MAT505 Mechanical Behavior of Materials
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Course description: This course is intended to bridge the introductory materials science knowledge to mechanical behavior of various crystalline and amorphous systems. It covers the influence of microstructure on the mechanical behavior of materials including metallic alloys, polymers and ceramics. The main objective of the course is to explain the fundamentals laws of elasticity followed by plastic behavior and deformation. In the meantime, the ways in which microstructure and defects are exploited to fabricate high-performance materials that are applied to today’s technologies ranging from aerospace to toughened ceramics will be described. The content includes and is not limited to stress-strain relations, elastic and plastic deformation, dislocations, dislocation interactions, work hardening, vacancies, interaction of precipitates with defects, glass transition in polymers, creep in materials, brittle fracture and ductile fracture, viscoelastic behavior and case studies that span a wide variety of phenomena including fatigue in alloys.

The outline of the course can be summarized under the following titles:

1. Stress, strain and deformation (2-3 weeks)
   - Definition of stress and strain, engineering and true stress/strain
   - Stress-strain curves
   - Generalized Hooke’s law, relations in elasticity, tensor representations
   - Principal and shear stresses on an arbitrary plane, Mohr’s circle

2. Line and planar defects in crystalline inorganic materials and plastic deformation (2 weeks)
   - A general overview on commonly observed defects in crystalline solids
   - Stress-strain curves: The plastic part in alloys
   - Dislocation types and their characteristics
   - Slip and shear
   - Interaction of grain boundaries with dislocations
   - Dislocation reactions

3. Basic strengthening mechanisms of alloys (1-2 weeks)
   - Phase transformations: Why do we need them?
   - Solid solutions, ordering and precipitates
   - Conditions for stabilization of a desired precipitate in a matrix
   - Work hardening
   - Grain-boundary strengthening
   - Precipitation hardening, solid solution hardening
   - Dispersion hardening
   - Comparison of ferrous alloy strengthening vs. non-ferrous alloys
4. **Fracture: Brittle fracture and ductile fracture (2 weeks)**

Formation of a crack in a crystal  
Fracture of metals and alloys  
Fracture of ceramics  
Modes of fracture  
Failure types of alloys  
Failure of polymer materials

5. **Creep and high temperature deformation (1-2 weeks)**

Vacancies at high temperatures and dislocation activation energy.  
Diffusion of vacancies under stress  
Polycrystalline creep vs. single crystal creep  
Creep embrittlement  
Dynamic annealing  
Creep resistant alloy design

6. **Time dependent behavior, viscoelasticity (1-2 weeks)**

Maxwell model, Kelvin-Voigt model, standard linear solid model and combinations thereof to represent time dependent deformation of materials, specifically polymers. A basic introduction to the Laplace transform is given to solve problems. Dynamical Mechanical Analysis is discussed in relation to the viscoelastic material parameters.

7. **Some special materials, materials selection and case studies (depending on available time)**

Reference Books (at the moment):

- *Mechanical Metallurgy, George E. Dieter.*
- Physical Metallurgy Principles, Hill and Abbaschian
- Phase Transformations in Metals and Alloys, Porter and Easterling
- Principles of Polymer Engineering, McCrum, Buckley, Bucknall

A number of documents from online resources and compiled by the lecturer will be shared with the class.