3.22 Mechanical Properties of Materials
Spring 2008

For information about citing these materials or our Terms of Use, visit: http://ocw.mit.edu/terms.
Effects of radiation on mechanical behavior of crystalline materials

Hannah Brice, Jerod Ketcham, Michael Short
MIT Department of Materials Science and Engineering
Cambridge, MA 02139  USA

May 2008
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

Microscopic Mechanism: Creep

- Coble Creep
  - Grain boundary diffusion
  - Strongest in fine-grained materials – our steels!
  - Proportional to:
    • Stress
    • $1 / (\text{grain size})^3$
    • 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...

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...

Graphs Constructed in Maple with arbitrary scaling