Plastics Processing
Plastics Processing

- Plastics can be machined, cast, formed, and joined with relative ease requiring little post-processing or surface-finish operations
- Plastics melt or cure at relative low temperatures
- Plastics require less energy to process than metals
- Raw materials most commonly are pellets, powders
- Also available as sheet, plate, rod, and tubing (produced by extrusion, etc.)
- Liquid plastics used to make reinforced plastic parts (composite materials)
# Plastics Processes

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<th>Process</th>
<th>Characteristics</th>
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<td>Extrusion</td>
<td>Long, uniform, solid or hollow complex cross-sections; high production rates;</td>
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<td>low tooling costs; wide tolerances.</td>
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<td>Injection molding</td>
<td>Complex shapes of various sizes, eliminating assembly; high production rates;</td>
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<td>costly tooling; good dimensional accuracy.</td>
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<td>Structural foam molding</td>
<td>Large parts with high stiffness-to-weight ratio; less expensive tooling than in</td>
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<td>injection molding; low production rates.</td>
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<td>Blow molding</td>
<td>Hollow thin-walled parts of various sizes; high production rates and low cost for</td>
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<td>making containers.</td>
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<td>Rotational molding</td>
<td>Large hollow shapes of relatively simple shape; low tooling cost; low production</td>
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<td>Thermoforming</td>
<td>Shallow or relatively deep cavities; low tooling costs; medium production rates.</td>
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<td>Compression molding</td>
<td>Parts similar to impression-die forging; relatively inexpensive tooling; medium</td>
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<td>production rates.</td>
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<td>Transfer molding</td>
<td>More complex parts than compression molding and higher production rates; some</td>
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<td>scrap loss; medium tooling cost.</td>
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<td>Casting</td>
<td>Simple or intricate shapes made with flexible molds; low production rates.</td>
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<td>Processing of composite materials</td>
<td>Long cycle times; tolerances and tooling cost depend on process.</td>
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Extrusion

- Raw materials are thermoplastic pellets, granules, or powder
- Placed in hopper and fed into extruder barrel
- Screw blends pellets and pushes them down the barrel – through the feed, transition/melt, and pumping sections
- Barrel is heated from outside, and by friction
- Plastic (or elastomer) is liquefied and forced through a die under pressure
- Pellets for other plastics processes are made by extruding small-diameter rod and chopping into short segments
- Equipment costs on the order of $300,000
  - Rated by barrel diameter (D, 1-8 inch) and L/D ratio (5 to 30)
Extruded Products
Extrusion
Polymer Melts

- Viscosity reduces with temperature
- Polymer melts have viscoelastic properties
- This causes die swell during extrusion

![Viscosity vs Temperature Graph](image)

**FIGURE 15.2** Viscosity as a function of temperatures for selected polymers at a shear rate of $10^3$ sec$^{-1}$. Data compiled from [11].
Extrusion Die Swell

FIGURE 15.3  Die swell, a manifestation of viscoelasticity in polymer melts, as depicted here on exiting an extrusion die.

Swell ratio:  \[ r_s = \frac{D_x}{D_d} \]
Extrusion – Effects of Die Swell

Extrusion die

Extrudate profile

(a)

(b)

Orifice

Extruded section

Extruded section

Extruded section
Extrusion of Hollow Shapes

The view cross section of an extrusion die for shaping hollow cross sections such as A–A is a front view cross section showing how the mandrel is held in place; the tubular cross section just prior to exiting the die; die swell causes an enlargement. (Some die construction details are simplified.)
Extrusion Coating of Wires

FIGURE 15.11 Side view cross section of die for coating of electrical wire by extrusion. (Some die construction details are simplified.)
Extrusion of Sheet

FIGURE 18.4
Blown Film Extrusion

- Carried vertically
- Used to manufacture plastic film and plastic bags
- Mainly for materials such as LDPE and PVC
Injection Molding

- Similar to hot-chamber die casting of metals
- Pellets, granules, or powder are fed into heated cylinder, then forced into die chamber by hydraulic plunger or rotating screw system
- Pressures from 70-200 MPa (10-30 Kpsi)
- Cool molds for thermoplastics. Heated molds for thermosets
- Complex shapes and good dimensional accuracy
- Using metallic inserts, multiple materials/colors, and printed films can eliminate post processing or assembly operations
Injection Moldings
Injection Molding

- Cold-runner molds are similar to metal casting
- More expensive hot-runner molds have no gates, runners, or sprues attached to final part
Plastic Injection Molding
Cycle Time Breakdown

- Injection time
- Cooling time
- Discharge time
- Sealing point
- Sealed cooling
- Packing time
- Mold reset time
Injection Molding Two Plate Mold

cooling channels
runner
sprue
sprue bushing
cavity insert
core insert
cavity plate
molded part
core plate
ejector pins
two-plate and two-cavity mold
Injection Molding Die Mechanisms
Unscrewing Core

cavity insert
cavity
cavity plate
rotating threaded core pin
core plate
gear
gear rack
activated by hydraulic cylinder
unscrewing device
Injection Molding Capabilities

• High production rates
• Good dimensional control
• 5-60 second cycle times (or several minutes for thermoset materials)
• Molds with multiple cavities, made of tool steels (2 million cycles), aluminum (10,000 cycles), etc.
• Mold costs up to $20-200K
• Machines are usually horizontal with clamping forces 0.9-2.2 MN (100-250 tons)
• 100 ton machines cost $60-90K
• 300 ton machines cost $85-140K
Structural Foam Molding

• A variation of the injection molding process, developed for applications where stiffness is a primary concern, and particularly for large structural parts.
• Parts consist of a rigid, closed-cellular core surrounded by a continuous, solid skin.
• The polymer melt contains a dissolved inert gas; most commonly nitrogen, introduced in the extrusion screw.
• A predetermined shot size is injected into the mold cavity, the extruder valve is closed, and the foam material generates internal pressure and expands to fill mold cavity.
• A much lower pressure operation than the conventional injection molding system, which allows much larger parts to be molded.
Structural Foam Moldings
Reaction Injection Molding

Chemical reaction between two polymer materials - thermoset

- Large parts
- Low tooling costs
- Car bumpers are good examples for this process
Reaction Injection Moldings
Blow Molding

• Modified extrusion and injection molding processes

• Extrusion Blow Molding
  – Small tube is first extruded, usually vertically, then clamped and air blown inside to expand it to fit a much larger diameter mold
  – Air pressures 350-700 kPa (50-100 psi)
  – Can be a continuous process (corrugated pipe and tubing)

• Injection blow molding
  – Short tubular piece (parison) injection molded, transferred to a blow-molding die
  – Plastic beverage bottles and hollow containers

• Multilayer blow molding
  – Uses coextruded tubes or parisons
  – Plastic packaging for food and beverages, cosmetics and pharmaceutical industries
Blow Moldings
Blow Molding

Figure 18.9
Schematic illustrations of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine. Source: Encyclopedia of Polymer Science and Engineering (2d ed.). Copyright ©1985. Reprinted by permission of John Wiley & Sons, Inc.
Rotational Molding

- Premeasured quantity of powder placed inside warm mold
- Rotated on two axes inside a heated furnace
- Low equipment costs
- Longer process times
- Trash cans, boat hulls, buckets, toys, footballs
- 0.4 mm wall thickness possible
- Also, slush molding
Rotational Moldings
Thermoforming

- Plastic sheet is heated to a sag point (softened, but not melted)
- Heated sheet placed over a room-temperature mold and forced against it by vacuum pressure
- Stretch forming process – material thickness variations
- Advertising signs, refrigerator liners, appliance housings, shower stalls, packaging

1. Straight vacuum forming
2. Drape vacuum forming
3. Force above sheet
4. Plug and ring forming

- a. Heater
- b. Clamp
- c. Plastic sheet
- d. Mold
- e. Vacuum line
Thermo Formed Parts
Types of compression molding, a process similar to forging: (a) positive, (b) semipositive, and (c) flash. The flash in part (c) has to be trimmed off. (d) Die design for making a compression-molded part with undercuts.
Compression Moldings