MECHANICS OF POLYMER SOLIDS AND FLUIDS

ChBE/MSE/ME/PTFE 7771
Tuesdays, Thursdays: 12:30 pm - 1:45 pm
J. Erskine Love Manufacturing # 183

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Learning/Teaching Objectives:

(1) Provide students in Polymer Science & Engineering, Chemical Engineering and Materials Science and Engineering and Mechanical Engineering with a basic knowledge of the behavior of polymeric solids
(2) Enable students to use fundamental principles to solve real manufacturing problems related to plastic flow
(3) Provide students in Polymer Science and Engineering, Chemical Engineering, Materials Science and Engineering and Mechanical Engineering with a thorough and comprehensive background of polymeric flow as non-Newtonian fluid mechanics and rheology.
(4) Enable students to use fundamental principles to solve real manufacturing problems and rheology for polymers
(5) Apply computer techniques to simulate problems in rheology

Prerequisites: Basic courses on mechanics of solids and fluids; exposure to differential equations, tensor algebra and calculus, and computer programming are helpful, although not required.

Books:

Reference Books:

Theory of Elasticity, Sokolnikoff
Theory of Elasticity, Timoshenko
Mechanical Properties of Solid Polymers, I. M. Ward
The Mathematical Theory of Plasticity, Hill
Plasticity, Theory and Application, Mendelson
Foundations of Solid Mechanics, Y.C. Fung
Advanced Fracture Mechanics, M. F. Kanninen and C. H. Poplar
The Structure and Rheology of Complex Fluids, R. G. Larson
Introduction of Fluid Dynamics, S. Middleman
Transport Phenomena, R. B. Bird, W. E. Stewart, E. N. Lightfoot
Principles of Non-Newtonian Fluid Mechanics, G. Astarita, G. Marrucci
An Introduction to the Mechanical Properties of Solid Polymers 2nd Edition, I. M. Ward (Author), J. Sweeney, Wiley

Dynamics of Polymeric Liquids, Vol I, 2 nd edition, R. B. Bird, R. C. Armstrong, O. Hassager, Wiley-Interscience

Handouts from various solid mechanics books will be given. The last two books are ones directly related to this course, especially the last one. It is a very good book, but somewhat expensive. But there are cheaper options such as renting.

Two main sections:

Foundations of Mechanics, constitutive equations of solids and fluids, and flow

(1) Basic Framework for Solid Mechanics

Indicial notation, force balance & momentum balance, state of stress, principal stresses

(2) Constitutive Equations for Solids (stress-strain behavior of polymers)

Material symmetry & anisotropy, large deformation & non-linearity

(3) Failure Conditions for Polymers, Yield and Post Yield Behavior (Flow of Solids)

Yielding, three-dimensional yield conditions, especially Tresca and von Mises yield criterion
Plasticity, flow rule, loading & unloading behavior, consistency condition
Strain hardening
Mullins and Payne effects in polymer systems

Mechanics of polymer solution and melt (non-Newtonian fluids)

(1) Framework of Fluid Mechanics

Mass and momentum balance equations; energy equations; kinematics; and boundary conditions.

(2) Non-Newtonian Fluids

Structure of Polymeric Fluid
Flow Phenomena in Polymeric Fluids
Material Functions
- Steady Shear Flow
- Small Amplitude Oscillatory Flow
- Inception of Steady Shear Flow
- Cessation of Steady Shear Flow

Sudden Shearing Displacement
Creep
Constrained recoil
Constitutive Equations

(3) Generalized Newtonian Fluids

Concept of Generalized Newtonian Fluids
Viscometric Flow
Power law, Ellis, Carreau-Yashuda, Bingham plastic fluids, etc

(4) Numerical Methods

Calculus of Variations
Weighted Residual Method
Finite Element Method
Applications using commercial software
Development of computer programs (introduction due to lack of time)

(5) General Linear Viscoelastic Fluids

Generalized Maxwell Fluid
Jeffreys Model
Differential and Integral Representations

(6) Convected and Corotational Models for Polymers

Convected Derivatives
Ordered Fluids
Criminale-Ericksen-Filbey Fluids
Reiner-Rivlin Fluids, etc

(7) Quasi-Linear Differential Polymer Models

Oldroyd's Fluid B
White-Metzner Model
Oldroyd 8-Constant Model
Giesekus Model
Johnson-Segalman fluids

(8) Integral Forms

Single Integral Constitutive Equations
Quasi-Linear Integral Models
Non-Linear Integral Constitutive Equations
K-BKZ Equation

Rivlin-Sawers Equation
Doi-Edwards Equation
Memory Integral Expansions

(9) Anisotropic Polymeric Fluid Flow

Introduction to liquid crystals, anisotropic (LC) flow, pattern formation, Ericksen-Leslie theory, molecular theory of Leslie viscosities, introduction to nematic and smectic crystal flow.

(10) Introduction to Kinetics of Polymeric Liquids

Dumbbell, bead-spring chain, bead-rod-spring models

(11) Numerical Applications (time permitting)

Solution to Boundary Value/Initial Value Problems
Development of Computer Algorithms
Simulation using POLYFLOW, FIDAP, etc.
Fiber Spinning
Mold Filling, etc.

(12) Current Developments

Grading Policy:

Two quizzes (or tests)
Finals: Comprehensive
10 % Homework, 30 % for each quiz, 30 % Finals

Fall Break: Oct 17,18
Withdrawal Deadline: Oct 29, 4:00 pm.
Finals: Thursday, Dec 15 11:20 AM - 2:10 PM
Tentative dates: Quizzes (tests): September 29 and November 3.

Any changes in syllabus will be announced with adequate notice.

I would strongly recommend using discussion groups in Canvas or just meet in person as student groups for discussions, rather than using Groupme, Whatsapp, etc., since it can pose unnecessary risks in any course, even though they became very popular. If one student even remotely put some hints for a question or something similar (and we don't have any control on each student), everyone in the group can get punished for academic integrity violation - not just the one who posted it, if someone in the group happen to report it to the administration. (here is an example:https://georgiastatesignal.com/georgia-

state-students-warn-about-cheating-through-groupme/ and there are many such articles). But, that is just a suggestion for consideration.