University of Virginia

Department of Physics

Physics 606: How Things Work II

Lecture #34 Slides:

Knives and Steel

Knives and Steel

Question:

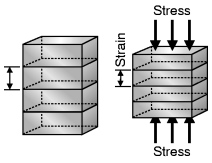
If you take a steel paper clip and bend it repeatedly, will it become stiffer or less stiff with each new bend (at least initially)?

Observations About Knives

- Some knives keep a better edge than others
- Some knives chip while others bend
- Some knives rust while others don't
- Some rust-resistant knives don't keep an edge
- Some rust-resistant knives aren't magnetic

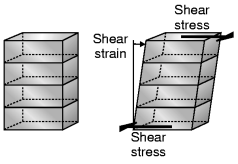
Stress and Strain

- When you squeeze a material, its thickness decreases
  - Stress: the force per unit of top surface area (pressure)
  - Strain: the fractional change in thickness
- For small stresses, strain is determined by the compressibility of the atoms themselves
- Since most steels contain similar atoms, most have the same relationship between stress and strain



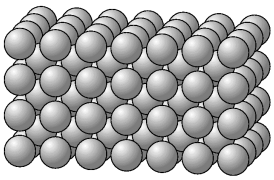
Shear Stress and Shear Strain

- When you bend a material, it flexes
  - Shear stress: the force per unit of cross sectional area
  - Shear strain: the angle of bend in the material
- For small shear stresses, shear strain is determined by atomic properties
- Since most steels contain similar atoms, most have same relationship between shear stress and shear strain



Steel Crystals

- Steel is a crystalline material
- Crystals have large regions of orderly atoms
- Surfaces of atoms can "slip" across one another

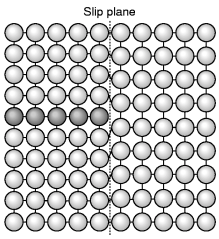


Elastic and Plastic Deformation

- For small shear stresses, steel deforms elastically
  - Deformation involves no overall shifting of atoms
  - Deformation vanishes when shear stress is removed
  - Forces involved are proportional to distortion
- For large shear stresses, steel deforms plastically
  - Deformation involves shifting atoms (slip)
  - Deformation is permanent
  - Forces involved are less than proportional to distortion

Controlling Slip

- Dislocation defects assist slip
  - Extra row of atoms allows a sheet of atom to slip gradually
- Thermal energy assists slip
  - It helps dislocations move
  - Dislocations help slip
- To stop slip
  - Eliminate dislocations (difficult)
  - Lower temperature (awkward)
  - Spoil crystal structure (easy)
  - Hardened steel is harder to bend



Spoiling Crystal Structure

- Work hardening
  - Working breaks up crystals into tiny bits that won't slip
- Alloying
  - Introducing alien crystallites impedes slip in steel crystals
- Heat treatment
  - Changes crystallite sizes and mixtures to alter ease of slip

Question:

If you take a steel paper clip and bend it repeatedly, will it become stiffer or less stiff with each new bend (at least initially)?

Steel and Carbon 1

- Below 723 C, iron and most steels are *bcc* ferrite
  - Ferrite doesn't dissolve carbon well
  - Carbon in steel forms hard crystallites of iron carbide
  - Depending on size and shape, these crystallites impede slip
- Above 723 C, iron and most steels are *fcc* austenite
  - Austenite dissolves carbon well
  - Austenite usually does not contain iron carbide
  - Austenite is quite susceptible to slip
  - Austenite is nonmagnetic