Outline for Rheology / Processing Lectures for Polymer Science & Engineering

Introduction

- How does this material relate to the previous material in the course?
  - previously material covered
    - how to make polymers (polymerization)
    - the chemical structure of polymers
    - properties of polymers and how to change them
  - talk about processing
    - definition of processing
    - what do we mean by processing
    - how are polymers processed (thermosets vs. thermoplastics)

- manufacture of polymers

- introduction to processing
  - what fundamentals are important?
    - heat transfer -- melting the plastic
      - how much heat? what mechanisms?
    - melt flow (velocities, pressures, stresses ... rheology)
    - mixing (not covered here)
    - cooling (how fast will the part cool -> productivity)
    - pumping (the extruder acts as a pump)
    - basic processing
      - melting the plastic - extruders
      - shaping the plastic - dies, injection molding, blow molding
      - cooling the plastic - mold cooling, air and water cooling

- discuss some basic processes based upon articles produced
  - (show samples, basics of processes, advantages, limitations)
    - film (blown film line)
    - sheet (extruded from die, calendering)
    - example of thermoforming (cup, tray)
    - handleware (extrusion blow molding, milk bottle)
    - example of injection molding
    - large bottles (injection RHB)
    - small bottles (injection blow)
    - fibers and yarn (extrusion through spinnerets)
    - plastic pipe
    - coated wire

- categories of processing

- comment on material differences for different processes
Rheology

What is rheology? Why is it important?
helps us in understanding the forming or shaping of plastic articles
provides important material information for analysis and design
proves useful as a quality control tool.

Examples of it's importance
- injection molding
- extrusion / coextrusion
- die design
- quality control
- profile extrusion

Summary of important variables
viscosity (both shear and extensional)
density
thermal properties

Description of the flow equations

Flow regimes
- laminar vs turbulent flow, Reynolds number definition
- definition of viscosity, units
- examples of viscosities in materials and shear rates in processes
- limitations of flow (instabilities)

Viscosity models
- ideal fluid
- Newtonian fluid
- graphical presentation of viscosity data
- power law fluid
- effects of temperature
  pressure
  molecular weight
  structure

How do we measure rheological properties? What are the limitations of these techniques? How can we extend the analysis?
- what properties are important?
  bulk, shear, tensile or extensional
- melt index measurements
  discuss what they mean
- cone and plate rheometers
- capillary rheometry
  Rabinowitsch correction
- other rheometers (Couette viscometer)

Solution of flow equations for simple geometries
- Newtonian flow in a slit
  - force balance or momentum balance equations
  - computation of shear stresses
  - strain rate values
- power law flow in a tube
Extrusion

- definitions, concepts and products
- description of the extruders
  - continuous process
  - functions include melting, mixing and pressure generation
  - description of the parts
  - sizes of extruders
  - power requirements
  - resin feed system (hopper / dryer)
  - heating and cooling of the barrel
  - screw design
- discussion on dies
  - flow of Newtonian fluids through channels
  - die characteristics
- analysis of the extrusion process
  - description of the pumping capability
  - analysis of heat needed
  - description of the melting process
- work sample problems in extrusion
- description of some extrusion processes
  - pipe extrusion
  - wire coating
  - blown film extrusion
- problems encountered during extrusion
  - die swell
  - shear heating
  - melt fracture
  - sag
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**Injection Molding**

- basic process description
  - physical processes involved
  - tight tolerances on parts
  - high pressures
- machine description
  - terminology of machine and parts
  - functional components on the machine
    - resin feed system (hopper / dryer)
    - screw, barrel and accumulator
    - temperature control
    - mold (cavity, runners, cooling channels, ejector system)
    - clamping system
    - unit to supply power (hydraulic)
    - control unit
- description of the injection molding cycle
- part cooling
  - models for cooling
    - penetration model
    - cooling of slab
  - cooling parameters
- multicavity molds
- areas of concern
  - part filling
  - part cooling
  - defects
- comparison of injection vs extrusion