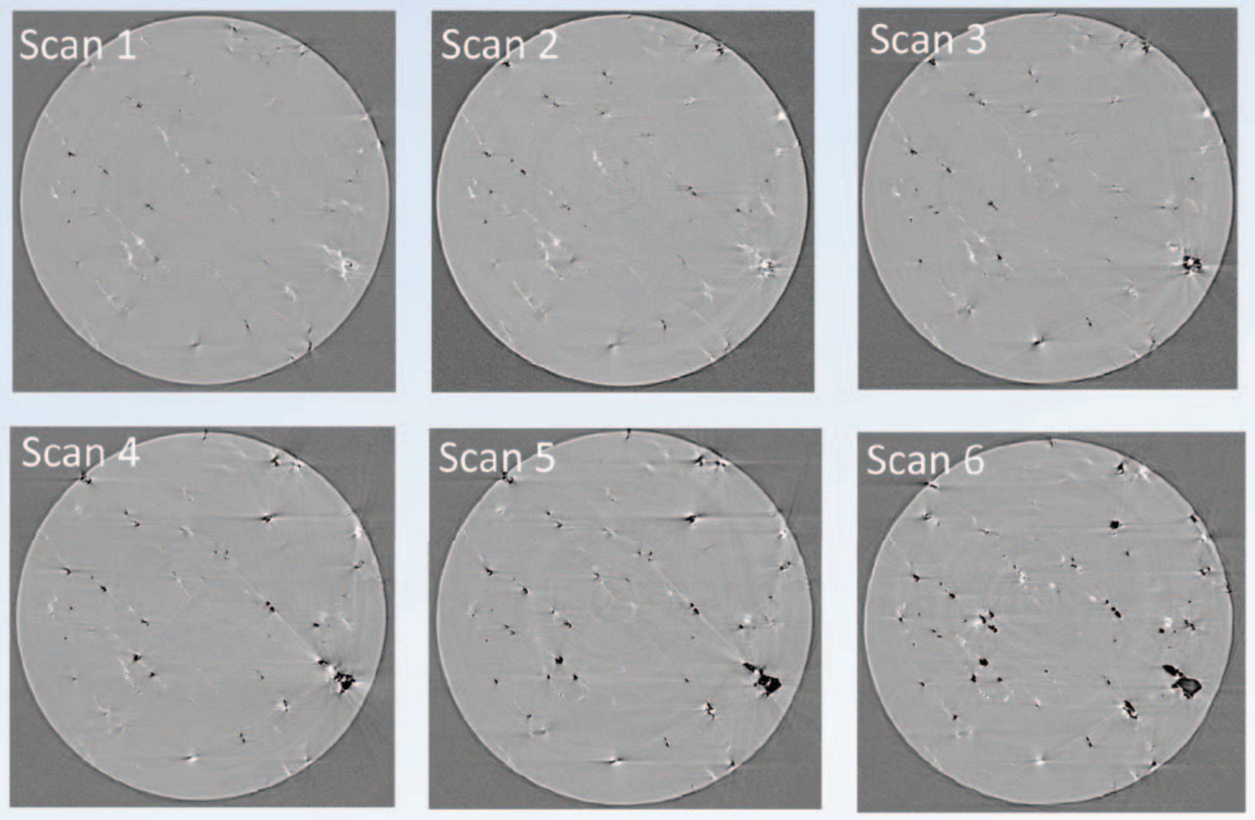
- Loading part of stress-strain curve similar for different loading directions
- Failure strain different for different loading directions



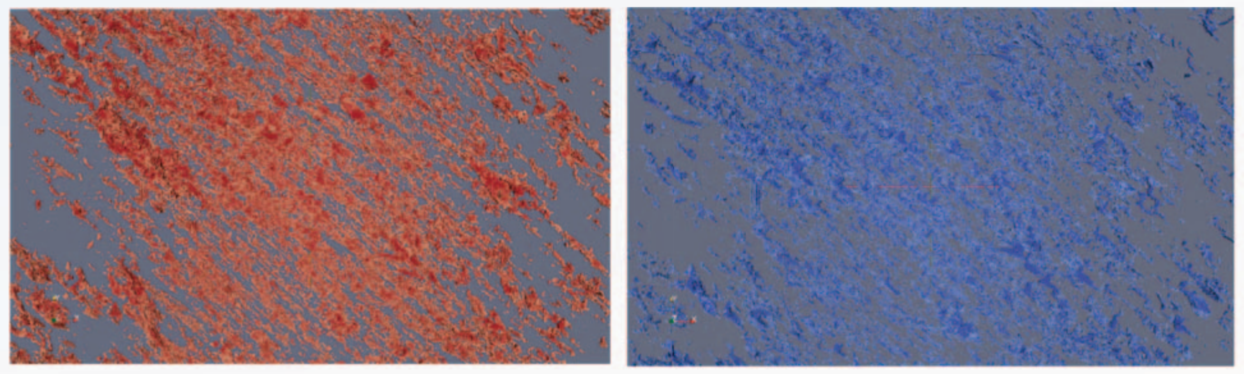
In-situ X-Ray CT Experiment at LBNL ALS



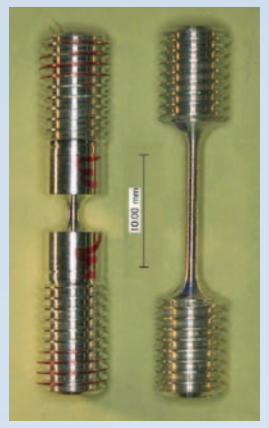
Damage Evolution



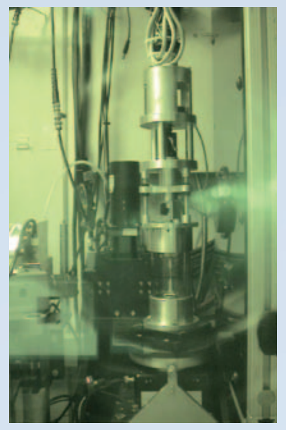
3D Microstructure



Particles | Voids

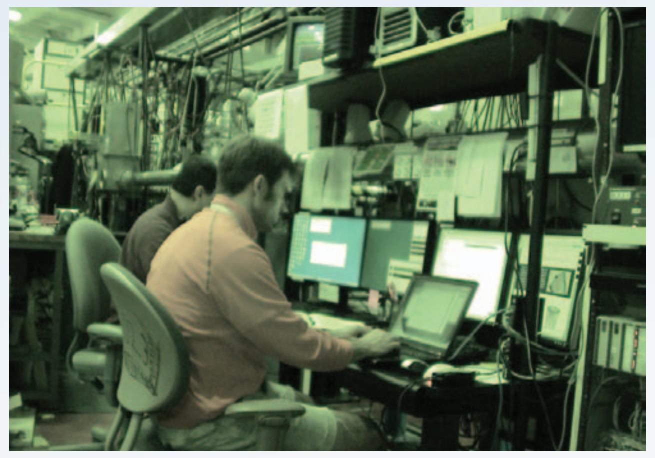


Specimens



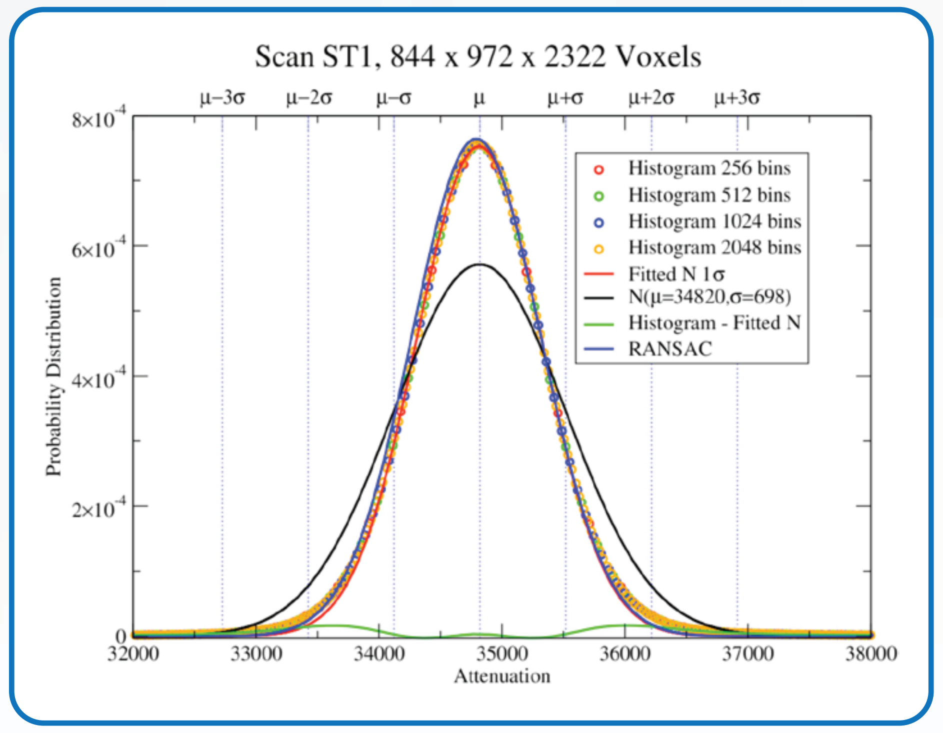
Custom Loading Stage

X-Ray Enclosure

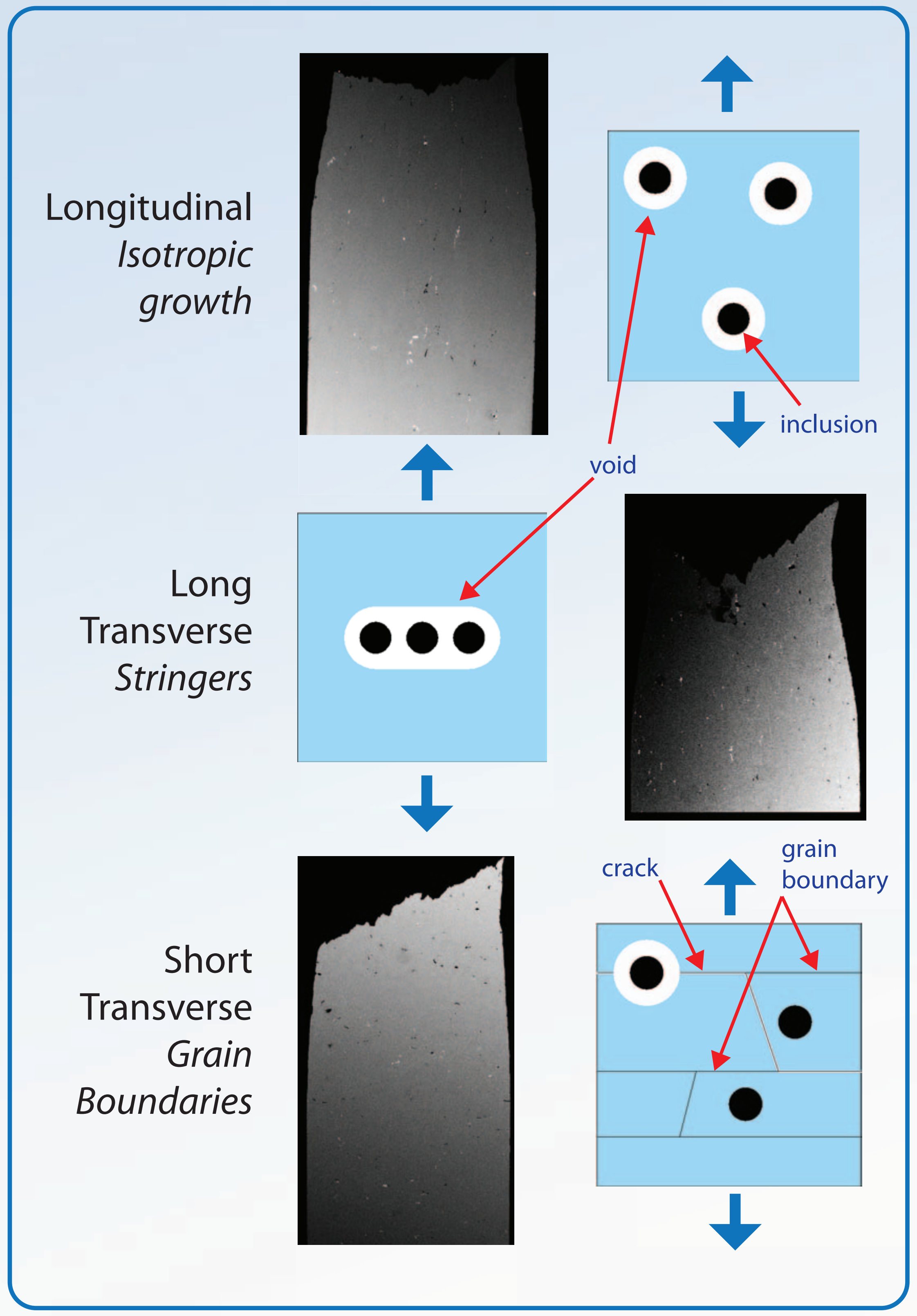


Reconstruction

Statistical Analysis



Mechanisms



Constitutive Model

Elastic Energy:

$$W^e(\boldsymbol{\epsilon}^e, T) = W^{e,\mathrm{vol}}(\theta^e, T) + W^{e,\mathrm{dev}}(\boldsymbol{\epsilon}^e, T),$$

$$W^{e,\mathrm{vol}}(\theta^e, T) = \frac{\kappa}{2}\left[\theta^e - \alpha(T - T_0)\right]^2 + \rho_0 C_v T \left(1 - \log\frac{T}{T_0}\right),$$

$$W^{e,\mathrm{dev}}(\boldsymbol{\epsilon}^e, T) = \mu \parallel \mathrm{dev}(\boldsymbol{\epsilon}^e) \parallel^2,$$

Stored energy of cold work:

$$W^p(\epsilon^p, \theta^p, T) = W^{p,\mathrm{vol}}(\theta^p, T) + W^{p,\mathrm{dev}}(\epsilon^p, T),$$

$$W^{p,\mathrm{vol}}(\theta^p, T) = \frac{n\sigma_0(T)\epsilon_0^p}{n+1} N \frac{4\pi a^3}{3} g(\theta^p, n),$$

$$W^{p,\mathrm{dev}}(\epsilon^p, T) = \frac{n\sigma_0(T)\epsilon_0^p}{n+1}\left(1 + \frac{\epsilon^p}{\epsilon_0^p}\right)^{\frac{n+1}{n}},$$

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