3.22 Mechanical Properties of Materials
Spring 2008

Effects of radiation on mechanical behavior of crystalline materials

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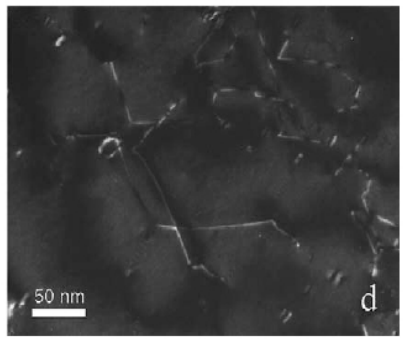
What does radiation DO?

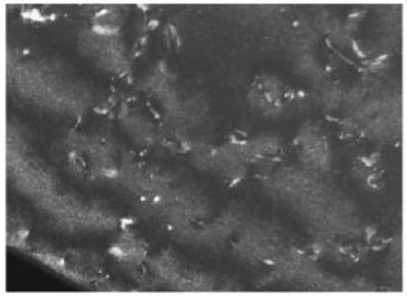
- **Material Focus:** High strength steels such as T91 (Fe-9Cr-1Mo : 0.2 at% C)
  - **Application of interest**
    - -Nuclear reactors

- Forms of radiation, flux in materials measured in #/(cm2*sec)
  - -Alphas, Betas, Other Charged Particles
  - -Gamma Rays
  - -**Neutrons**

- **Effects on materials**
  - **Creates defects everywhere!**
  - ➢Increased Yield Strength
  - ➢Decreased toughness
  - ➢Increased Rate of Surface Corrosion
  - ➢**Increased Creep Rate**



Unirradiated T91



Irradiated T91

X. Jia, Y. Dai. "Microstructure of Martensitic Steels T91 and F82H after irradiation in SINQ Target-3." *Journal of Nuclear Materials* 318 (2003): 207-214.

Microscopic Mechanism: Creep

$$\dot{\varepsilon}_{II} = \kappa \frac{\sigma}{d^3} D_o e^{-\frac{Q_{GB}}{RT}}$$

Steady State Creep Rate - Coble Creep

- Coble Creep
  - -Grain boundary diffusion
  - -Strongest in fine-grained materials – our steels!
  - -Proportional to:
    - •Stress
    - •1 / (grain size)^3
    - •Vacancy to grain-boundary diffusion activation energy
      - •Typically half that for lattice diffusion

- •Processing and Design to avoid Coble Creep:
  - -Anneal to increase grain size
  - -Decrease stress on components

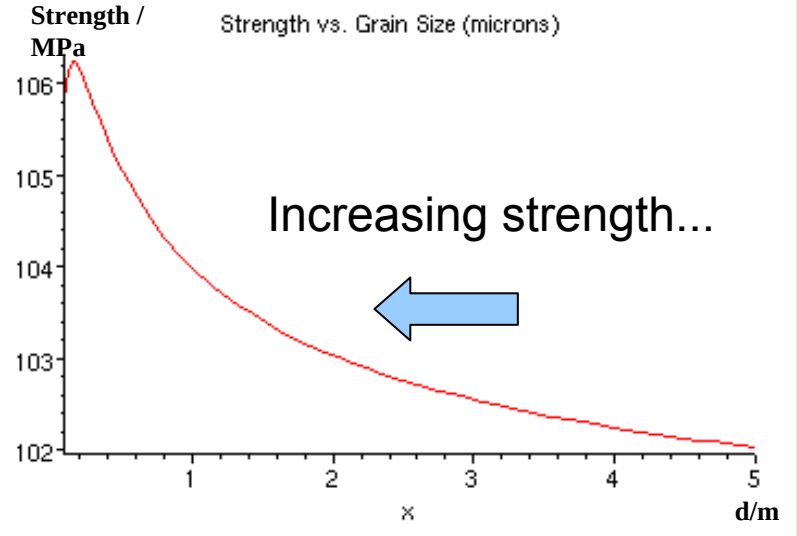
BUT…this reduces yield strength as shown by Hall-Petch: $\sigma_y = \sigma_o + \frac{K}{\sqrt{d}}$

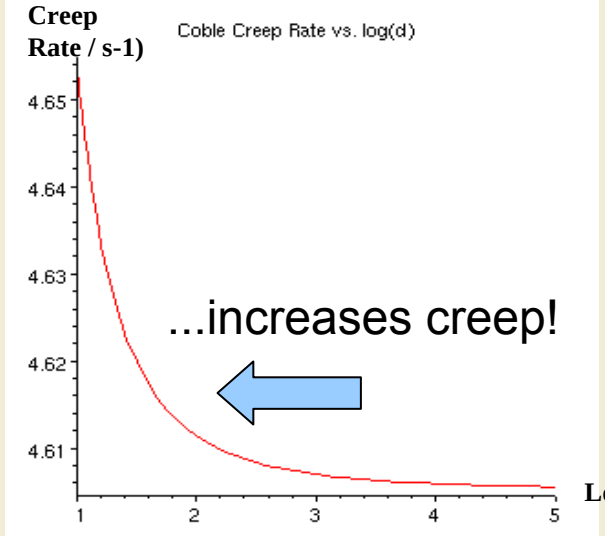
SO…..

Optimization & Prediction

Optimization

Find balance between strength and creep resistance…





Graphs Constructed in Maple with arbitrary scaling

Coble Creep Rate increases by $d^{-2.5}$ faster than strength.

- **Prediction – Example Decision in Reactor Design**
- Picking grain size for steel
  - Determine maximum creep rate from allowable thinning
  - Determine minimum grain size from creep rate
  - Check other parameters – strength, UTS...