BMM3643 Manufacturing Processes Forming & Shaping Polymer Processes

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Chapter Synopsis

This chapter will expose students to various forming and shaping polymer processes into used product. Selection of suitable processes are based on complexity of product design and process capabilities. It is important to considered the best process due to its huge implication to production costs.

Chapter Information

Lesson Objectives:

Forming and Shaping Polymer Processes

Lesson Objective:

At the end of this lecture, students should be able to understand and explain the following:

- Analyze the differentiate between various types of forming and shaping processes for plastics such as extrusion process, injection molding and blow molding.
- Analyze the process characteristics and capabilities of plastics extrusion, injection molding and blow molding.

Introduction

Plastic processing can be categorized in THREE main group;

a) Continuous products with uniform cross sections:
   - Extrusion: Wall-siding, pipes and door molding
   - Calendaring (continuous rolling to obtain desired thickness): Shower curtain, table cloths
   - Film blowing: Plastic bags, Irrigation water hose

b) Cavity filling:
   - Injection molding: toy trucks, toothbrush
   - Blow molding: water containers and bottles
   - Compression molding (thermosets) : Utensil handles

c) Gradually deposited layers:
   - Dipping
   - Fluidized bed coating

General Characteristics of Forming and Shaping Processes

Focus will be given for these 3 processes: **Extrusion, Injection Molding & Blow Molding**

TABLE 19.1

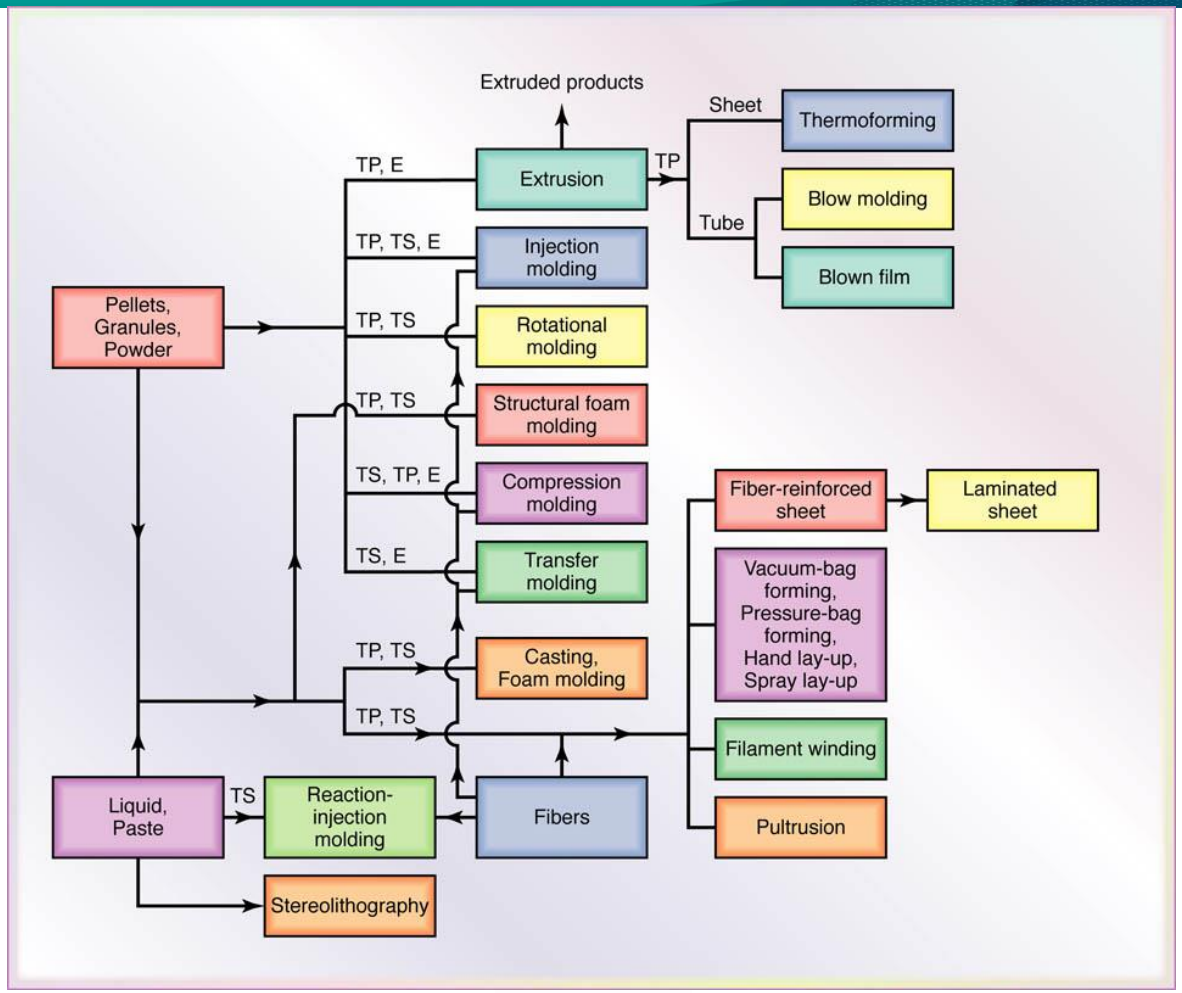
General Characteristics of Forming and Shaping Processes for Plastics and Composite Materials

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

Source by Kalpakjian Book, 2014

Forming and Shaping Processes

Flowchart of forming and shaping processes for plastics, elastomers, and composite materials. (TP = Thermoplastics; TS = Thermoset; E = Elastomer.)

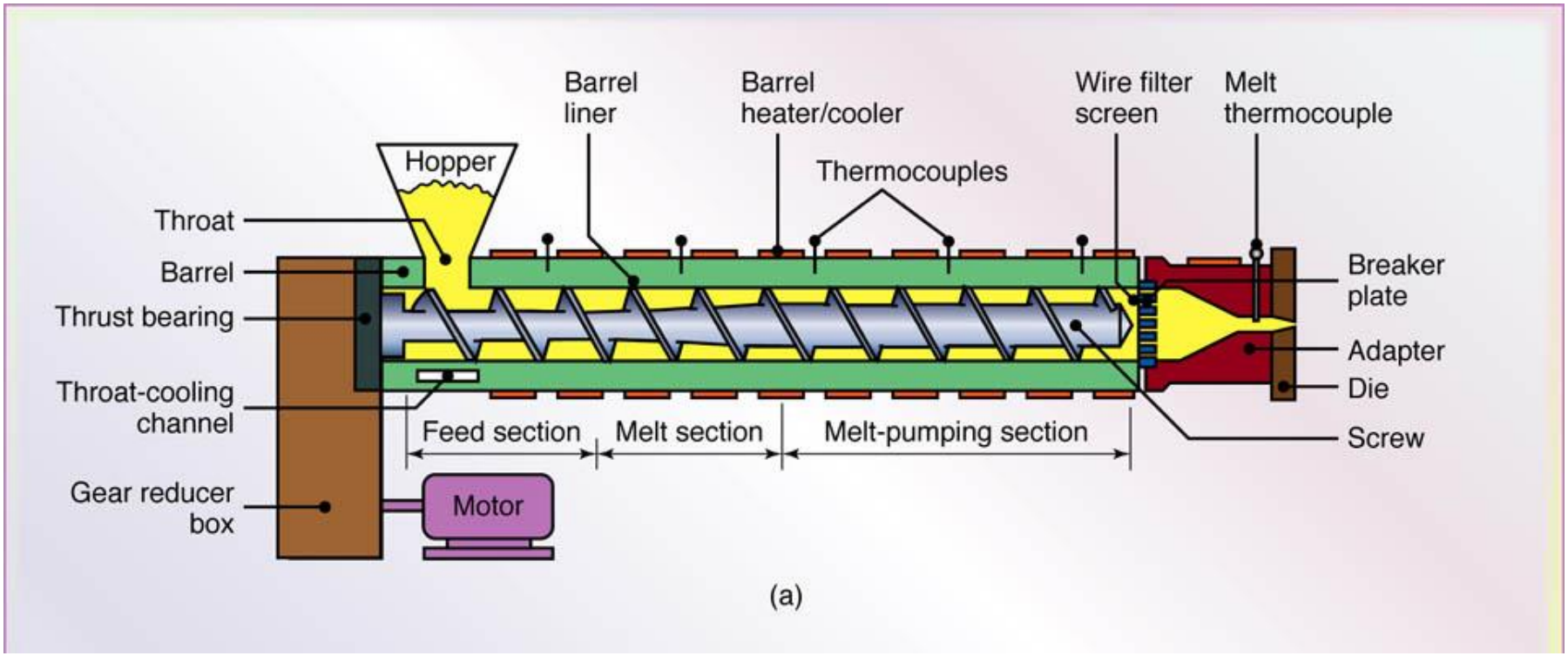


Source by Kalpakjian Book, 2014

1. Extrusion Process

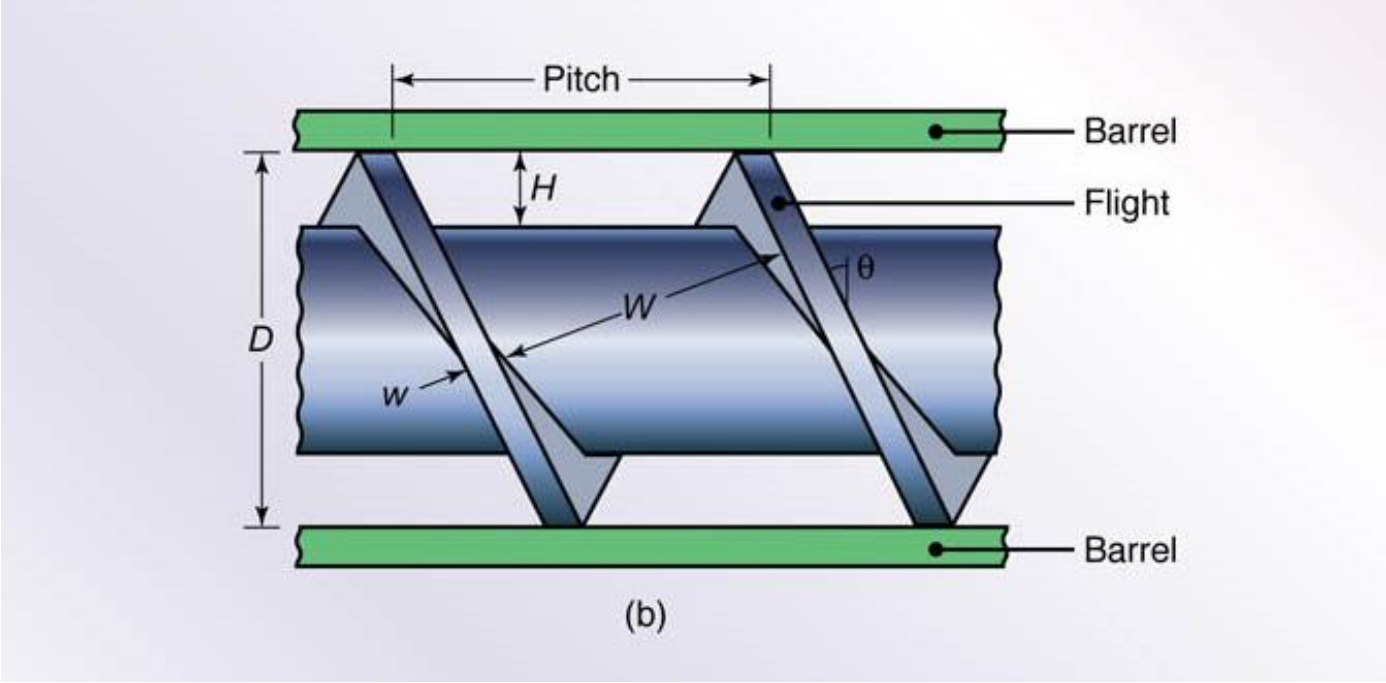
- Consists of complex shapes with constant cross-section.
- Types of parts can be extruded are such as solid rods, tubing, pipes, window frames & channels due to continuous supply and flow.
- Other examples are such as cable, strips and plastic coated electrical wire.
- Raw materials in the form of thermoplastic pallets, granules or polymer powder were poured into a hopper and fed into extruder barrel.
- The barrel with a screw to blend the pallets and conveys them down the barrel.
- Heaters around the extruder's barrel heats the pellets and melting them
- Screw has 3 main sections
  - Feed section
  - Melt or transition section
  - Pumping section

Extruder Schematic



(a) Schematic diagram of a typical screw extruder. Intricate shapes can be extruded with relatively simple and inexpensive dies. Source by Kalpakjian Book, 2014.

Extruder Schematic (cont.)

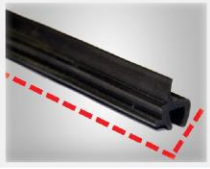
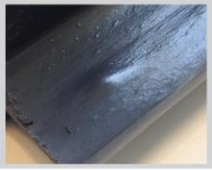


(b) Geometry of an extruder screw. Source by Kalpakjian Book, 2014.

- Thickness of helical ribbon, H
- Width of helical ribbon, W
- Shape of helical screw
- Pitch of helical screw
- Flight angle of helical screw, θ
- Ratio of barrel length to its diameter, L/D
- Screw rotational speed
- Properties of polymers (viscosity, etc..)
- Working temperature

Source by Kalpakjian Book, 2014

Defects in Extrusion Process

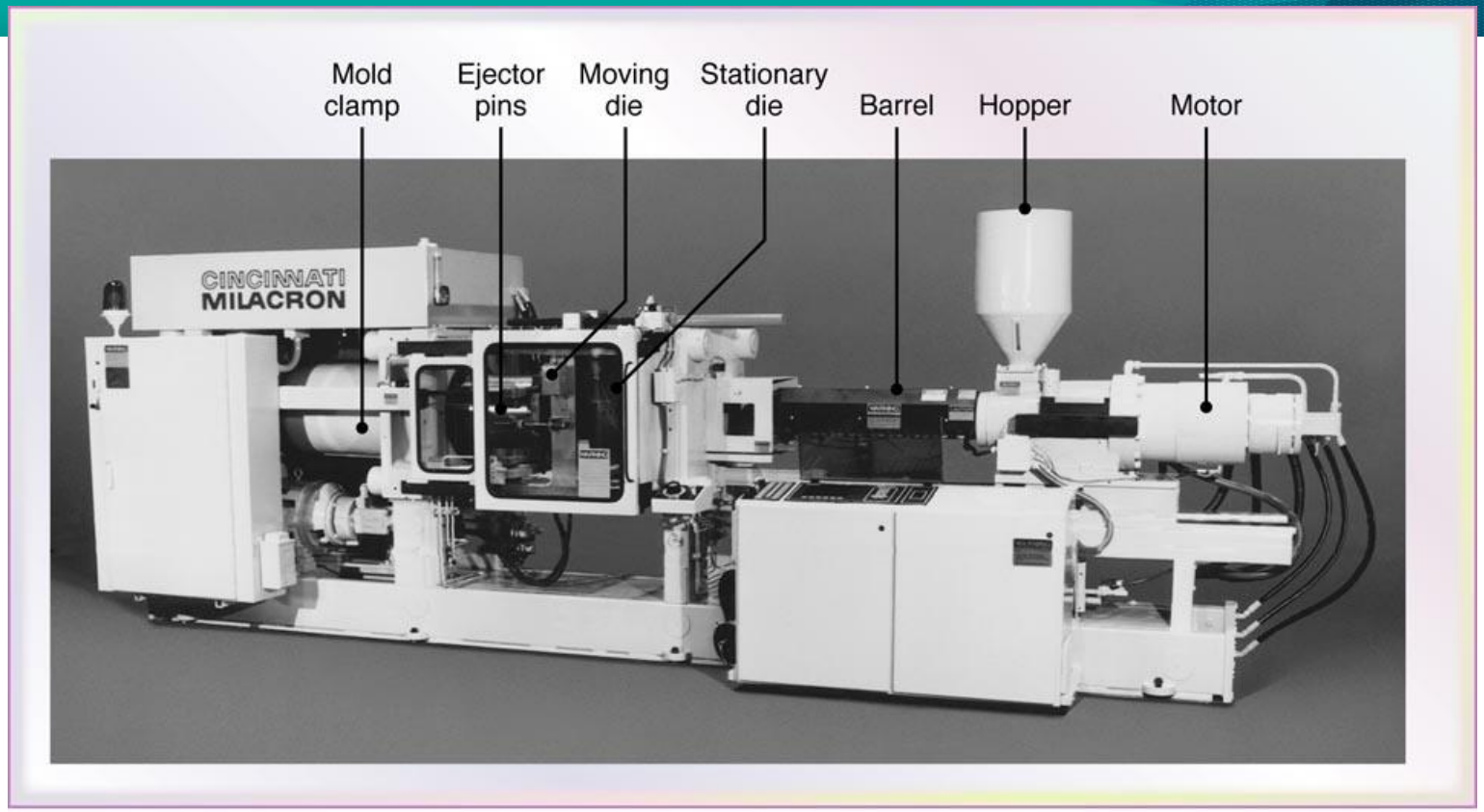
Problem	Image	Cause	Solution
1. Lumpy Surface		Too cold	• Increase all temperatures • Increase screen packs
2. Surging		Equipment or Settings	• Take off puller irregular • Motor speed varies • Inconsistent Rpm's • Uneven feed • Bridging in hopper • If Ammeter is varying by 5% or more , increase temperature of the feed
3. Orange Peel Surface		Overheating	• Raise die temperature • Decrease speed
4. Pimples on Surface		Resin Gels	• Increase screens • Decrease speed
6. Excessive Shrinkage		Too much stress	• Cool slower • Decrease speed • Design die with lower draw down
6. Bubbles		Moisture	• Dry Material at 220F for one hour

Source by http://www.sylvin.com

2. Injection Molding

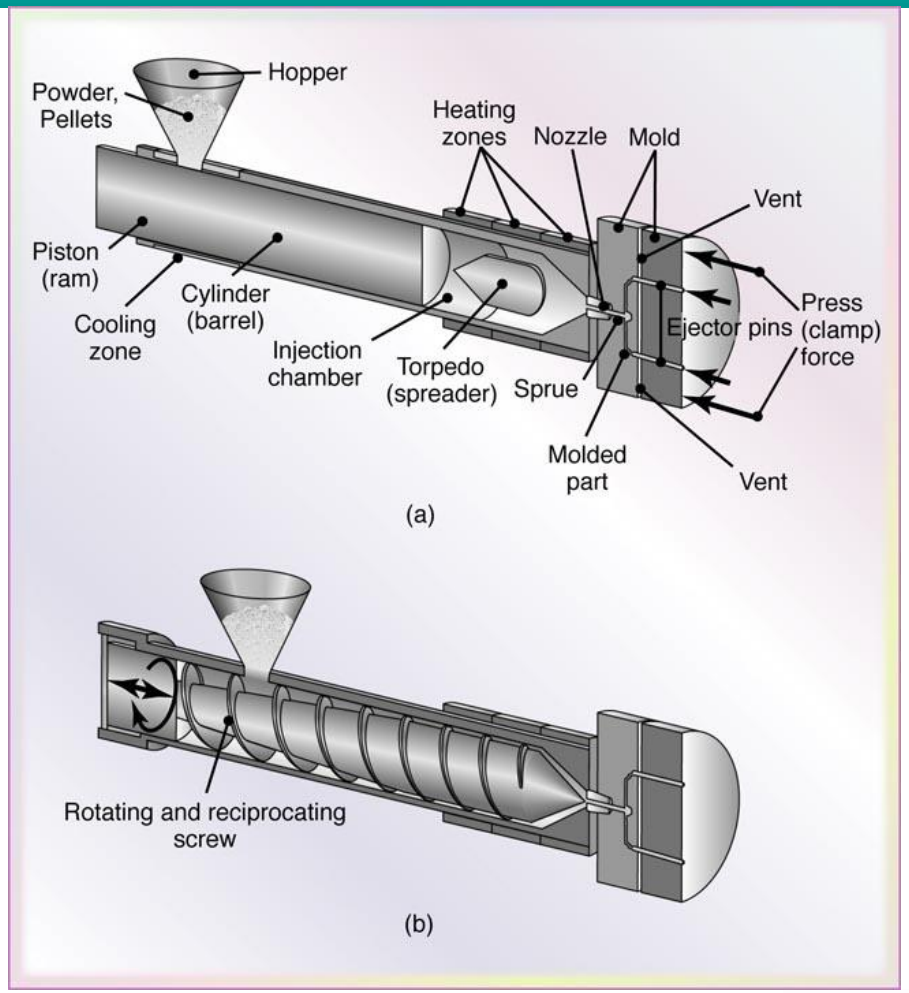
- Quite same with extrusion process which involved heated barrel.
- Pellets or granules fed into heated cylinder.
- Molten plastic forced into mold cavity.
- Consists of several components such as runners, cores, cavities, cooling channels, inserts, knock out pins and ejectors

Injection Molding Machine



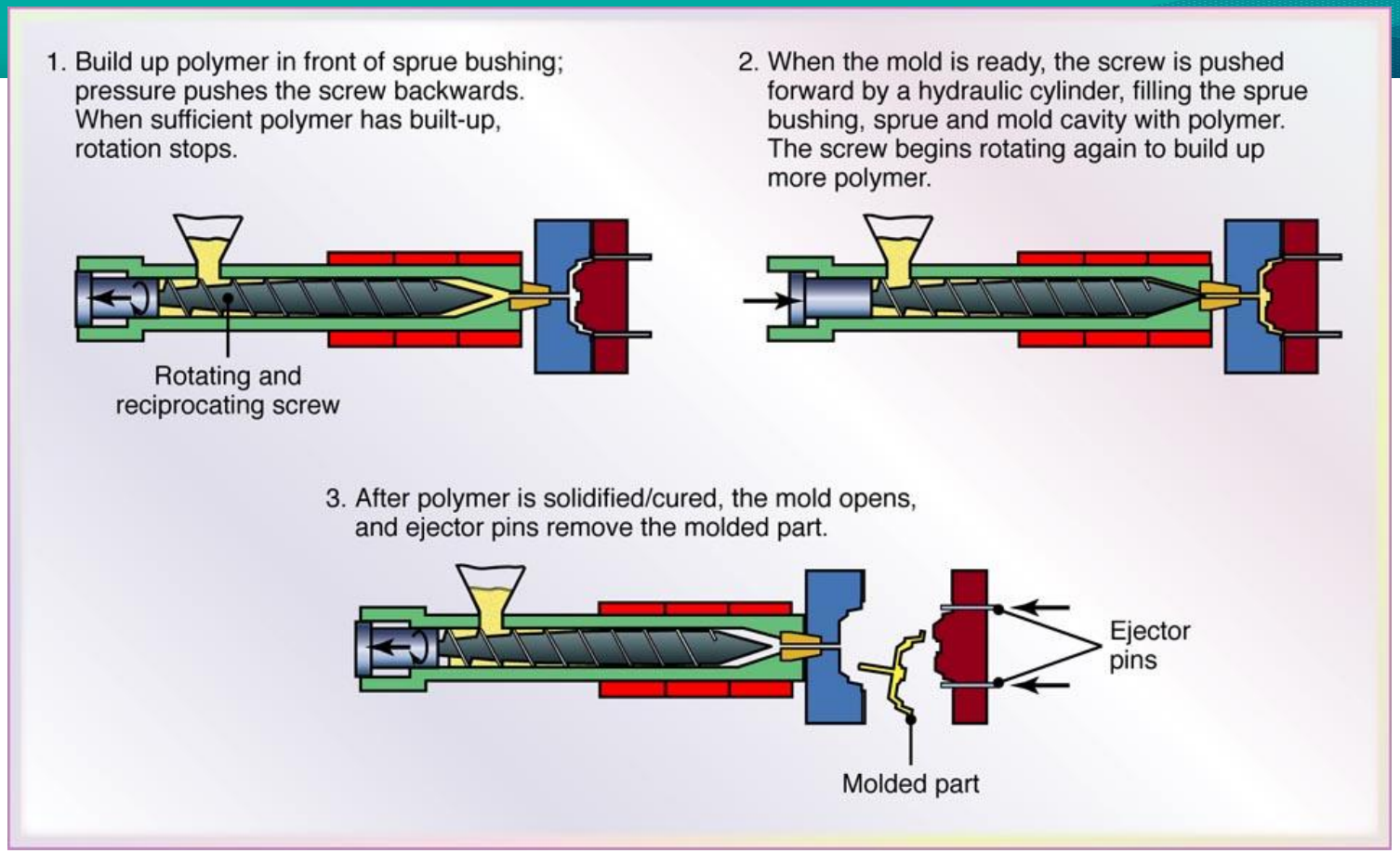
A 2.2-MN (250-ton) injection molding machine. The tonnage is the force applied to keep the dies closed during the injection of molten plastic into the mold cavities and hold it there until the parts are cool and stiff enough to be removed from the die. *Source*: Courtesy of Cincinnati Milacron, Plastics Machinery Division.

Injection Molding Schematic



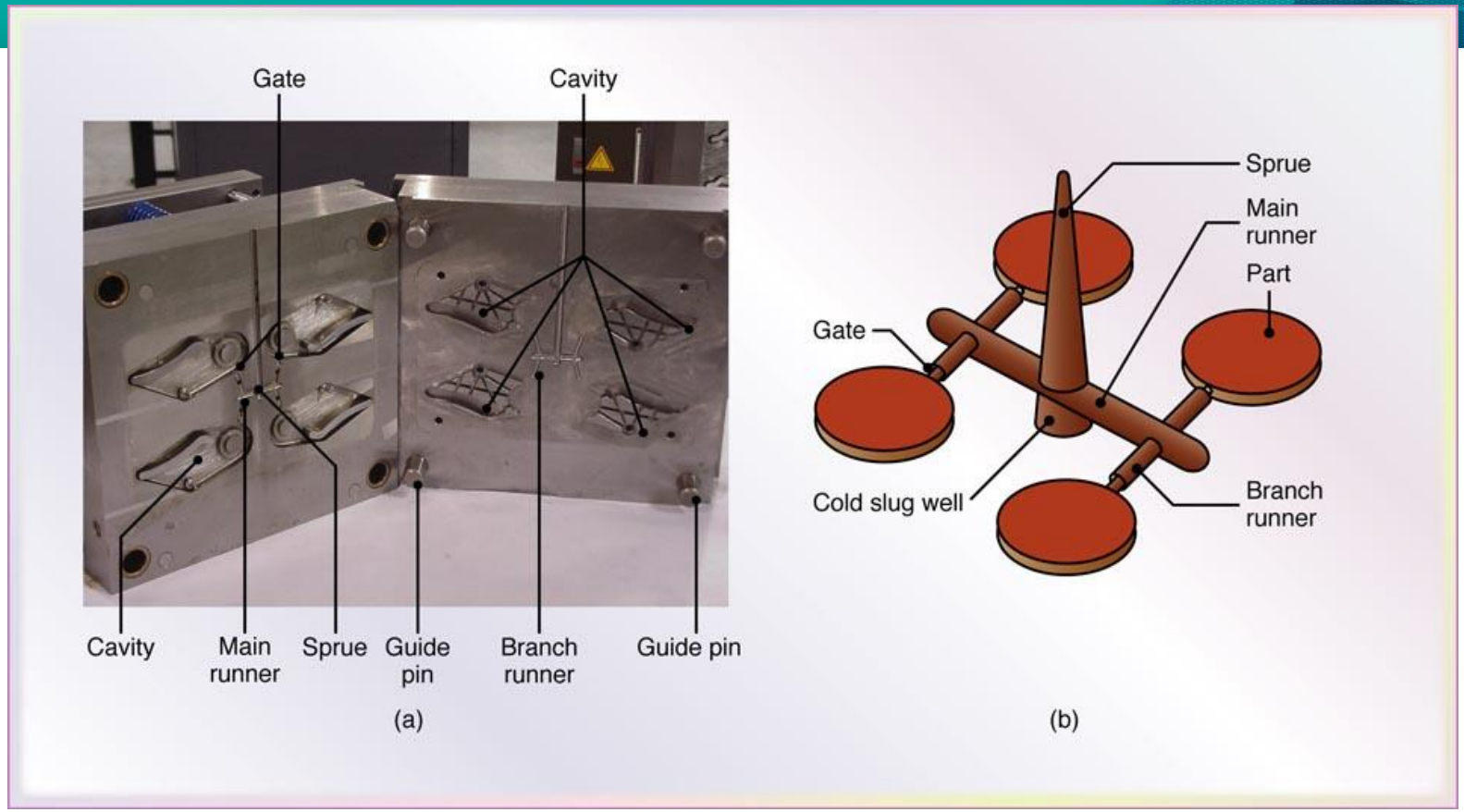
Schematic illustration of injection molding with (a) plunger and (b) reciprocating rotating screw. Source by Kalpakjian Book, 2014.

Steps in Injection Molding Process



Sequence of operations in the injection molding of a part with a reciprocating screw. This process is used widely for numerous consumer and commercial products, such as toys, containers, knobs, and electrical equipment. Source by Kalpakjian Book, 2014.

Mold Features for Injection Molding



Schematic of mold features for injection molding. (a) Two-plate mold with important features were identified. (b) Four parts showing details and the volume of material required. *Source*: Courtesy of Tooling molds West. Inc.

Source by Kalpakjian Book, 2014

Types of Molds in Injection Molding

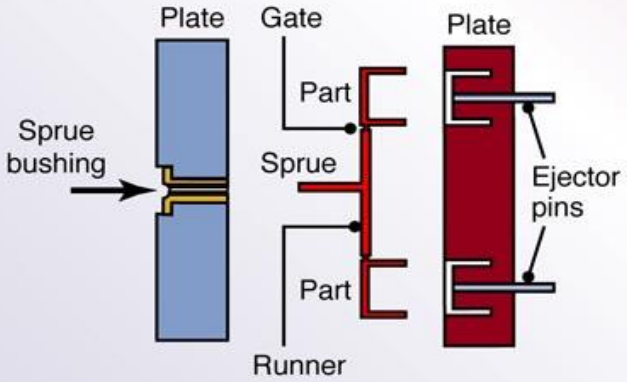
3-basic types of molds

i. Cold runner two plate mold
   - Need trimming process to removed the channel connecting mold cavity to the end of barrel

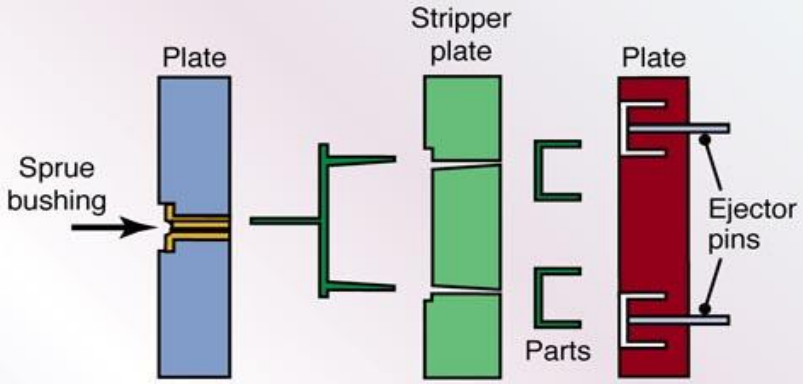
ii. Cold runner three plate mold
   - The runner automatically separated from the part when the mold open

iii. Hot runner mold
   - Molded part consists of no gates, runners or sprue

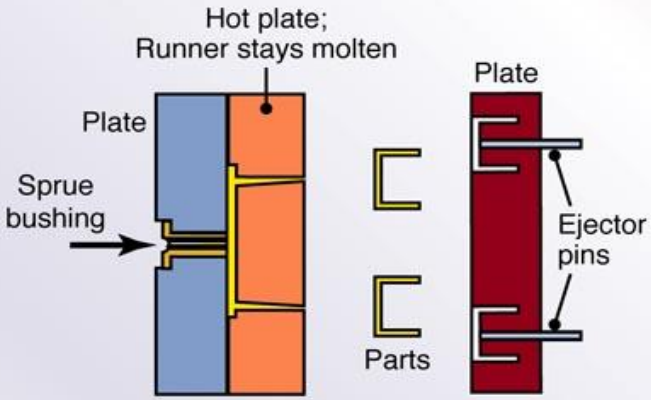
Types of Molds: Schematics



two-plate mold



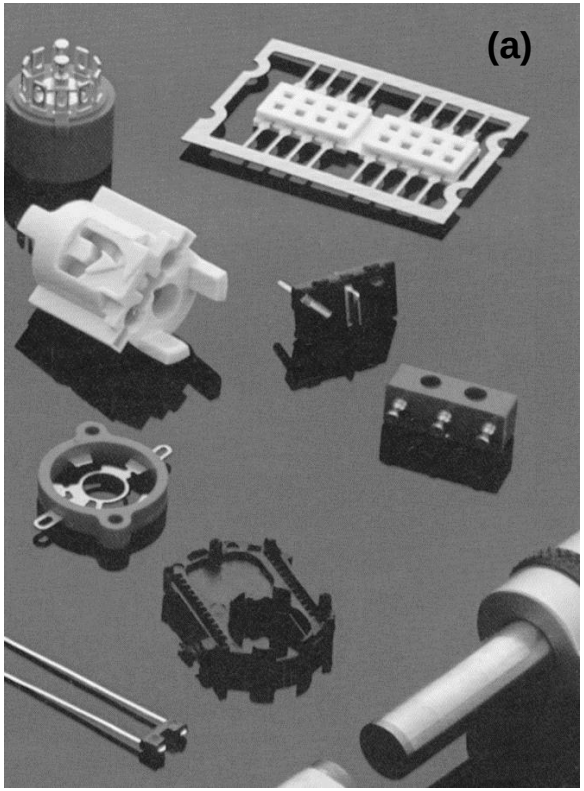
three-plate mold



hot-runner mold

Source by Kalpakjian Book, 2014

Products Made by Injection Molding



Typical products made by injection molding, including examples of insert molding.
Source: (a) Courtesy of Plainfield molding, Inc. (b) Courtesy of Rayco mold and Mfg. LLC.

Process capabilities

- High production rates
- Good dimensional control
- Cycle time range 5 to 60 sec's
- mould materials- tool steels, beryllium - Cu, Al
- mould life:
  - 2 million cycles (steel moulds)
  - 10000 cycles (Al moulds)

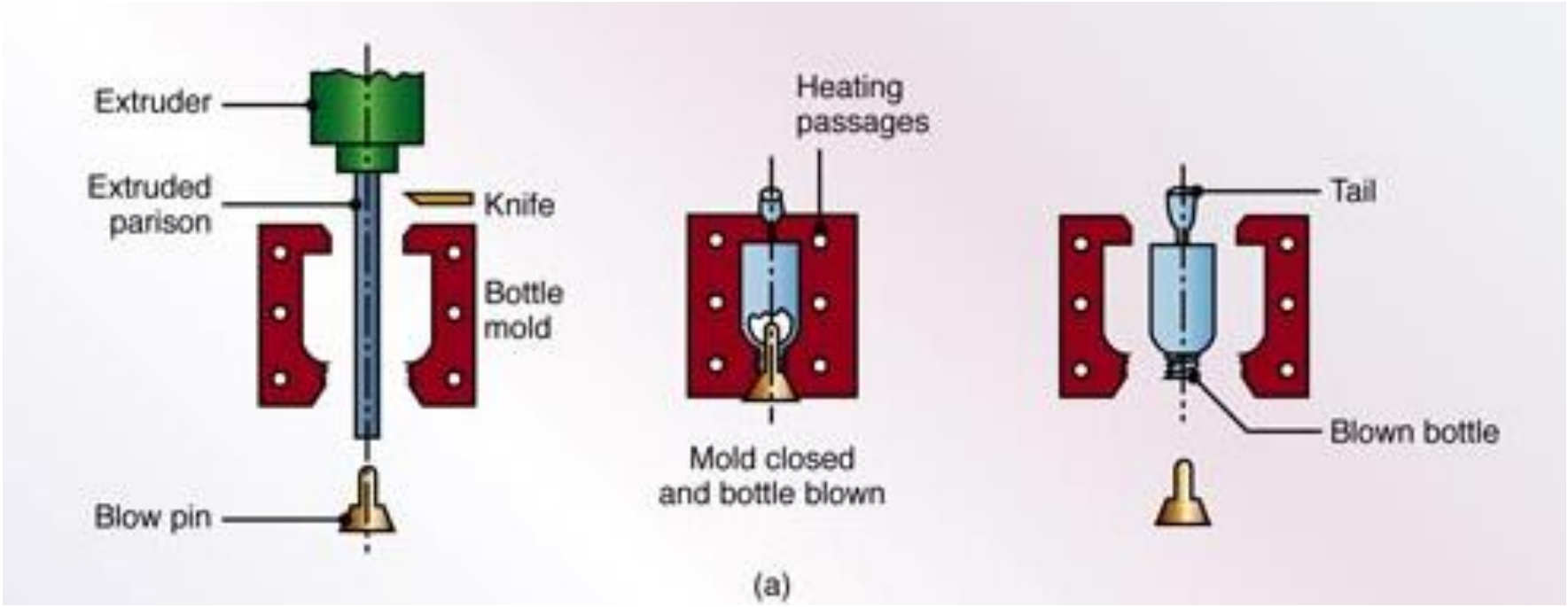
Injection Molding in FKM Lab

Courtesy of Faculty of Mechanical Engineering Laboratory, UMP

3. Blow Molding

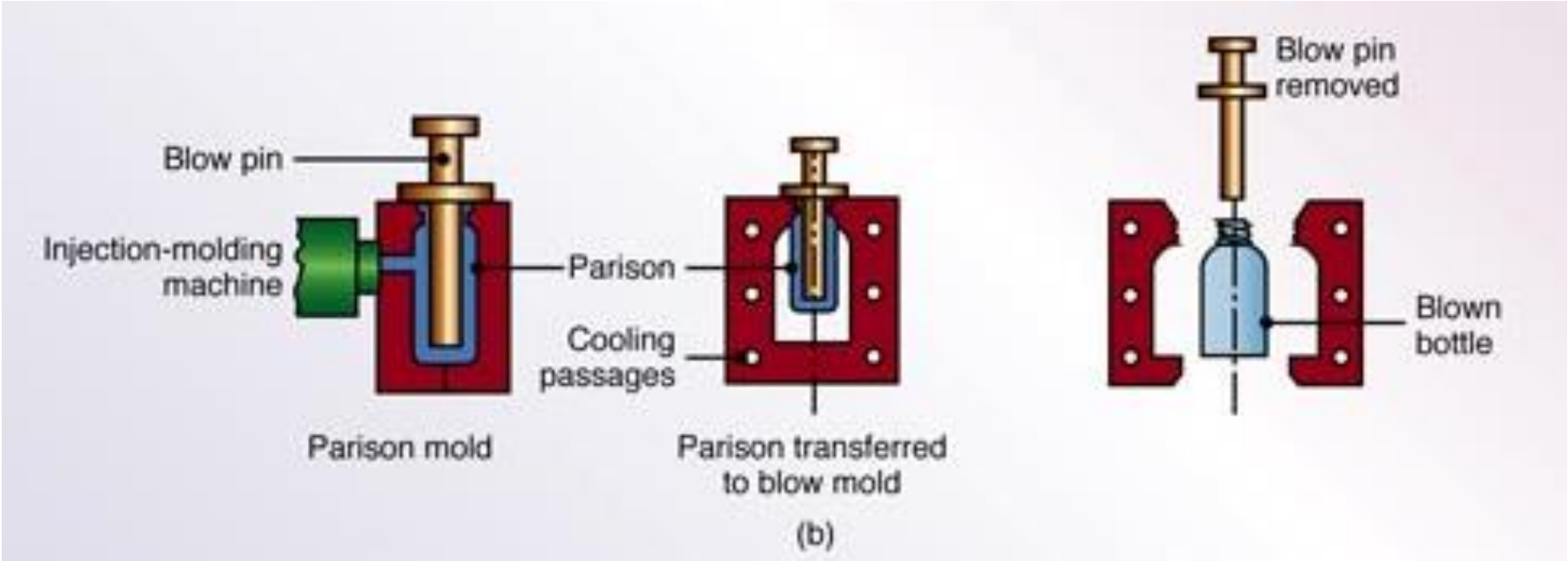
- Modification of extrusion and injection molding process.
- A short tubular piece was expanded and pressed against the container walls by pressure and cooled once contact with the die mold.
- A tube was extruded and clamped to the mold with cavity larger than tube diameter.
- The tube then blown outward to fill the mold cavity.

Blow Molding (extrusion)



Schematic diagram of (a) the extrusion blow-molding process for making plastic bottles. Source by Kalpakjian Book, 2014.

Blow Molding (injection)



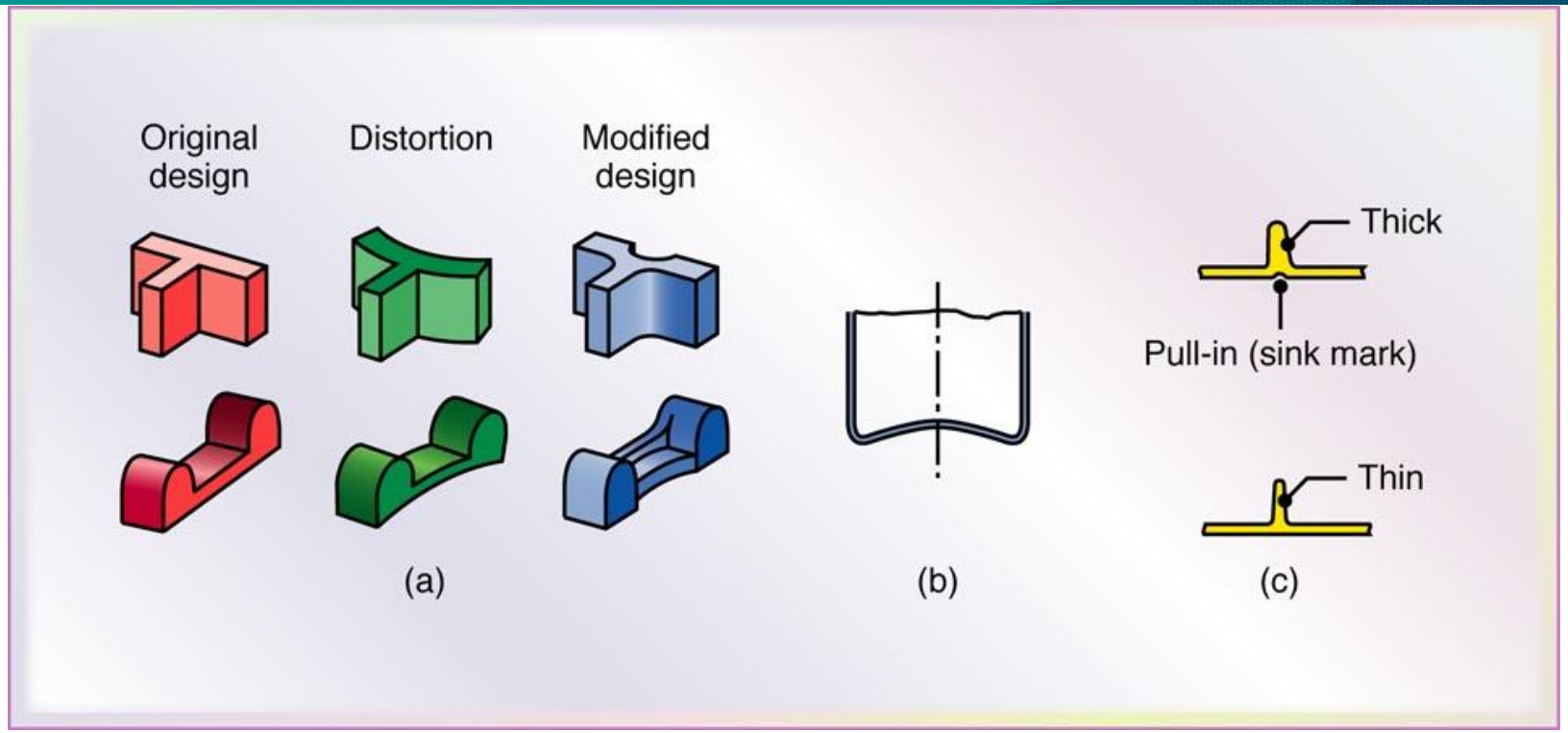
Schematic illustrations of (b) the injection blow-molding process.

Source by Kalpakjian Book, 2014

General Design Considerations

- Product design:
  - Material selection in order to meet product requirements.
  - Product produced without any defect (sink marks and stress concentration,).
  - Location of gate, runner, ejection pin for tool design.
- Tool design:
  - Tool material for manufacturing volume and tool life.
  - Tonnage of press & number of cavities in a tool.
  - Position of gate, ejection pin and runner for tool design.

Design Modifications

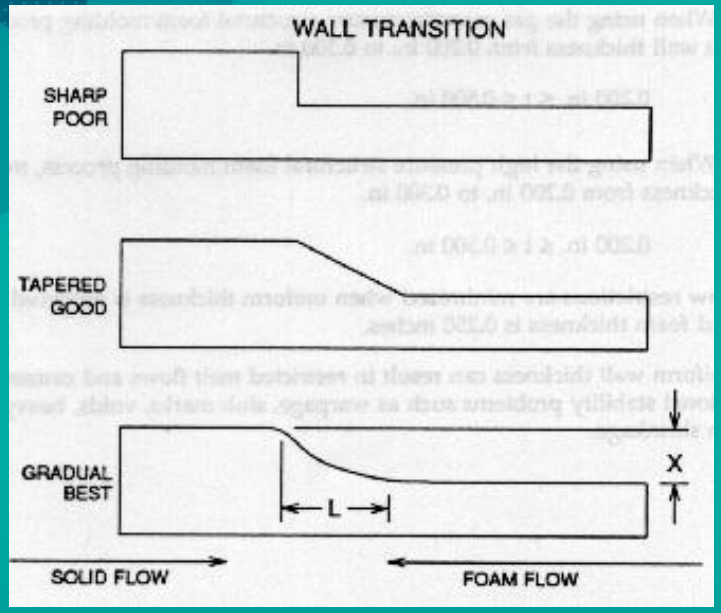


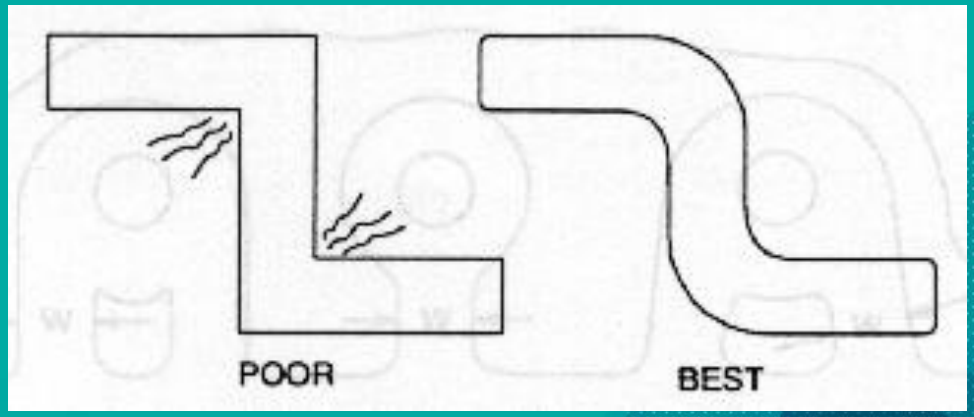
Examples of design modifications to minimize or eliminate distortion in plastic parts: (a) recommended design changes to minimize distortion; (b) stiffening the bottoms of thin plastic containers by doming – a technique similar to the process used to shape the bottoms of aluminum tin cans; and (c) design change in a rib to minimize sink mark (pull-in) caused by shrinkage during the cooling of thick sections.

Source by Kalpakjian Book, 2014

DESIGN CONSIDERATIONS FOR PLASTIC PARTS

- Avoid sharp variation of wall thickness
- Avoid sharp corners

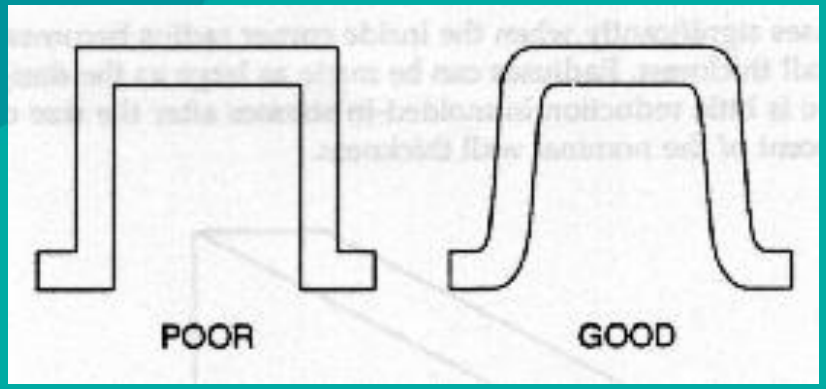


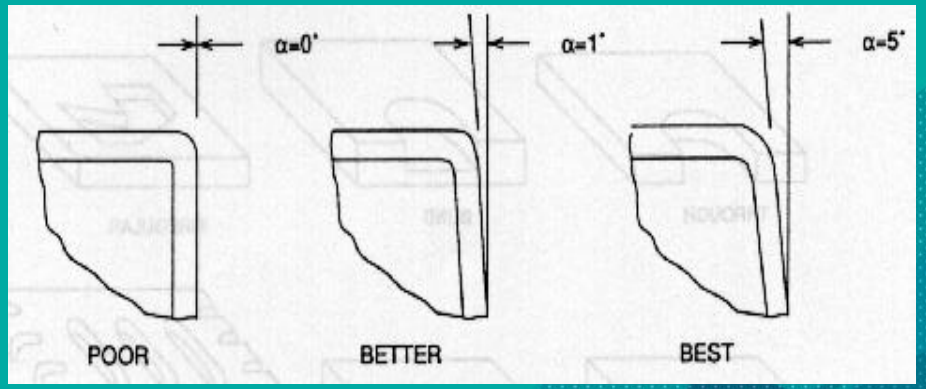


Source by Kalpakjian Book, 2014

DESIGN CONSIDERATIONS FOR PLASTIC PARTS

- Provide generous draft angles, 5^{o} or more
- Avoid needs of side-pull (reading assignment)

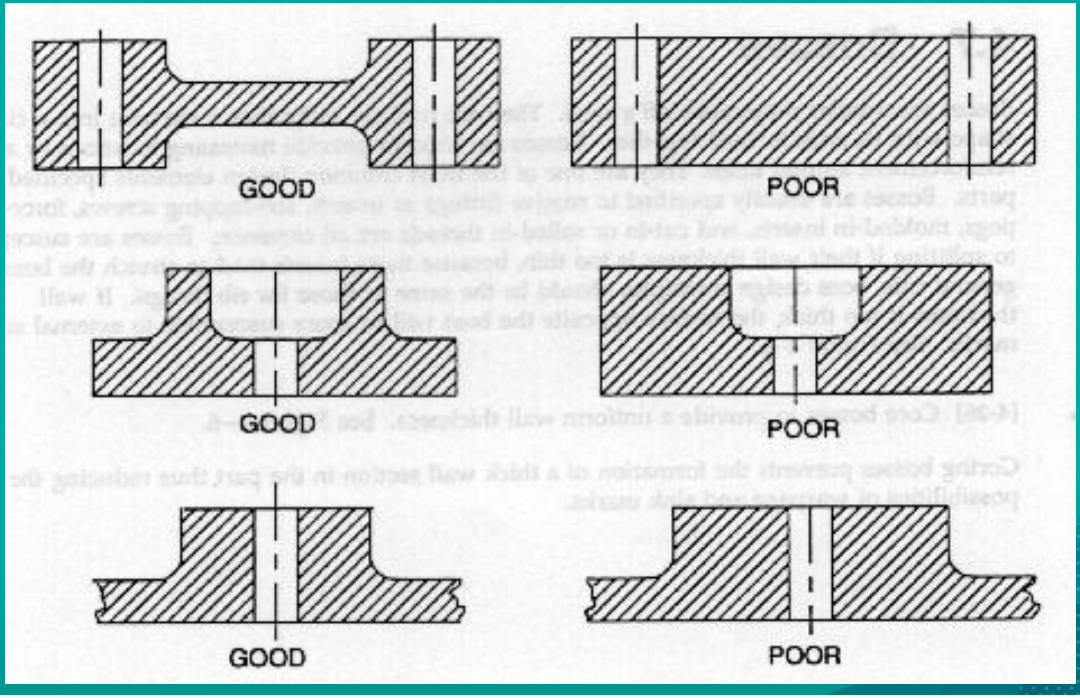




Source by Kalpakjian Book, 2014

DESIGN CONSIDERATIONS FOR PLASTIC PARTS

- Core bosses to ensure uniform thickness (minimize impact of variable shrinkage)



Source by Kalpakjian Book, 2014

End of chapter Forming and Shaping Polymer Processes