# MECHANICS OF POLYMER SOLIDS AND FLUIDS

## CHBE/MSE/ME/PTFE 7771

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**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.

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
Finals: Comprehensive

15 % Homework, 25 % for each quiz, 35 % Finals

Homework should be **uploaded properly**, and must be submitted on time.

Quizzes: September 29 and November 5.  Finals: Tuesday December 8