GLASSWORKING

1. Raw Materials
2. Shaping
3. Heat Treatment & Finishing
4. Production Design Consideration

Introduction
- Glass is one of three types of ceramic materials. The other two are traditional and new ceramics.
- A type of ceramics which is Non-crystalline [SiO₂(sand) + other oxides]
- Shaping: melting, casting, pressing and blowing or rolling.
- Glass remain in the glass state even after cooling.
- Typical Processing steps

1. Raw Materials
- The sand is washed and classified according to size (ideal size: 0.1 to 0.6mm).
  - Other ingredients such as soda ash (Na₂O), limestone (CaO), aluminum oxide, potash (K₂O) and other minerals.
  - Recycled glass is added (up to 100%).
- A starting material before melting is called 'charge'.
- Glass-melting furnace: 1500-1600°C typically for 24 to 48 hours.
- Temperature (up) dictates viscosity (down) for shaping.

2. Shaping Processes
- Three Categories
  - Discrete (bottles, jars, plates, light bulbs)
  - Continuous (sheet, plate and tubing)
  - Fiber-making (insulation and fiber optics)
- Shaping Piece ware
  - Casting – melting, solidifying, lapping & polishing
  - Spinning – centrifugal casting
  - Pressing – gob
  - Blowing – press-blow and blow-blow methods

Press-and-blow and Blow-and-blow

Shaping Flat and Tubular Glass
- Rolling of Flat Plate
- Glass Tubes (Danner process)

Float Process
Glass Fibers

- Fibrous glass – insulation
  - Centrifugal Spraying – molten glass in a rotating bowl flows out through small orifices.
- Long continuous filament – for composites and fiber optics

3. Heat Treatment & Finishing

- Annealing – get rid of undesirable internal stresses by heating at 500°C.
- Tempered glass – heated above tempering temperature and the surfaces cooled to induce compress stress on the surface. Shatters into numerous small fragments to take more energy.
- Finishing – grinding, polishing and cutting

SHAPING PROCESSES FOR PLASTICS

1. Properties of Polymer Melts
2. Extrusion
3. Sheet and Film
4. Fiber and Filament
5. Coating Processes
6. Injection Molding
7. Compression & Transfer Molding
8. Blow Molding & Rotational Molding
9. Thermoforming
10. Casting
11. Polymer Form
12. Design Consideration

Introduction

- Unlimited variety of part geometries
- Net Shape
- Less energy
- Lower temperature
- No finishing

1. Properties of Polymer Melts

- Viscosity
  - Newtonian fluid: \( \eta = \frac{\tau}{\gamma} \)
  - \( \eta \) = coefficient of shear viscosity
  - Pseudoplastic fluid: \( k = \frac{\tau}{\gamma^p} \)
- Viscoelasticity
  - Causes die swell
  - Swell ratio, \( S = \frac{D_2}{D_1} \)
- Mold Flow Index (MFI): A measure of flow and viscosity depending on temp. and shear rate
2. Extrusion
- Shaping process for polymers, metals & ceramics.
- A compression process – A material flows through a die orifice to provide long, continuous shaped material.
- Extrudate (extruded product) cut into desirable lengths.
- Equipment
  - Internal Diameter (25-150 mm)
  - L/D ratio ranges from 10 to 30.
  - The extruder screw rotates at about 60 rev/min.
- Feed section
  - Compression section – transforms to liquid
  - Metering section – the melt is homogenized and pressurized.

A simple plate model
Volume drag flow rate (m/s): \( Q_d = 0.5v_d w \)

Analysis of Extrusion
Into the eq. from a plate model
\[ Q_e = 0.5\pi^2 D^2 Nd_c \sin A \cos A \]

Back pressure flow (empirical) due to drag flow
\[ \dot{Q}_b = \frac{\pi D^2 \sin^2 A}{12 \eta} \left( \frac{dp}{dl} \right) = \frac{\pi D^2 \sin^2 A}{12 \eta L} \]

The resulting flow rate, assuming no leak flow
\[ Q_s = Q_e - Q_b = 0.5\pi^2 D^2 Nd_c \sin A \cos A - \frac{\pi D^2 \sin^2 A}{12 \eta L} \]

Design Parameters: \( D, d_c \), and \( A \)
Operating Parameters: \( N, p \) and \( \eta \)

Die Configuration & Defects
- Extruded shape
  - Solid Profiles
  - Hollow Profiles such as tubes
  - Wire and Cable coating (see text)
- Defects
  - Melt fracture
  - Sharkskin – residual stress on surface
  - Bambooning

3. Production of Sheet & Film
- 0.5 mm < Sheet thickness < 12.5 mm
- Film thickness < 0.5 mm
- Continuous & High Production
- Slit-die Extrusion
  - Water Quenching bath
  - Chill roll extrusion
- Blown-film Extrusion (Fig. 13.16)
- Calendering (2.5 m/s)
  - A series of rolls
4. Fiber & Filament Production
- Melt Spinning
- Dry Spinning – polymer in solution and the solvent evaporates

5. Coating Processes
- Wire and Cable coating
- Planar coating
  - Roll
  - Doctor blade
- Contour Coating
  - Dipping or spraying

6. Injection Molding
- Video in class
- Three Mold Types
- The Mold, Injection and Clamping Units
- Shrinkage: \( D_f = D_p + D_s S + D_s S^2 \)
- Defects
  - Short Shot
  - Flashing
  - Sink mark and void
  - Weld line
- Other Types (e.g.: Reaction Injection Molding)

7. Compression & Transfer Molding
- Compression Molding
- Transfer Molding

8. Blow Molding
- Blow Molding – uses air pressure to inflate soft plastic to make a hollow geometry inside a mold cavity.
9. Rotational Blow Molding

- Gravity is used to achieve the hollow form inside a rotating mold.
  - A predetermined amount is loaded
  - Heating and rotating
  - Cooling while rotating
  - The mold opens and the part release.

10. Thermoforming

- A flat thermoplastic is heated and deformed into the desirable shape
  - Forming – Vacuum, Pressure and Mechanical

11. Casting

- Steps
  - Pouring a liquid resin into a mold
  - Filling the cavity
  - Hardening
- Materials: acrylics, polystyrene, polyamides, PVC.
- Slush or shell casting

12. Polymer Foam Processing

- Polymer Foam – a composite of polymer and gas (air, nitrogen and carbon dioxide)
  - Introduction of gas
    - mechanical agitation
    - physical blowing agents
    - chemical blowing agents
  - Depending on the amount of gas and processing, open or closed cells

13. Design Consideration

- General consideration
  - Strength and Stiffness
  - Impact Resistance
  - Service temperature
  - Thermal expansion
  - Degradation
- Extruded Plastics
  - Wall thickness
  - Hollow sections
  - Corners
- Molded Part
  - Economic production quantities
  - Part Complexity
  - Wall thickness: reinforcing ribs
  - Corner radii and Fillet
  - Holes but careful
  - Draft
  - Tolerance
  
  See Table 13.2