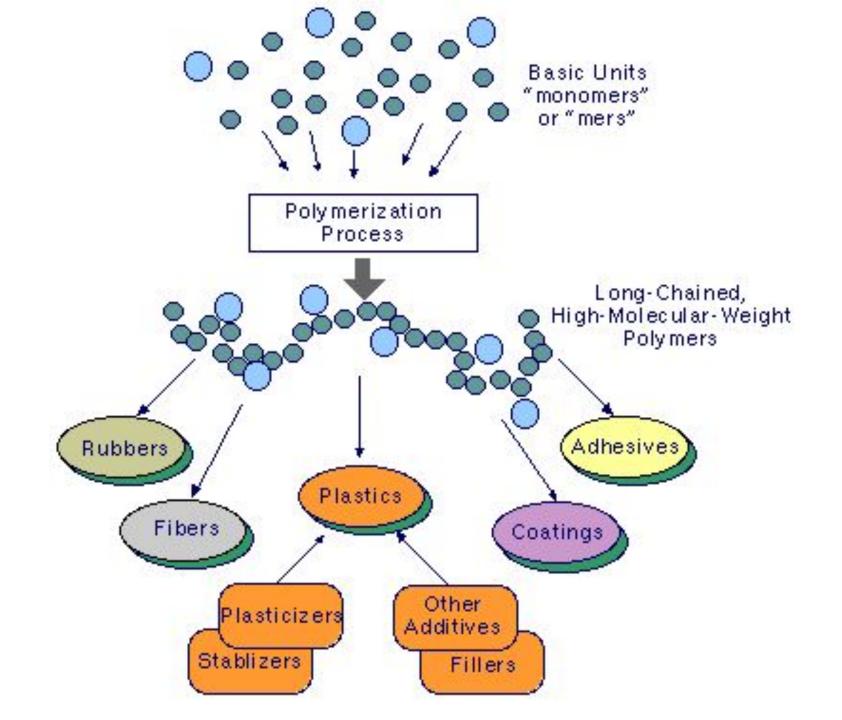
# POLYMER PROCESSING

Processing is the source of much of the variability in properties of synthetic polymers. Different processing conditions determine the difference between a milk jug and, to a great extent, high strength PE fibers (ultra oriented). Processing is one component of a series of steps that lead to a plastic product or component from raw feed stocks. Although each commodity polymer has a somewhat different sequence of industrial stages involved in bringing it to market, a simple and fairly exemplary case is a polyethylene bottle of shampoo.

The various grades polymers are partly composed of blends of different branch content, molecular weight and density from different synthetic reaction conditions. For example, a film blowing grade of polyethylene might contain a blend of linear low density polyethylene, branch content metallocene polyethylene and low density polyethylene.

Polymers offer certain unique problems in processing. They are viscoelastic fluids which display high viscosity and broad transition temperatures. Machinery is large and involves a significant energy input. Polymers degrade (chain breakup) resulting in a loss of properties with exposure to high temperatures and stress for an extended period of time.

Some basic processing operations and machinery are extrusion, screw extruder, fiber drawing, injection molding, blow molding, dip coating, calendering, mixing/dispersion, melting, modification, and introduction of additives.



### Mechanical + Thermal

- Thermoplastic solidified by cooling and reheated by melting
- Thermosets retain their structure when reheated after polymerization (usually crosslinked)
- Elastomers rubbers, deform readily with applied force
- Thermoplastic elastomers
- other

## **Major Processes**

- Extrusion
- Injection Molding
- Blow Molding
- Thermoforming
- Rotomolding

### **Formulation**

- Additives are used to modify properties and/or lower costs
- Additives: heat stabilizer, light stabilizer, lubricant, colorant, flame retardant, foaming agent, plasticizer
- Reinforcement: particulate minerals, glass spheres, activated carbon, fibers
- Blends, alloys, laminates

Reinforcing Boron, carbon, fibrous Increases heat-deflection minerals, glass, Kevlar fibers temperature (HDT). Resists shrinkage and warpage. Conductive Aluminum powders, carbon Improves electrical and thermal fillers fiber, graphite conductivity. Coupling Improves interface bonding between Silanes, titanates agents polymer matrix and the fibers. Flame Chlorine, bromine,

phosphorous, metallic salts

Calcium carbonate, silica,

Metal oxides, chromates,

Gas, azo compounds,

Monomeric liquids,

low-molecular-weight

clay

materials

carbon blacks

Colorants (pigments and dyes)

Blowing

**Plasticizers** 

retardants

Extender

fillers

Reduces the occurrence and spread of combustion.

Improves melt flow properties.

Protects from thermal and UV

degradation (with carbon blacks).

Generates a cellular form to obtain a

Reduces material cost.

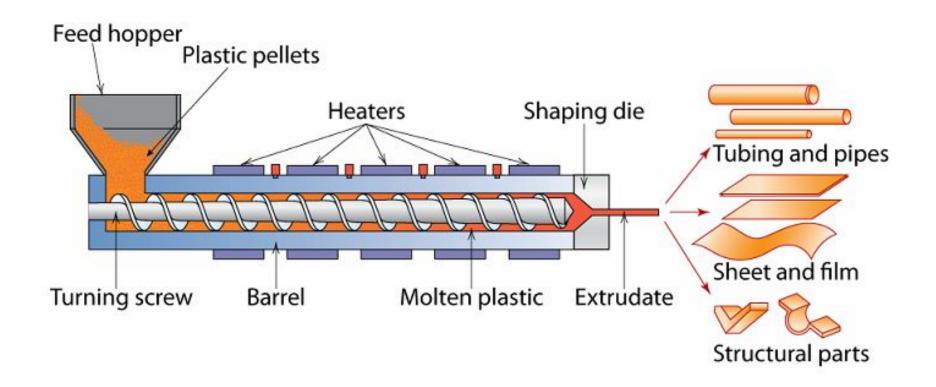
Enhances flexibility.

Provides colorfastness.

Increases tensile strength.

Increases flexural modulus.

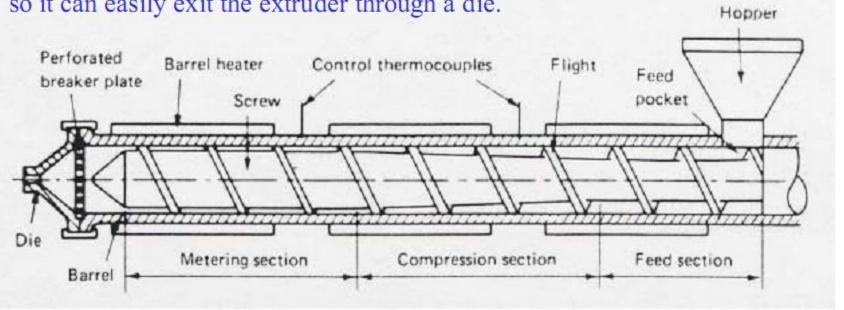
### **Extrusion**



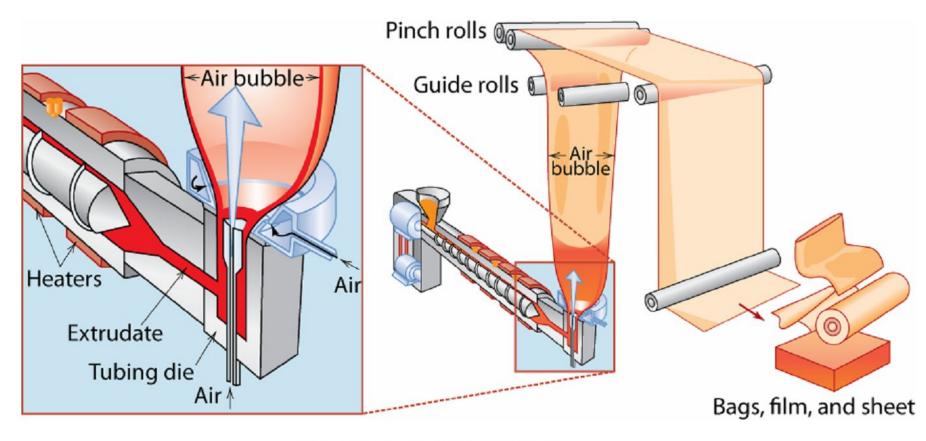
- Shaping: Die shape dictates the nature of the polymer product.
  - Circular die: Melt spinning of fibers
  - Slit die: Sheet casting
  - Annular die:
    - Film blowing
    - Pipes ( $\phi > 12 \text{ mm}$ ) and tubing ( $\phi > 12 \text{ mm}$ )
    - Wire coating

### Extruder: Plastication

- Cold polymer granules fed into a hopper and supplied to the screw by gravity
- Granules advance between the flights of the screw and the hot walls of the barrel
- As the polymer advances along the extruder, it becomes liquid (by melting or by passing through the glass transition)
- The polymer becomes pressurized at it moves along the extruder, so it can easily exit the extruder through a die.

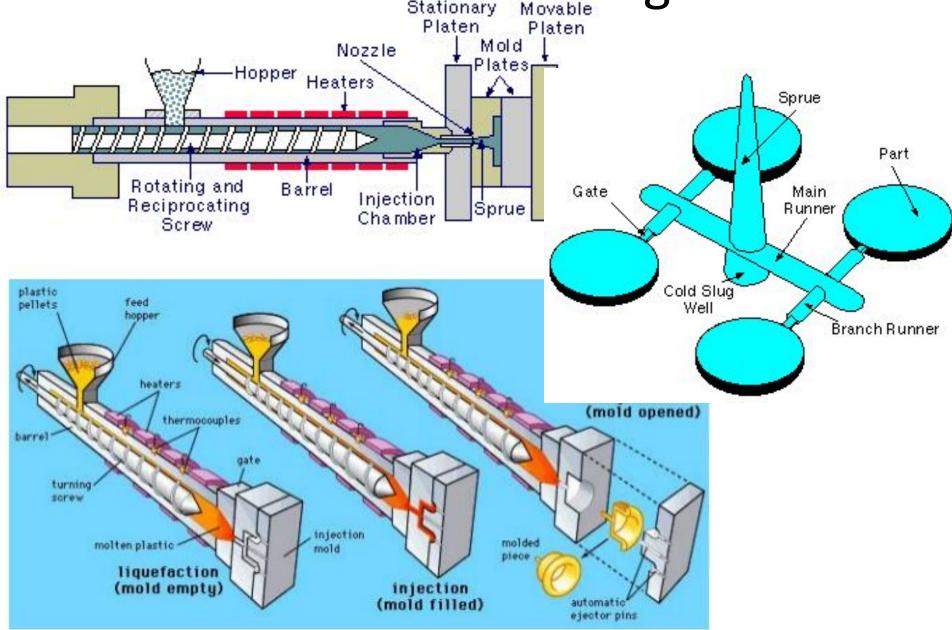


### Blown-Film Extrusion



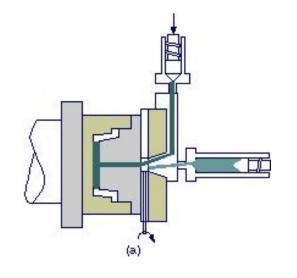
Adapted from Fig. 15.26, Callister 7e. (Fig. 15.26 is from Encyclopædia Britannica, 1997.)

Injection Molding

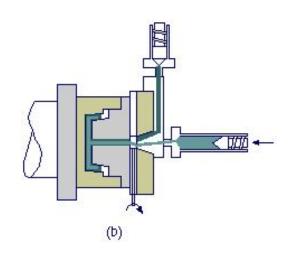


# Co-injection Molding

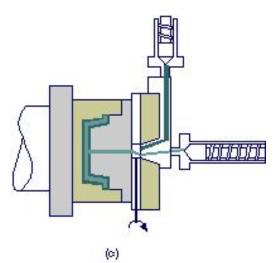
1. Inject Skin



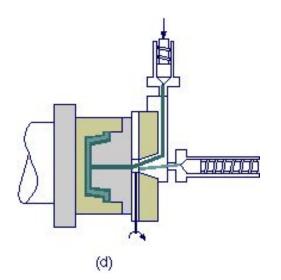
2.a. Inject Core



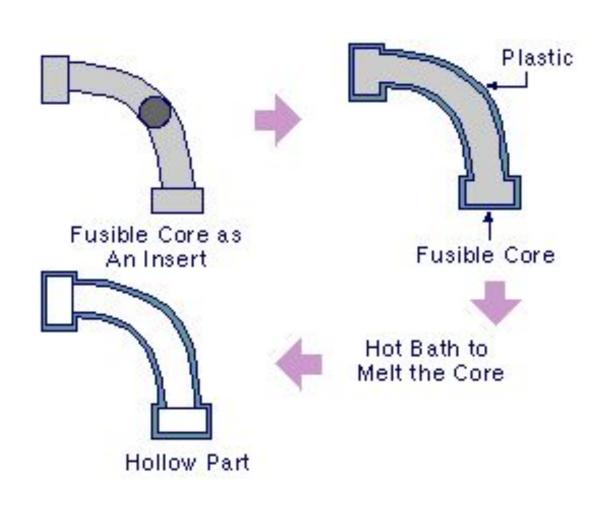
2.b. Continue injecting core until cavity is filled



3. Inject
Skin again
to purge
sprue.

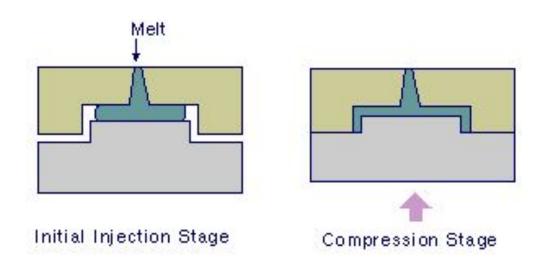


# Injecting hollow parts with complex interior geometry



## Injection - Compression Molding

Very similar to squeeze casting



### **Extrusion Blow Molding**

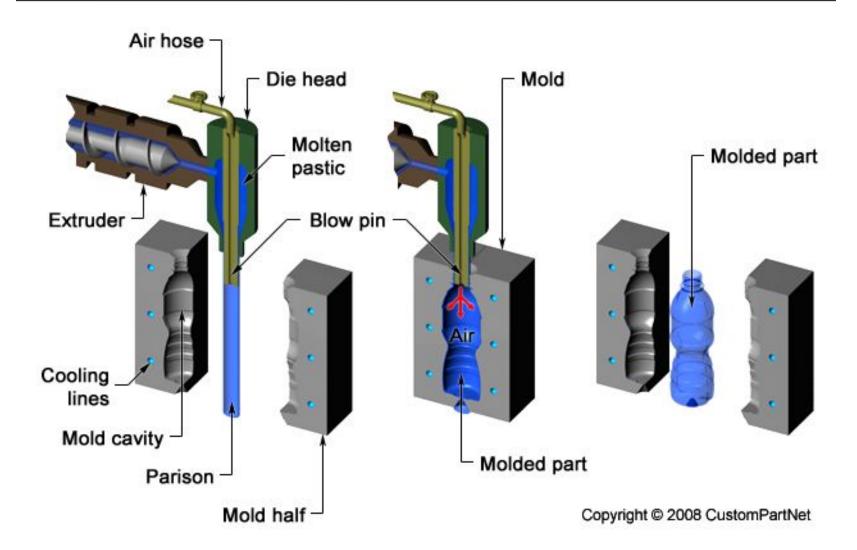
Parison Extrusion

**Blow Molding** 

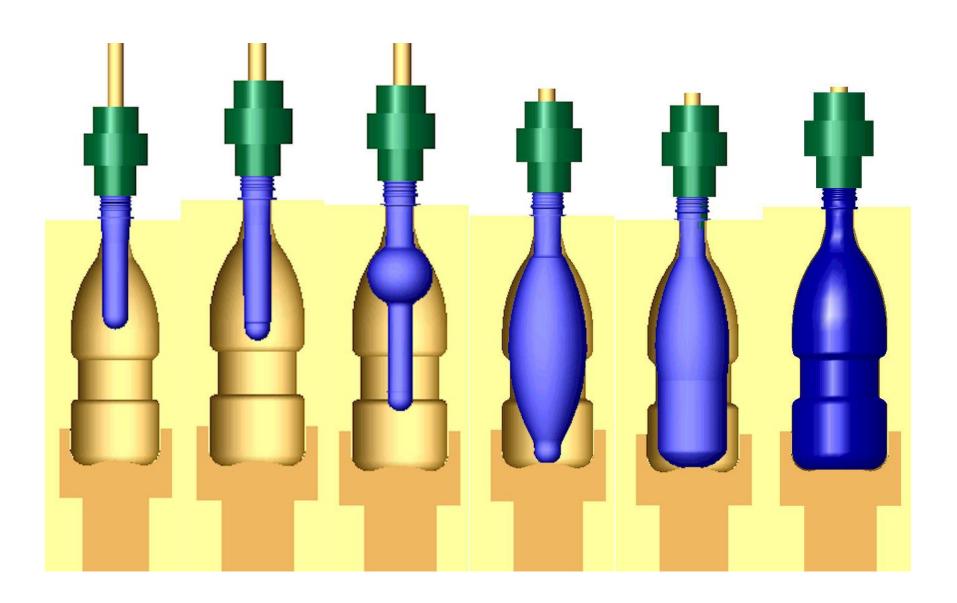
**Part Formed** 

(Cross-section)

(Cross-section)

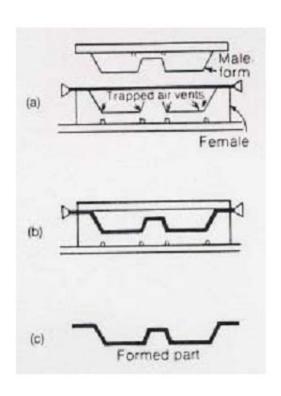


### Injection Blow Molding

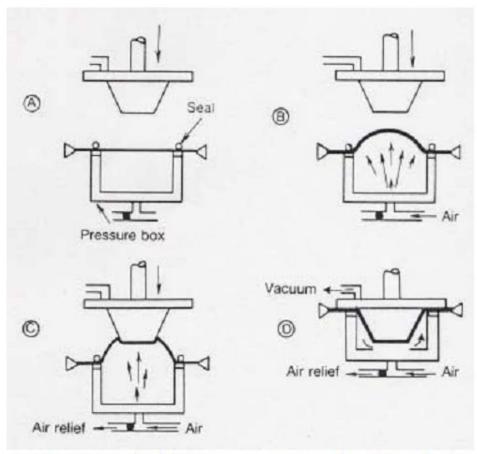


# Thermoforming

 Application for large formings, thin wall packaging, short-run or prototype products. Much lower initial investment than injection molding.



With matched molds



Pressure-bubble vacuum-snapback technique

# Calendaring

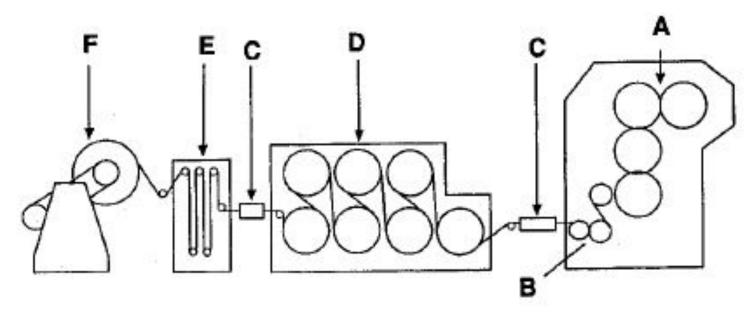


Figure 1.5 Schematic view of an inverted "L" calender plant for the production of plastic sheeting. Molten polymer is dropped into the calender system at A. Continuous sheet is formed by passing the melt between the rolls. One of the surfaces is given texture by an embossing roll, B. Thickness gauges, C, provide data for control of the process. The sheet is cooled, D, tensioned using wind-up accumulators, E, and accumulated on the wind-up roll, F (Holmes-Walker, 1975).

Thin and thick section calendaring is used to make wide sheets (8-12 ft).

### **Foams**

- Major area: insulation for housing, sound control,...
- Materials:
   polystyrene,
   polyurethanes, ...
- Reaction injection molding example

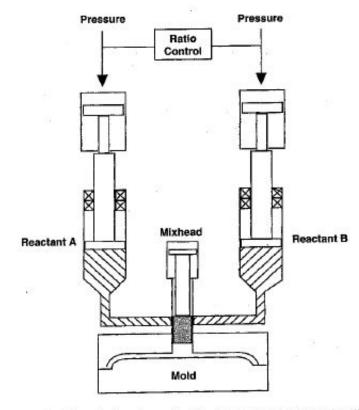


Figure 1.10 Schematic view of a reaction injection molding (RIM) machine. When the mixhead valve opens, two liquid reactants, A and B, flow at high pressure (100–200 bar) into the mixhead chamber. There they mix by impinging flow and begin to polymerize as they flow into the mold (C.W. Macosko, 1989).