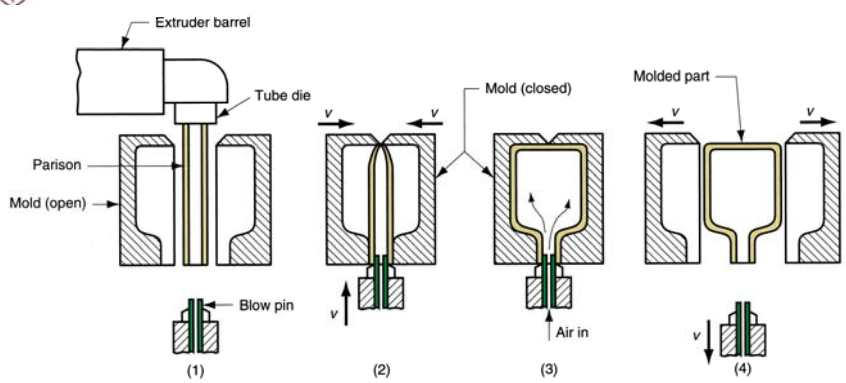
Outline

- Blow Molding Process
  - *Extrusion Blow Molding*
  - *Injection Blow Molding*
  - *Stretch Blow Molding*
- Thermoforming Process
- Analysis of Polymer Extrusion
- Example 1: *Extrusion*
- Example 2: *Blow Molding*

Blow Molding Process

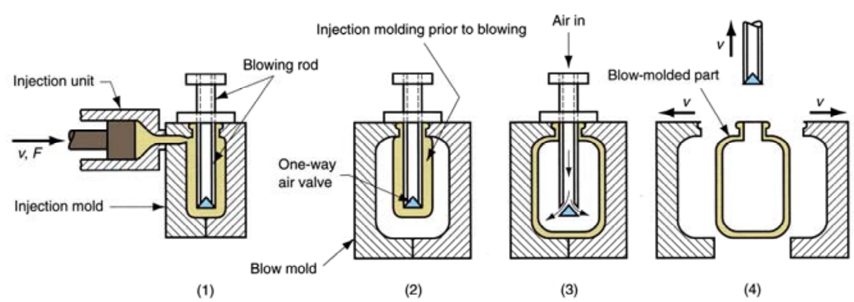
- Molding process in which air pressure is used to inflate soft plastic into a mold cavity
- Important for making one-piece hollow plastic parts with thin walls, such as bottles
- Since these items are used for consumer beverages in mass markets, production is typically organized for ………… quantities
- Accomplished in two steps:
  1. Fabrication of a starting tube, called a …………
  2. Inflation of the tube to desired final shape
- Forming the parison is accomplished by either
  - Extrusion or
  - Injection molding

Extrusion Blow Molding



(1) extrusion of parison
(2) parison is pinched at the top and sealed at the bottom around a metal blow pin as the two halves of the mold come together
(3) the tube is inflated so that it takes the shape of the mold cavity
(4) mold is opened to remove the solidified part

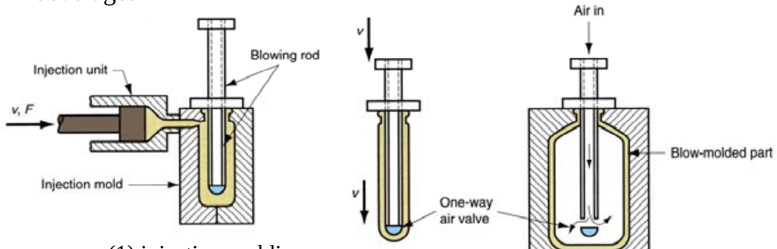
Injection Blow Molding



(1) parison is injected molded around a blowing rod
(2) injection mold is opened and parison is transferred to a blow mold
(3) soft polymer is inflated to conform to the blow mold
(4) blow mold is opened and blown product is removed

Stretch Blow Molding

- Variation of injection blow molding in which blowing rod extends downward into parison in step 2, stretching the soft plastic for a more favorable stressing of polymer than conventional blow molding
- Resulting structure is …….. rigid, with ……… transparency and ……. impact resistance
- Most widely used material is polyethylene terephthalate (PET) which has very low permeability and is strengthened by stretch blow molding
- Combination of properties makes it ideal as container for carbonated beverages



(1) injection molding of parison (2) stretching (3) blowing

Materials and Products in Blow Molding

- Blow molding is limited to thermoplastics
- Materials: high density polyethylene, polypropylene (PP), polyvinylchloride (PVC), and polyethylene terephthalate
- Products: disposable containers for liquid consumer goods, large shipping drums (55 gallon) for liquids and powders, large storage tanks (2000 gallon), gasoline tanks, toys, and hulls for sail boards and small boats

Rotational Molding

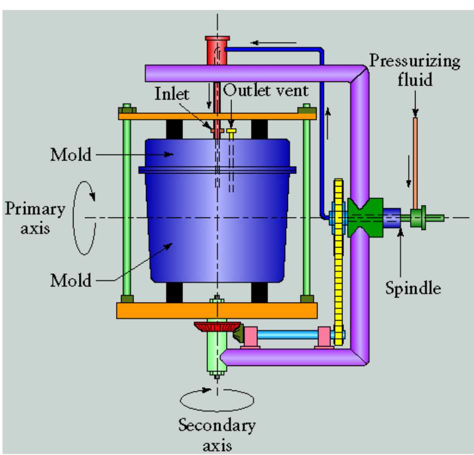


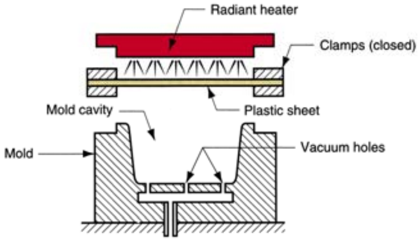
FIGURE 10.27 – (*Kalpakjian*) The rotational molding (rotomolding or rotocasting) process.

- A predetermined amount of polymer powder is loaded in the mold. The mold is heated while rotating on two perpendicular axis.
- Gravity is the acting force in this process not the centrifugal forces, this results in uniform thickness.
- Molds are …….. and ……. expensive.
- Products: Trash cans, buckets, hollow toys, and plastic footballs can be made by this process.

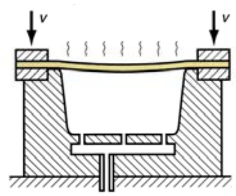
Thermoforming

- Flat thermoplastic sheet or film is heated and deformed into desired shape using a mold
- Heating usually accomplished by radiant electric heaters located on one or both sides of starting plastic sheet or film
- Widely used in packaging of products and to fabricate large items such as bathtubs, contoured skylights, and internal door liners for refrigerators

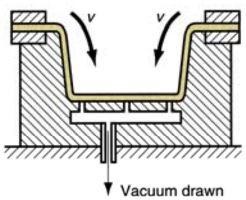
Vacuum Thermoforming Process: *Negative Mold*



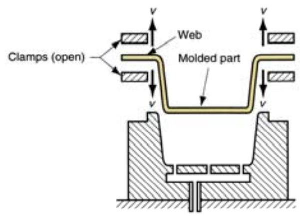
(1) a flat plastic sheet is softened by heating



(2) the softened sheet is placed over a concave mold cavity



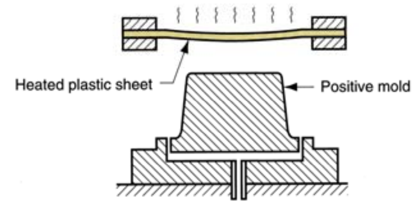
(3) a vacuum draws the sheet into the cavity



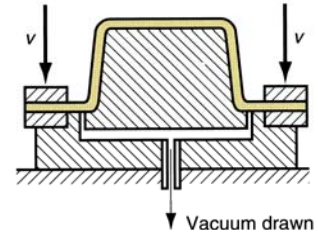
the part is removed and subsequently trimmed from the web

the plastic hardens on contact with the cold mold surface

Vacuum Thermoforming Process: *Positive Mold*



(1) the heated plastic sheet is positioned above the convex mold



(2) the clamp is lowered into position, draping the sheet over the mold as a vacuum forces the sheet against the mold surface

Negative Molds vs. Positive Molds

Negative mold – concave cavity

Positive mold - convex shape

- Both types are used in thermoforming
- For positive mold, heated sheet is draped over convex form and negative or positive pressure forces plastic against mold surface

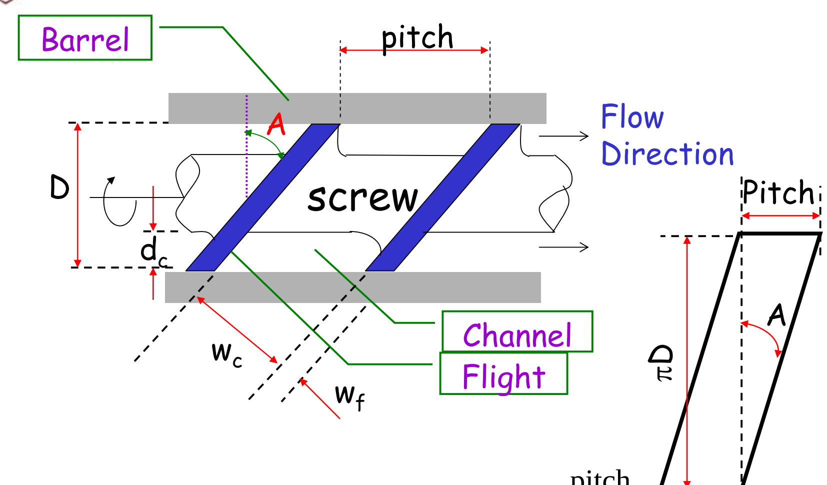
Materials for Thermoforming

- ……. thermoplastics can be thermoformed, since extruded sheets of thermosetting or elastomeric polymers have already been cross-linked and cannot be softened by reheating
- Common TP polymers: polystyrene, cellulose acetate, cellulose acetate butyrate, ABS, PVC, acrylic (polymethylmethacrylate), polyethylene, and polypropylene

Applications of Thermoforming

- *Thin films*: blister packs and skin packs for packaging commodity products such as cosmetics, toiletries, small tools, and fasteners (nails, screws, etc.)
- *Thicker sheet stock*: boat hulls, shower stalls, advertising displays and signs, bathtubs, certain toys, contoured skylights, internal door liners for refrigerators

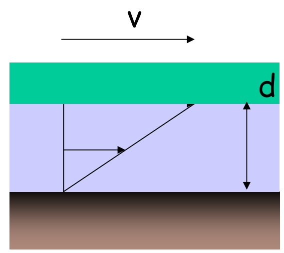
Analysis of Extrusion



A: the helix angle of the screw $\tan A = \dfrac{\text{pitch}}{\pi D}$

Analysis of Extrusion

Transport Mechanism: Drag Flow between barrel and channel



A simple plate model

Volume drag flow rate (m^3/s)

$$Q_d = 0.5 v\, d\, w$$

In relation to the extrusion screw

$v = \pi D N \cos A$

$d = d_c$

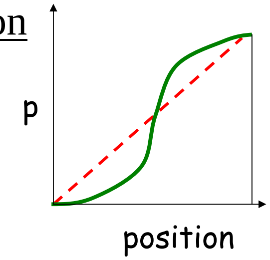
$w = w_c = (\pi D \tan A - w_f)\cos A$

Assuming Wc>>Wf → $w = w_c \approx \pi D \sin A$

Analysis of Extrusion

Substitute w in the eq. from a plate model

$$Q_d = 0.5\pi^2 D^2 N d_c \sin A \cos A$$



Back pressure flow:

$$Q_b = \frac{\pi D d_c^3 \sin^2 A}{12\eta}\left(\frac{dp}{dl}\right) \approx \frac{p\pi D d_c^3 \sin^2 A}{12\eta L}$$

The resulting flow rate, assuming no leak flow

$$Q_x = Q_d - Q_b = 0.5\pi^2 D^2 N d_c \sin A \cos A - \frac{p\pi D d_c^3 \sin^2 A}{12\eta L}$$

- Design Parameters: D, d_c and A
- Operating Parameters: N, p and η

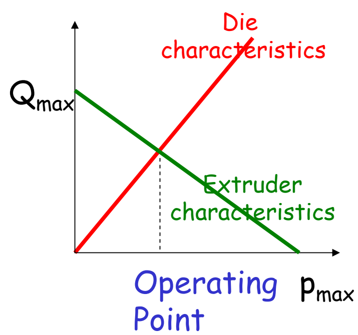
Analysis of Extrusion

Zero flow condition due to high back pressure

$$Q_x = Q_d - Q_b = 0$$

To find the maximum head pressure

$$p_{max} = \frac{6\pi D N L \eta \cot A}{d_c^2}$$



Extruder Characteristics

Die Characteristics

$$Q_x = K_s p \qquad \text{where } K_s = \frac{\pi D_d^4}{128\eta L_d}$$

For a circular die opening

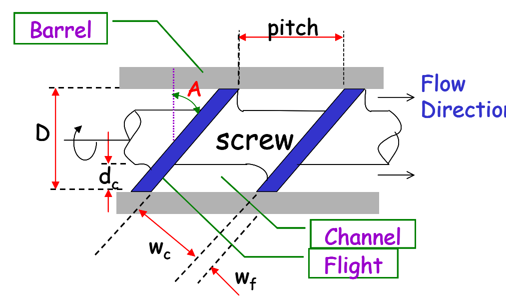
Ks: is a shape factor

Example 1: *Extrusion*

An extruder barrel has a diameter of 4.0 in and an L/D ratio of 28. The screw channel depth is 0.25in. and its pitch is 4.8 in. It rotates at 60 rev/min. The viscosity of the polymer melt is 100 * 10^{-4} lb-sec/in^2. What head pressure is required to obtain a volume flow rate of 150 in^3/min?

$$Q_d = 0.5\pi^2 D^2 N d_c \sin A \cos A$$

$$Q_b \approx \frac{p\pi D d_c^3 \sin^2 A}{12\eta L}$$



Example 2: *Blow Molding*

A blow molding operation produces a 6.25-in-diameter bottle from a parison that is extruded in a die whose outside diameter is 1.25 in. and inside diameter is 1.00 in. The observed diameter swell ratio is 1.24. What is the maximum air pressure that can be used if the maximum allowable tensile stress for the polymer is 1000 lb/in^2?

Next time:

Review of Polymer Processing