MSE160 Notes

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Contents

1 Introduction

1.1 Types of Material

- There are three classes of material (though not all materials fall under these categories):
  - Metals
  - Ceramics
  - Polymers
- **Metals** (e.g. Fe, Cr, Cu, Zn, Al) are held together with *mellatic* bonds and is described by **bond theory**.
- **Ceramics** (e.g. poreclain, concrete) are held together with *ionic* bonds and are *brittle*. A lot of them are metal oxides.
- **Polymer** (Teflon®, Gore-tex®, polyethylene) *tend* to be from *covalent bonds*

> **Warning:** The word plastic actually describes a material property, and not a material type. There are plastics that are not polymers.

- Examples of materials that do not fall under this classification scheme include wood, skin, superconductors, and more.

1.2 Elastic Behaviour

- Hooke's law tells us that $F = -k\Delta x$, where Δx is the displacement from equilibrium.
- **Engineering stress** is defined as $\sigma = \dfrac{F}{A_0}$ where A_0 is the *initial* (unloaded) cross-sectional area.

> **Warning:** Due to material properties, the cross sectional area of a spring can change as it elongates or compresses, so the engineering stress only refers to the initial cross sectyional area. The *true stress* refers to the force divided by the real area.

- **Engineering strain** is defined as $\varepsilon = \frac{\Delta \ell}{\ell_0}$ and the two are related via the **Young's Modulus**:

$$\sigma = E\varepsilon \tag{1}$$

- There are two possible definitions for elastic deformation. When viewing it from a macroscopic perspective:

  Definition: During elastic deformation, the sample dimensions return to their original dimensions upon unloading.

  but it is also possible to view it from a microscopic perspective:

  Definition: During elastic deformation, atoms return to their original positions upon unloading.

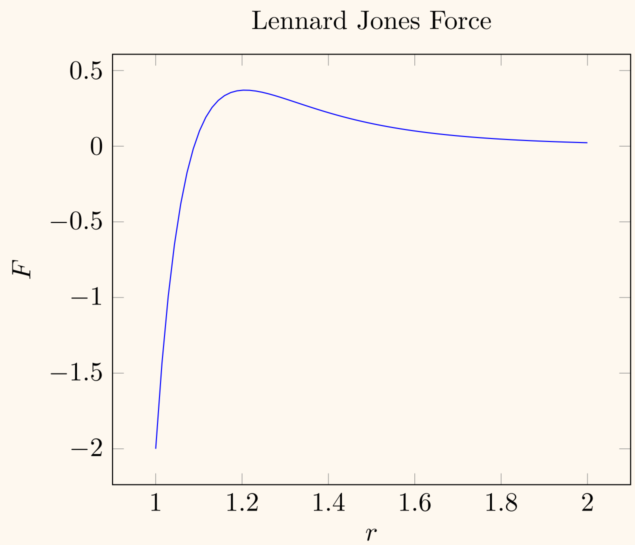
1.3 Simple Model for Bonding in solids

- A crudge (but quite accurate) model is to assume nearby atoms in a solid are connected by springs. (This is actually Einstein's model of solid, except he modeled the interactions as quantum harmonic oscillators)

  Idea: A more realistic model would be using the Lennard-Jones potential, which gives the force between two atoms as:

$$V = -\frac{a_1}{r^{13}} + \frac{a_2}{r^7} \tag{2}$$

  and is graphically represented below (here, $a_1 = 5$ and $a_2 = 3$ for illustration purposes only)



  When the two atoms are close to each other, the force scales roughly linearly with displacement, which is exactly the description of Hooke's Law.

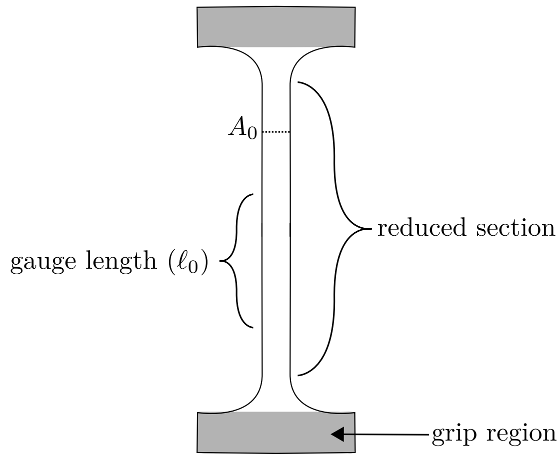
- Specifically, the Young's Modulus can be recovered by defining it as:

$$E \propto \left.\frac{dF}{dr}\right|_{r=r_0} \tag{3}$$

  where r_0 is the equilibrium distance and is only dependent on the material. Permanently deforming a metal will not change its Young's Modulus.

1.4 Getting a stress-strain curve

- The tensile specimen is in a **dogbone** shape as illustrated below:



1.5 Poisson's Ratio and Shear

- When a material deforms, it does not deform in only one direction. The **poisson's ratio** ν relates the strain in all three directions:

$$\nu = -\frac{\varepsilon_R}{\varepsilon_Z} = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z} \tag{4}$$

  for a cylindrically symmetrical material.

- Shear stress is defined as

$$\tau = \frac{F}{A_0} \tag{5}$$

  and shear strain is defined as:

$$\gamma = \frac{\Delta \ell}{\ell_0} \tag{6}$$

- Similarly, shear stress and strain is related via the shear modulus G:

$$\tau = G\gamma \tag{7}$$

- The Young's modulus and the shear modulus is related via the poisson ratio:

$$E = 2G(1+\nu) \tag{8}$$