Lecture 1 - Intro to Micromechanics

Dr. Nicholas Smith

Wichita State University, Department of Aerospace Engineering

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schedule

- Feb 2 - Intro to Micromechanics
- Feb 4 - Tensor review, Anisotropic Elasticity
- Feb 9 - Coordinate Transformation
- Feb 11 - 1D Micromechanics (HW1 Due)

outline

- introduction
- syllabus
- micromechanics
- software
- plotting

about me

Figure 1: family picture

education

- B.S. in Mechanical Engineering from Brigham Young University
  - Worked with ATK to develop tab-less gripping system for tensile testing composite tow specimens
  - Needed to align the specimen, as well as grip it without causing a stress concentration

education

- M.S. and Ph.D. from School of Aeronautics and Astronautics at Purdue University
  - Worked with Boeing to simulate mold flows
  - First ever mold simulation with anisotropic viscosity

research

Figure 2: picture of chopped carbon fiber prepreg

research

Figure 3: picture of lamborghini symbol made from compression molded chopped carbon fiber

- No simulation is currently able to predict fiber orientation from these processes
- Part of the challenge is that we only have information from initial state and final state
- I want to quantify intermediate stages using a transparent mold

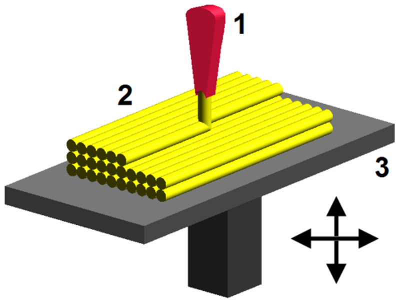

Figure 4: picture illustrating the fused deposition modeling 3D printing process, where plastic filament is melted and deposited next to other filament, and fuses together

introductions

- Name
- Student status (Undergrad, Masters, Ph.D)
- Full time or part time student?
- One interesting thing to remember you by
- What are you hoping to learn in Micromechanics?

course textbook

- The textbook used in this class is: *Introduction to Micromechanics and Nanomechanics*, Shaofan Li and Gang Wang
- Homework will be given in handouts
- I will supplement the text with some material from my former professor at Purdue
- In particular, this book teaches micromechanics, but also links traditional micromechanics to smaller scales
- My intent is to focus primarily on the micro-scale and above

office hours

- I will e-mail everyone in the course a Doodle link we can use to find the optimal office hours
- Let me know if you do not receive the e-mail, you may need to update your information in Blackboard
- Take advantage of office hours, this is time that I have already set aside for you
- If the regular office hours do not work for your schedule, send me an e-mail and we can work out a time to meet

tentative course outline

- Section 1 - analytical methods
    - Anisotropic elasticity
    - Coordinate transformation
    - 1D analysis (voigt-reuss)
    - Eshelby
    - Mean-field

tentative course outline

- Section 2 - numerical methods
    - Finite elements
    - Variational calculus
    - Fourier methods

tentative course outline

- Section 3 - damage
    - Damage
    - Dislocation
    - Final project (due 15 May)

grades

- Grade breakdown
  - Homework 40%
  - Final Project 60%
- Follow a traditional grading scale

final project

- Model some multi-scale problem using the techniques taught in this class.
- You should use at least one micromechanics software tool, compare your results to a converged finite element model, and make an appropriate comparison to an analytical model.
- More details on the final project will be given later in the course.

- Consider the cost (to you or others) of your being in class
- I ask that you refrain from distracting behaviors during class
- When you have something more important than class to take care of, please take care of it outside of class

micromechanics

electrostatic force

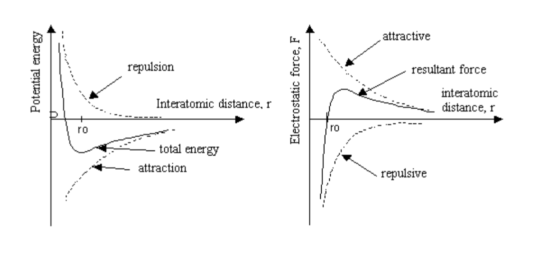

Figure 5: a diagram plotting inter-atomic forces vs distance between atoms

micromechanics

- Many problems involve heterogeneous materials
- Composites, biomechanics
- Micromechanics is used to homogenize in order to predict global behavior
- Can also be used in reverse to de-homogenize (or localize) global stresses/strains

homogenization

- In a composite laminate, the ABD matrix is used to homogenize the various laminae
- Different materials will have different methods for homogenization
- Eshelby, Mori-Tanaka are two analytic methods
- There are also many numerical methods that can be used to homogenize

de-homogenization

- De-homogenization, or localization, is often valuable in predicting failure
- Stiffness, load-displacement are “global” effects, can be predicted well with some homogenized material
- Failure initiates at the local level, need to know stress in fiber/matrix (for composites)

- While the term “micromechanics” implies a certain scale, the methods we will use in this class are mathematically general
- Can be used at any scale where the continuum assumption is valid
- We only need some periodic structure

software

finite elements

- Many specialized micromechanics tools exist for various problems
- Standard finite element software is always used as the benchmark to which micromechanics is compared
- Everyone will need access to FEA software in this class
- Class examples will use COMSOL, since we have a class-kit license for that, but you are free to use any software package you have access to and are comfortable with

comsol

- the files needed for installation can be downloaded here[1]
- need to have WSU on-campus IP address to access license (can use vpn[2])
- license format -> port number @ hostname
- port number: 1718, hostname: aecomsol.wichita.edu
- note: you do not need to install the license manager, and in this class we will not need Acoustics, Heat Transfer, Microfluidics, or Non-Linear Structural Mechanics modules

[1] https://drive.google.com/open?id=1IT4IlM9j0nTDVDE9L8QhhhpKa7RXEjyw

[2] https://vpn.wichita.edu

python

- while I do not require you to use python, I use it for many examples so I will provide some installation instructions
- a minimal installation can be done by installing conda[3]
- afterwards install libraries using `bash conda install ipython jupyter matplotlib numpy pandas scipy`
- alternatively, you may use a cloud-based python installation, such as the one provided by Microsoft[4]

[3] https://conda.io/miniconda.html
[4] https://notebooks.azure.com/

micromechanics

- You are encouraged to find specialized micromechanics software for your final project
- Different micromechanics software tools will utilize different theories to homogenize/de-homogenize
- SwiftComp is available here[5] (uses variational calculus)
- Some others are CRAFT[6] (uses Fourier transforms)
- MAC/GMC[7] (uses generalized method of cells)

[5] https://cdmhub.org/
[6] http://craft.lma.cnrs-mrs.fr/
[7] https://www.grc.nasa.gov/WWW/StructuresMaterials/MLP/software/mac-gmc/

- Another software alternative, although not strictly micromechanics, is the MOOSE Framework
- This is a little bit more similar to a standard FEA program (albeit open source and less user friendly)
- But it does have some multi-scale capabilities built in via the “multi-app” interface

plotting

plotting

- Plotting is an important part of graduate work, and this course
- There are many software programs which can generate good scientific plots
  - Microsoft Excel
  - MATLAB
  - Maple
  - Mathematica
  - Python
  - R
  - Plot.ly
- You are welcome to use whatever software you desire, I will use Python for a quick demonstration

plotting

- To make a good scientific plot, we must first decide what we are plotting, and which plot style will best illustrate our data
- Let us consider as an example the popular Halpin-Tsai equations

$$P_c = P_m \left(\frac{1 + \zeta \eta f}{1 - \eta f} \right)$$

$$\eta = \frac{P_f / P_m - 1}{P_f / P_m + \zeta}$$

halpin-tsai

- Where f is the fiber volume fraction, and P is some property, with c indicating composite properties, f indicating fiber properties and m indicating matrix properties

halpin-tsai

- The parameter, ζ is determined based on the type of property and composites (axial vs. transverse modulus, long vs. short fibers, etc.)
- For axial stiffness of oriented short-fiber composites, we will use $\zeta = 2l/d$
- Where l/d is the aspect ratio of the fibers

plotting

- We are interested in plotting the effect of aligned, short-fiber reinforcements
- In our chosen software (Excel, MATLAB, Python), we set up the aspect ratios we will simulate (x-axis of plot)
- Then we calculate ζ, η at each aspect ratio
- It is often desirable to generalize equations as much as possible. We can divide by *Pm* to find the normalized version, *Pc*/*Pm*.

plotting

View rendered example here[8]

[8] http://nbviewer.jupyter.org/github/ndaman/multiscale/blob/master/examples/Halpin-Tsai%20Example.ipynb