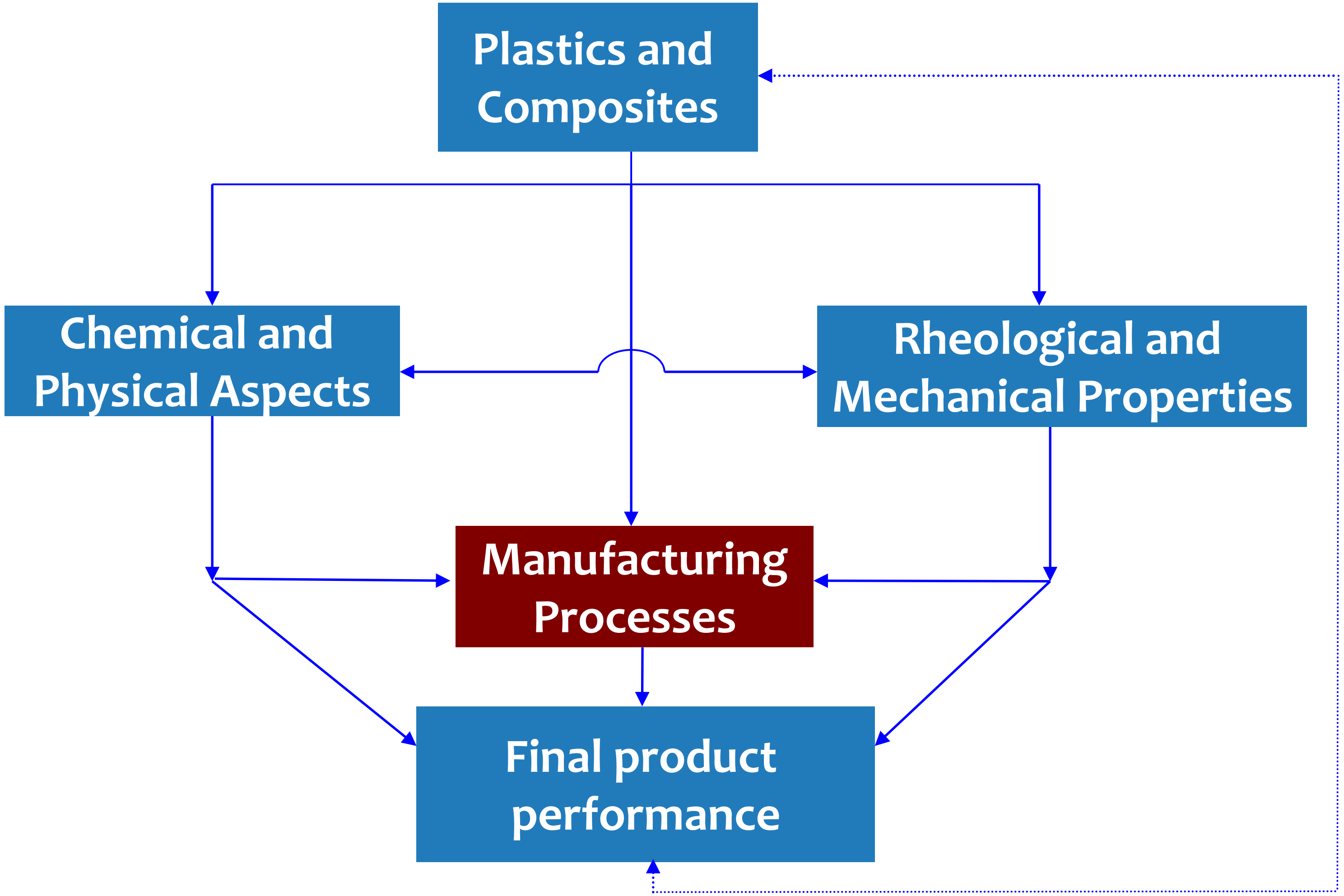
Tecnológico de Monterrey

# EXTRUSION

Dr. Jaime Bonilla Ríos

# Conceptual map of the course



# Extrusion

Extrusion = *Ex* (out) + *Trudere* (push)

The molten plastic is continuosly pushed by arotating screw en rotación through a die with a specific shape to get cables, pipes, films, etc.

# Extrusion: Blow molding

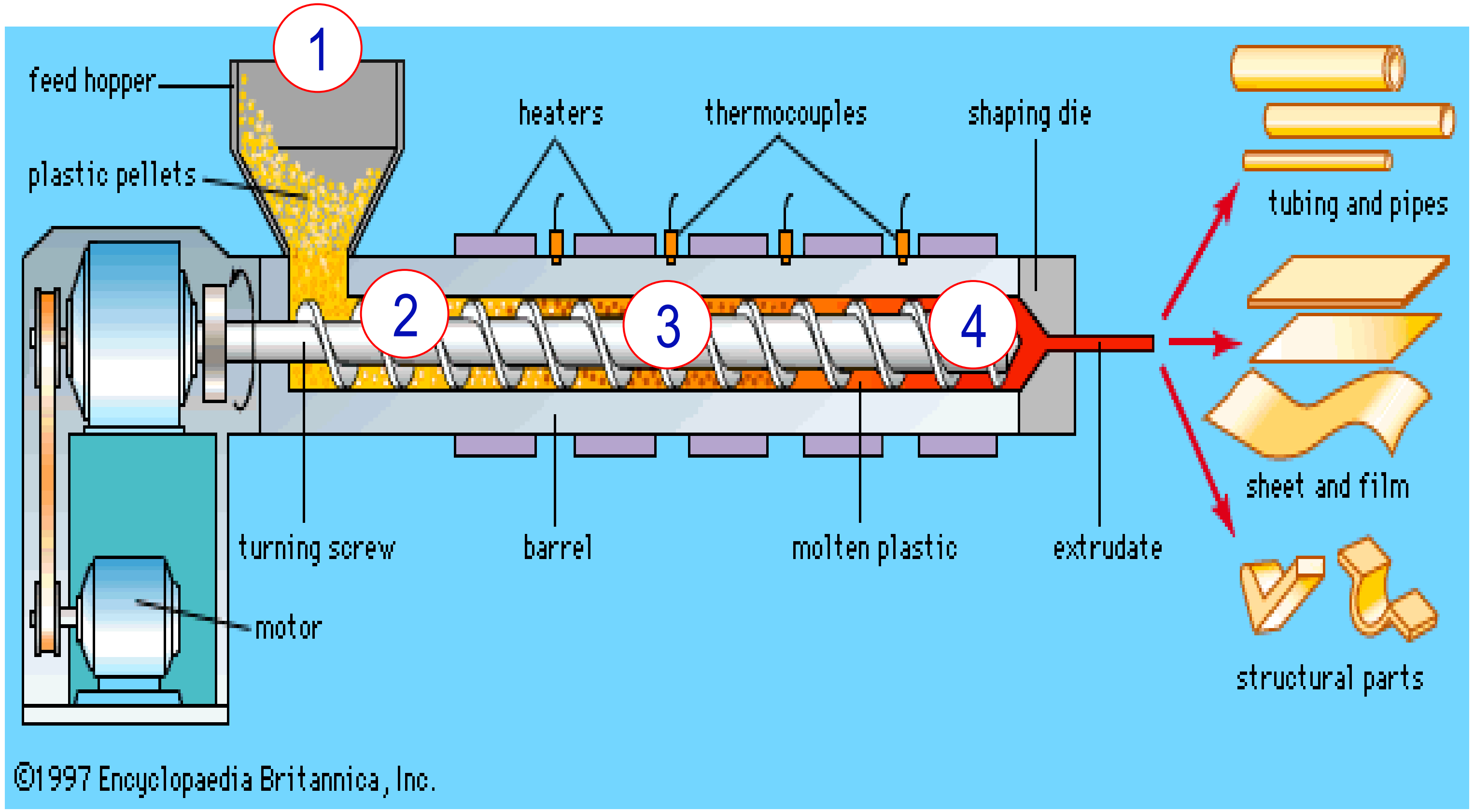



**Figure 2A:** Longitudinal section of a screw extruder. Plastic pellets are fed from a hopper into the barrel of the extruder, where the pellets are gradually melted by mechanical energy generated by a turning screw and by heaters arranged along the barrel. The molten polymer is forced through a die, which shapes the extrudate into a number of products such as the examples shown.

# Main processing parameters

**Operation:**

- Screw rotating frequency (rpm)
- Barrel temperature profile

**Design:**

- Screw diameter $\Rightarrow$ *Transfer heat area*
- Screw length $\Rightarrow$ *Residence time*
- Thread design $\Rightarrow$ *Mixing efficiency*

L/D = 8 - 10 (rubber)
L/D = 24 (general)
L/D = 36 - 40 (vented extrusion)

# Extrusion: Blow molding

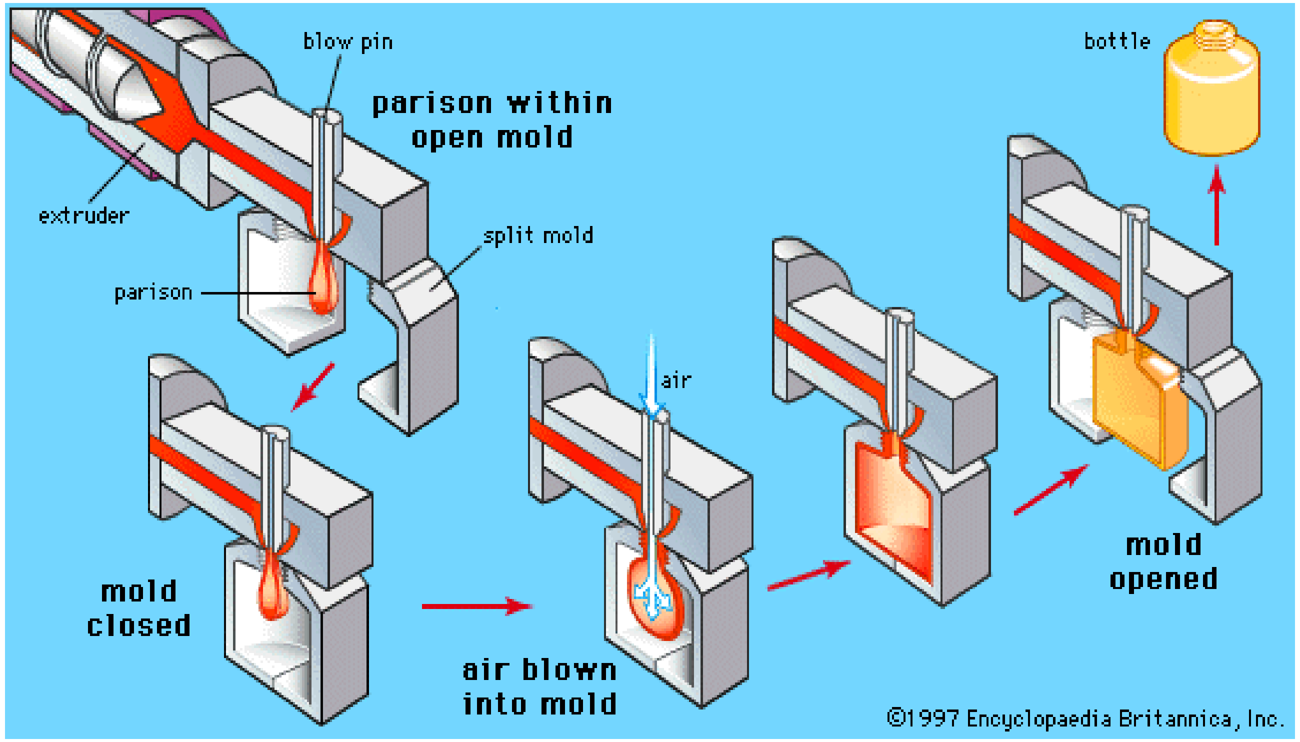
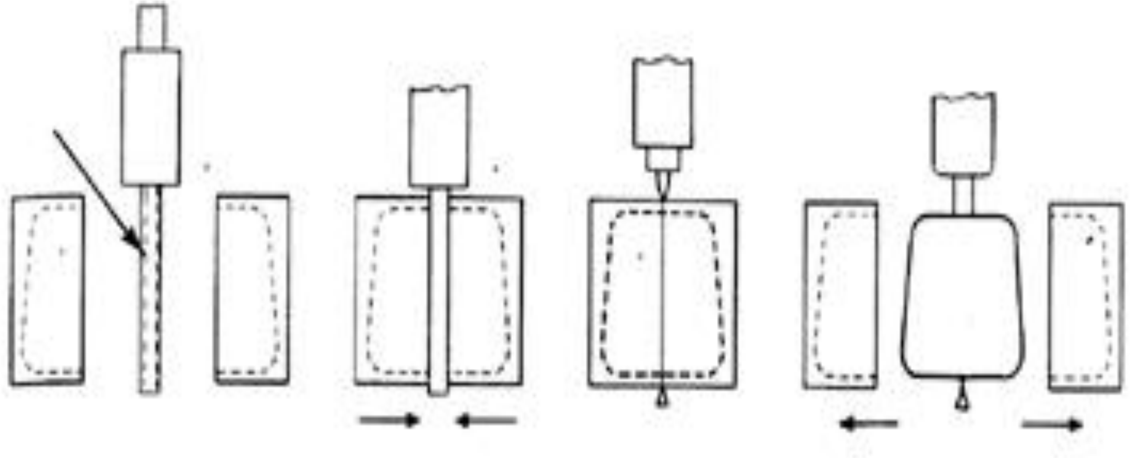



**Figure 4:** Blow molding of plastic containers. (Counterclockwise from top) A molten polymer is extruded into a hollow, tube-shaped parison. A split mold is closed around the parison, which is expanded against the sides of the mold by a stream of air. Once the plastic has solidified, the mold is

# Blow Molding



Parison Extrusion | Mold closes | Parison Blowing | Mold Opens

## Blow Molding Types of Processing

Continum Extrusion

Reciprocant Screw/Intermitent Extrusion

Intermitent Extrusion-Acumulative-Ram

Injection

To not interfere in the closure of the mold

$$\pi D_{vela}/2 < D_{molde}$$

# Extrusion: Blown Film

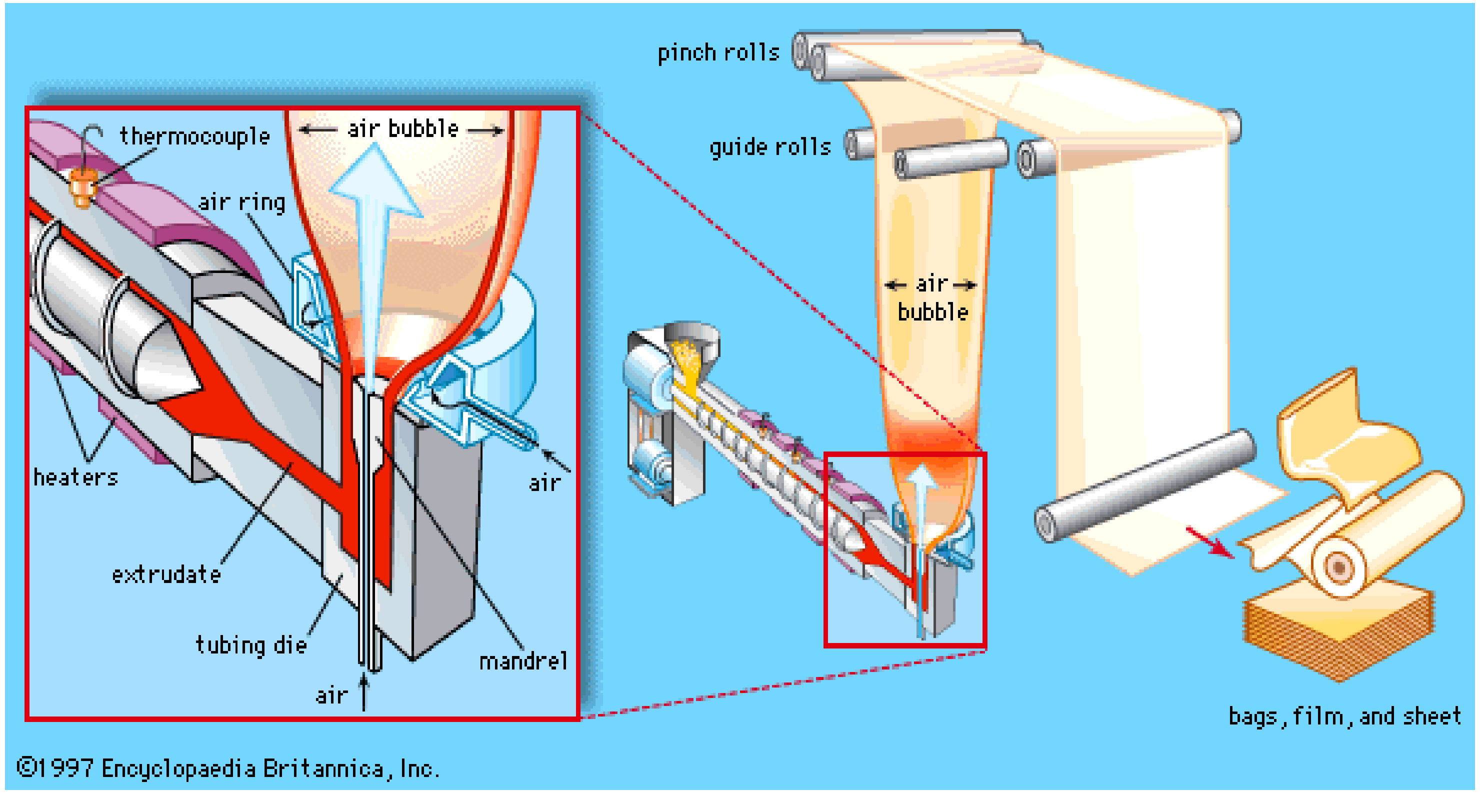


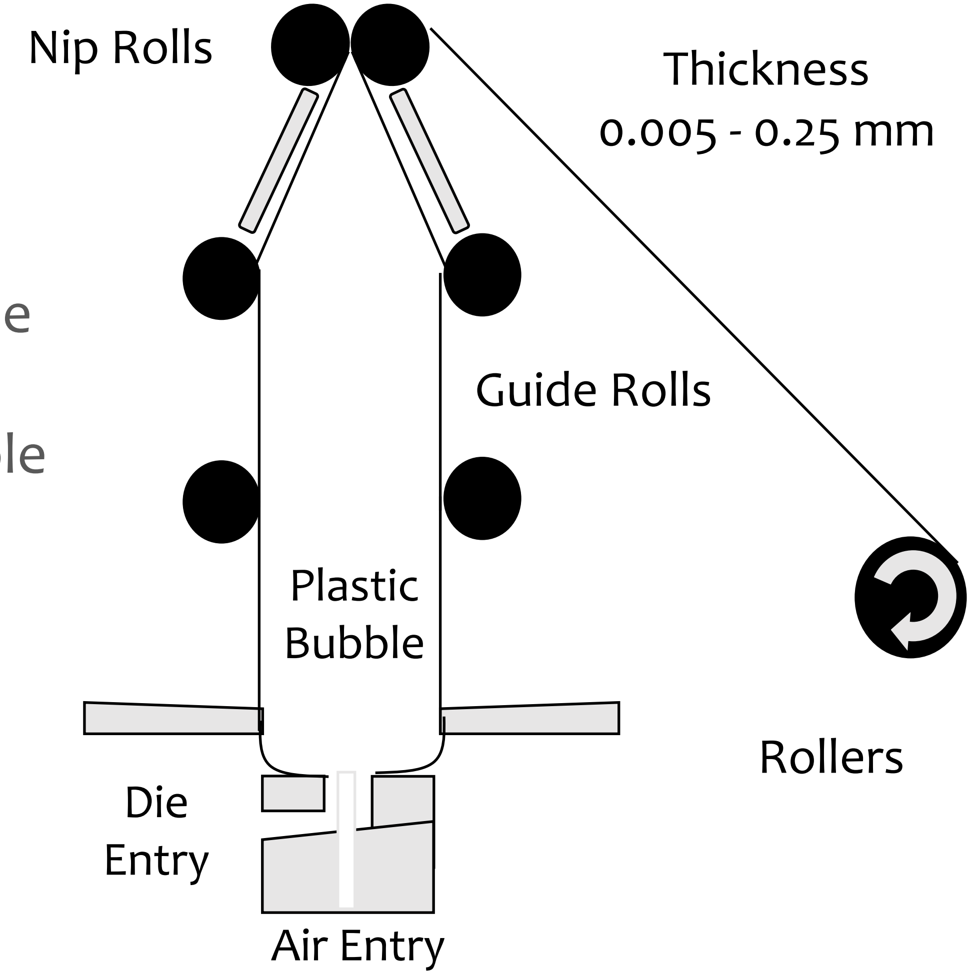

**Figure 2B:** Blow extrusion, in which molten extrudate is forced past a tubing mandrel, expanded into a balloon shape by a stream of air, drawn upward by rollers, and pinched into a collapsed sheet for cutting into a number of products.

# Extrusion: Blown Film

## Design and Operation Variables

1. The polymer is extrudates in a thin wall tube
2. Air is inject and trap inside the plastic bubble
3. The film is chill by cooling air

1. Blow-Up Ratio (1.5 a 4)
   ⇒ Orientation
2. Take-Up Speed
   ⇒ Directional Orientation
3. Die Gap(0.05 cm)
4. Die Diameter (10 - 120 cm)

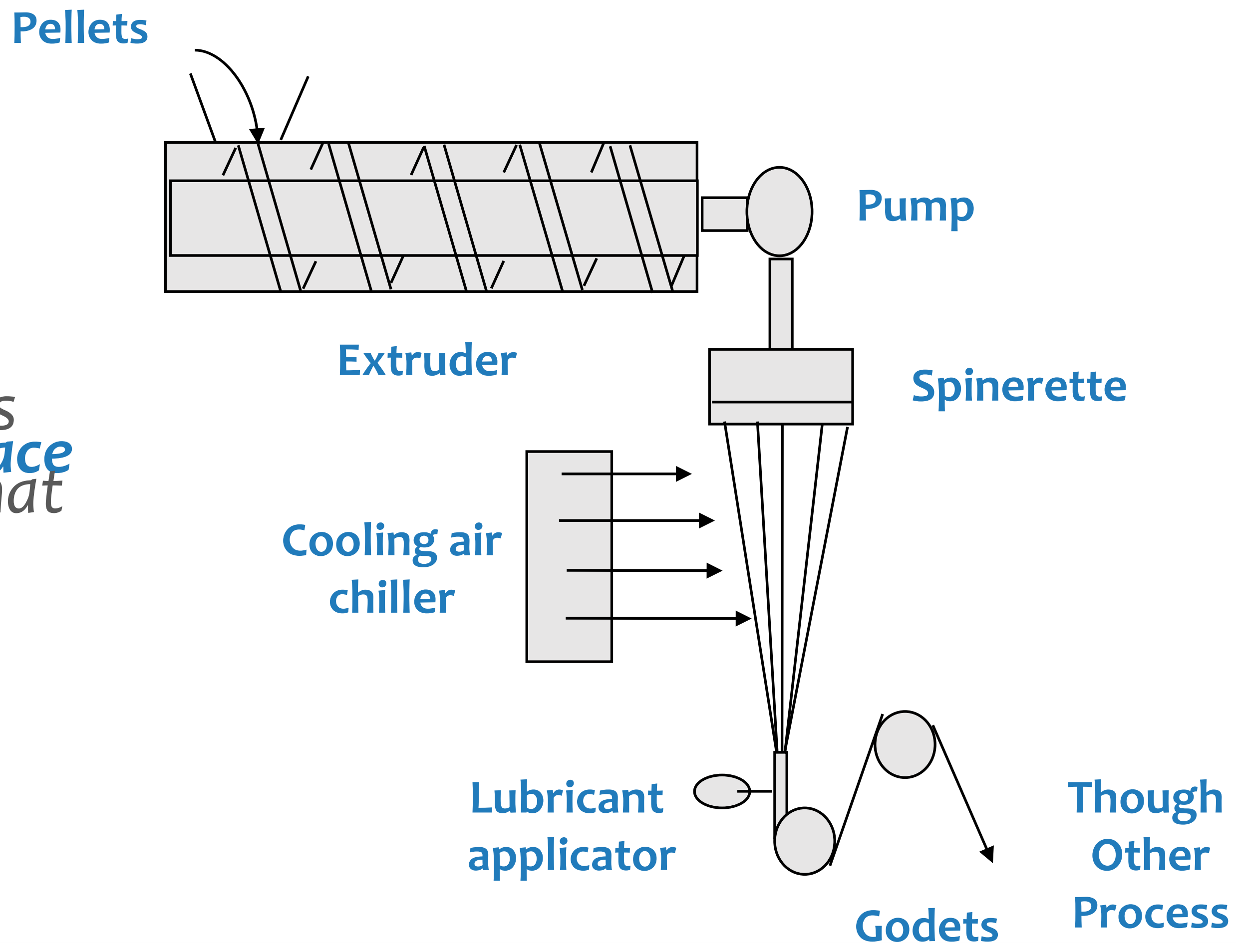


# Extrusion: Fiber Spinning

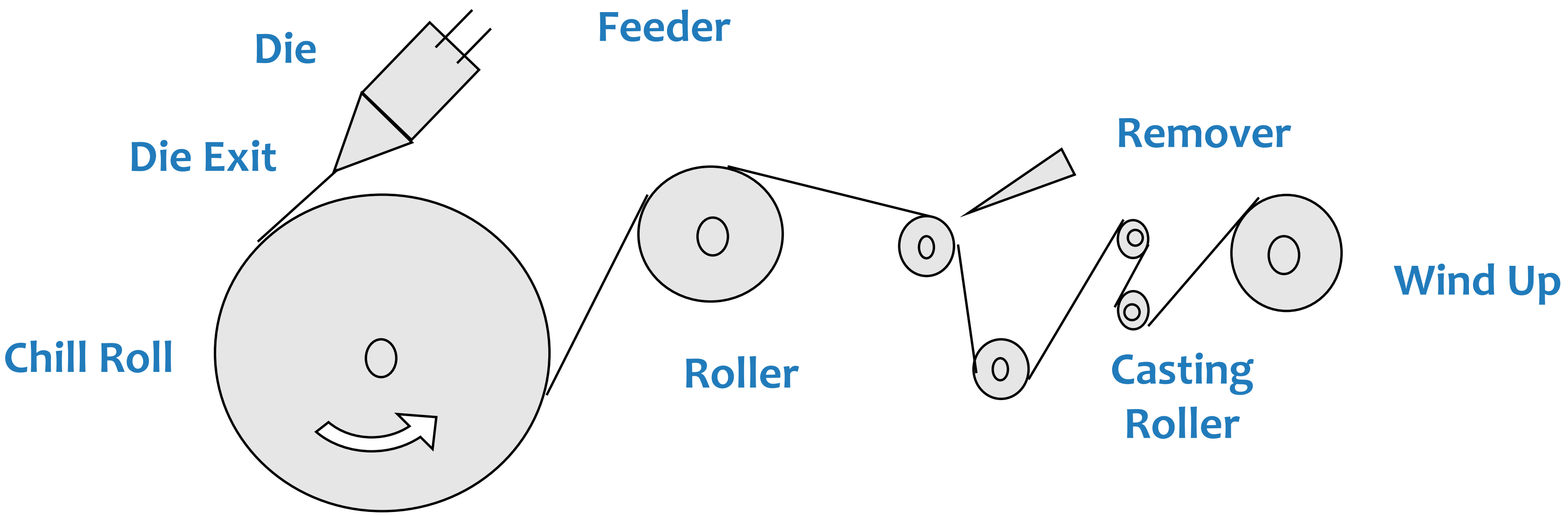
A new development is the Fiber wound by Coextrusion. In which 2 or more polymers are process to produce Multi-material fibers

*Fibers are characterize to has a length 100 times greater that their diameter*

***The fiber spinning is a free-surface Post-extrusion process.***



# Extrusion: Cast Film




## Design and operation variables:

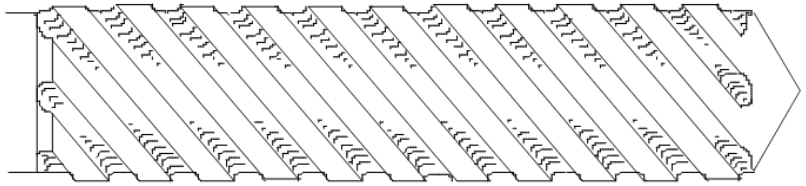
1. Rolls Temperature
2. Drawing Speed (2 m/min thicker films to 20 m/min thinner films)

# Comments

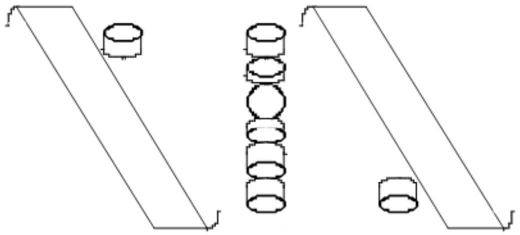
The shape and thickness of the product are determined by:

- Polymer Rheology
- Die Dimensions
- Cooling Conditions
- Relative Draw Speed to the Extrusion Speed

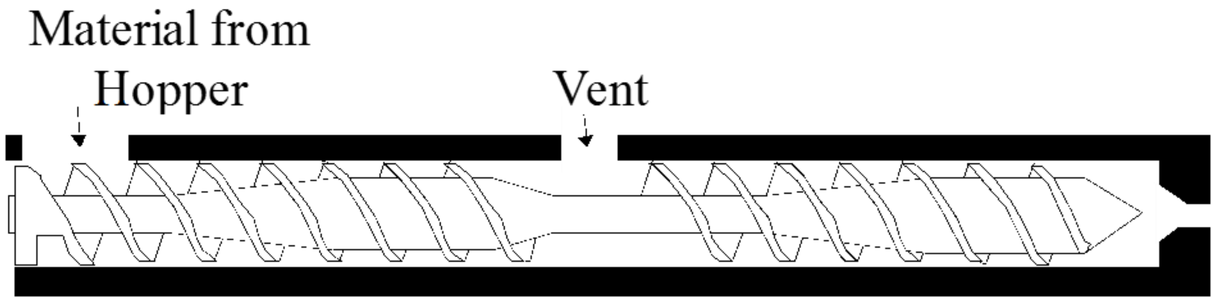
# Screw Configuration Design



**Dulmage Mixing Section** - Several such sections are often put at the end of the screw to enhance mixing



**Mixing Pins** - Inserted between final flights to enhance mixing

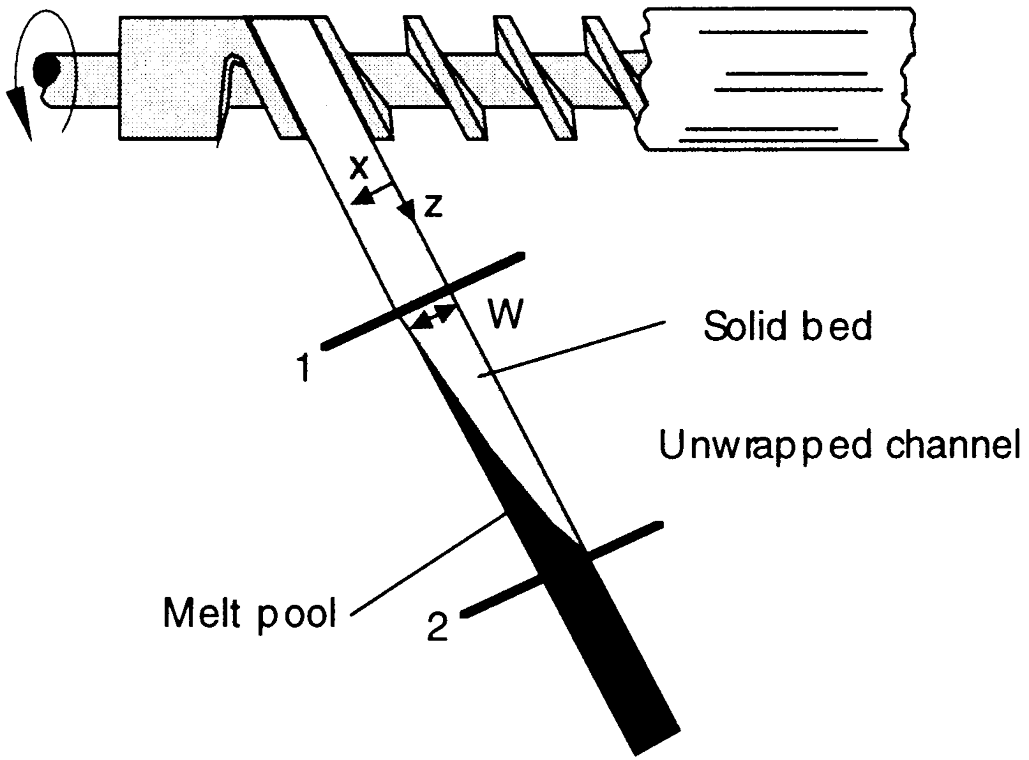



**Vented Barrel w/ Two Stage Screw** First stage meters & compresses. Material is then vented, and recompressed & metered in second stage.

# Melting (Transition) Zone

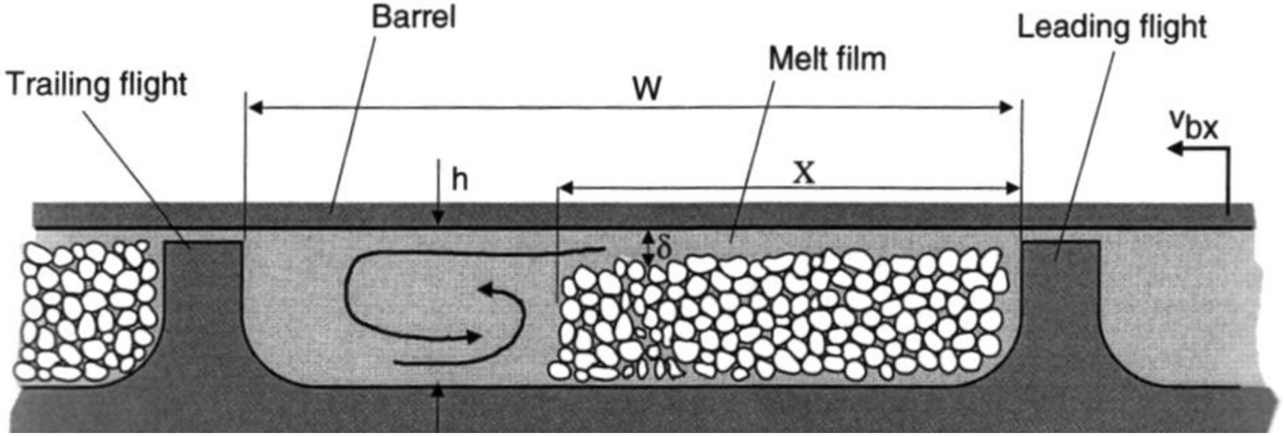
The melting, or transition, zone is the portion of the extruder where the polymer is transformed from a solid to a melt state. This is a gradual process wherein the compacted solid bed is replaced by with a melt pool.

The length of this zone is a function of material properties, screw geometry, and processing conditions.  While this is a key design parameter, the enormous complexity of this process makes accurate prediction of zone length almost impossible. Unpredictability has led to double-barrier screw designs that exercise greater control over the melting process.



# Melting (Transition) Zone

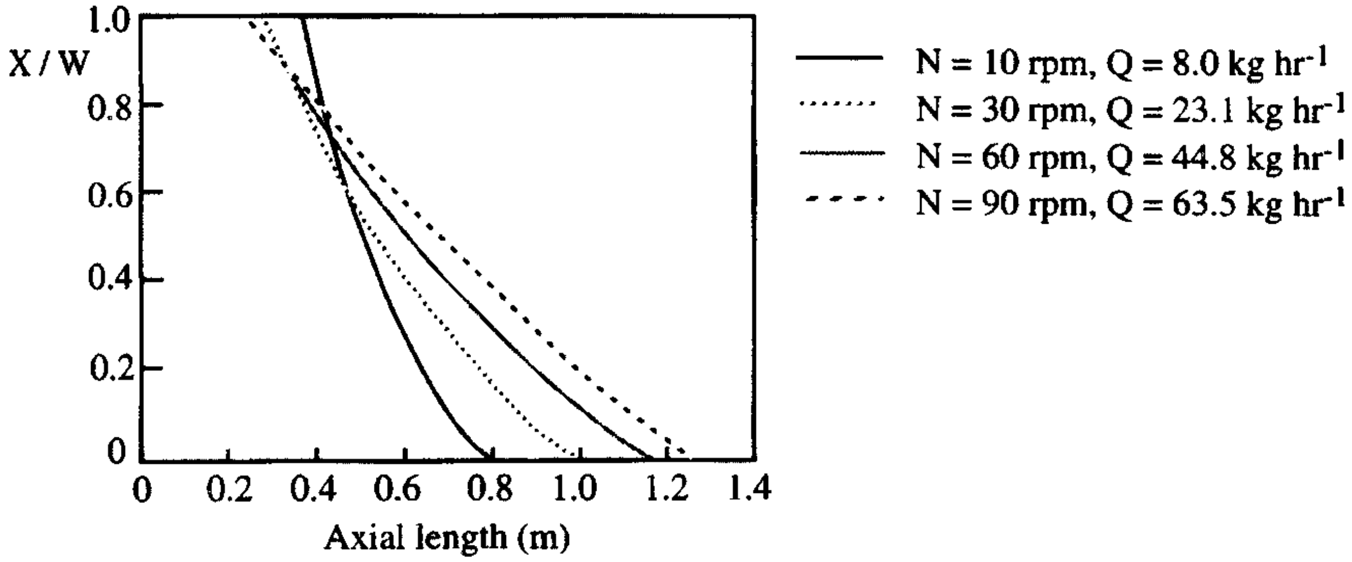
**Friction and heat conduction from the barrel wall** raises the material' s temperature to the melting point of a semi-crystalline polymer and/or the glass transition temperature, creating a melt film at the barrel surface.  Eventually, a melt pool forms at the rear of the screw channel.




Throughout the melting zone the solid bed should be depleted continuously, but if disintegration occurs, individual granules can be left in the melt pool with undesirable consequences.

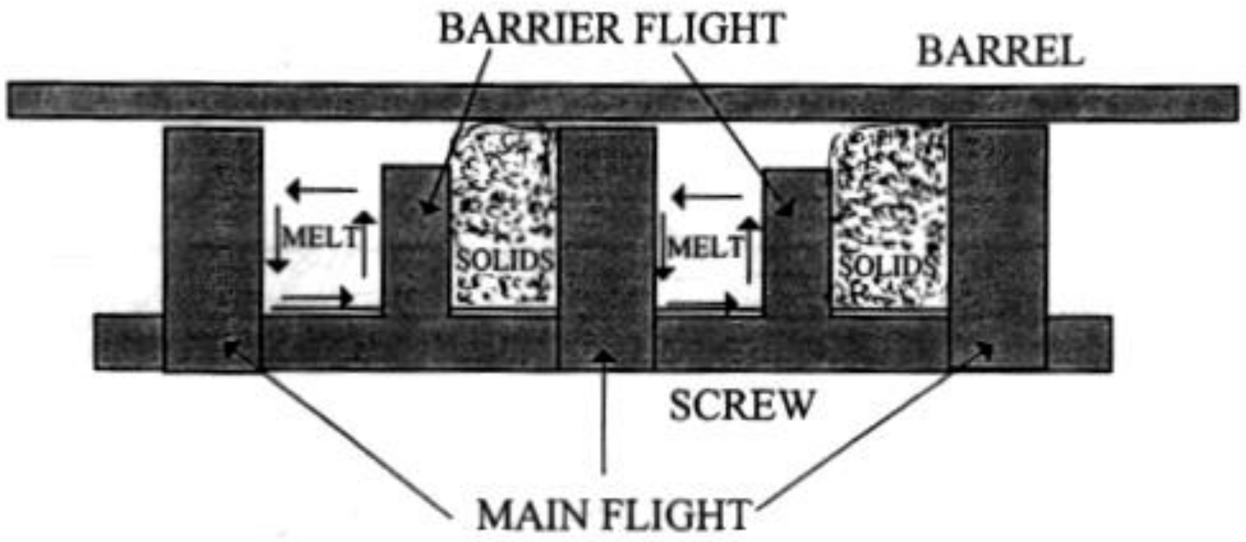
# Melting (Transition) Zone

- The most widely used model to predict melting in a plasticating single screw extruder is the Tadmor model, which remains imprecise despite numerous attempts to refine the analysis.  Below is a prediction of the normalized solids bed width (1.0 equals all solid, 0.0 is all melt).  Note the influence of rotation speed (N) on the flow rate (Q) as well as the length of the melting zone.

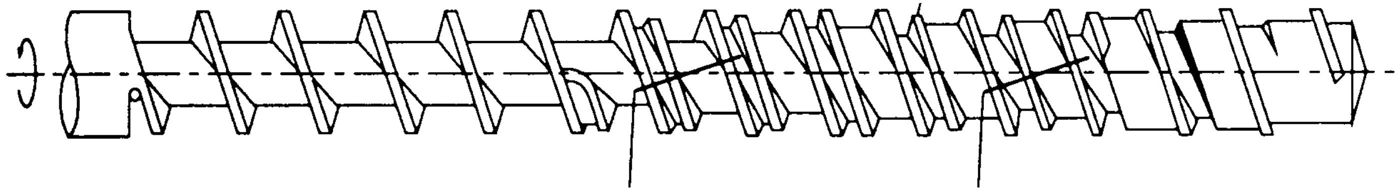


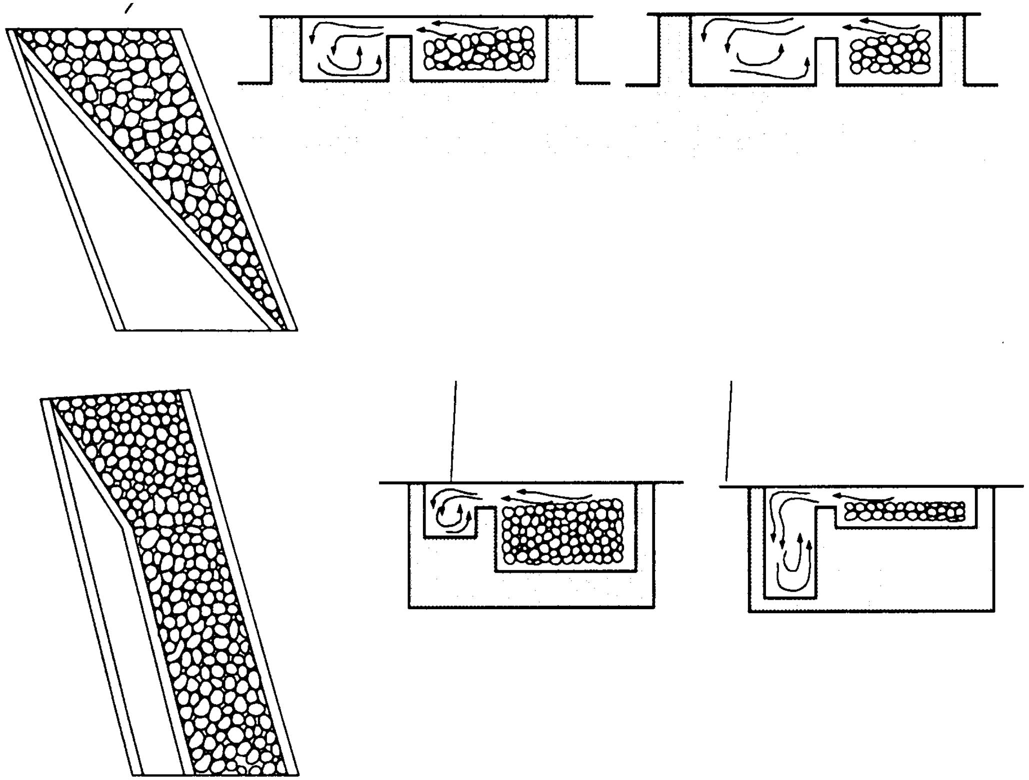
# Melting Zone – Double Barrier Screws

- There is a great interest in recent years in the so-called **barrier (or double-flighted)** screws. The solid bed and the melt are separated by the barrier flight:



# Melting Zone – Double Barrier Screws



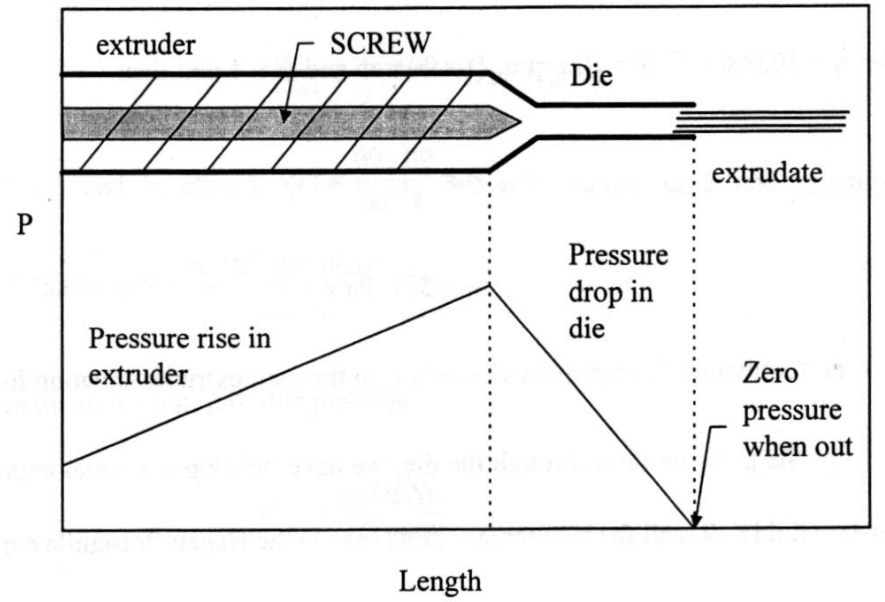


The Barrier screw maintains a constant solids bed depth and a width that declines continuously.

The Maillerfer screw maintains a constant solids bed width (maintaining good exposure to the barrel) that declines steadily in depth

# The Metering Zone

- Conventional single-screw extruders (without grooved feed sections) rely on the metering zone to develop the pressure needed to force the melt through the shaping die.




- Flow in the metering zone can be estimated by solving the equations of motion, making this section quite amenable to design calculations.

# Activities

- Finish the rest of this presentation by yourself

- Watch the following YouTube Videos:
  - Plastic extrusion: https://www.youtube.com/watch?v=Tp2Rdx69SSo
  - Plastic Blow Molding: https://www.youtube.com/watch?v=WLyaZbT97EI

- Do the following reading:
  - Melt Pressure in Single-Screw Extrusion- Alan Griff.
  - An Overview of Polymer Processing- J. Vlachopoulos and D. Strutt.
  - An Overview of Spun bonding and Melt Blowing Technologies- S.R. Malkan.

- Be prepared for a Reading Control Quiz

# Advantages of the Blowing Methods

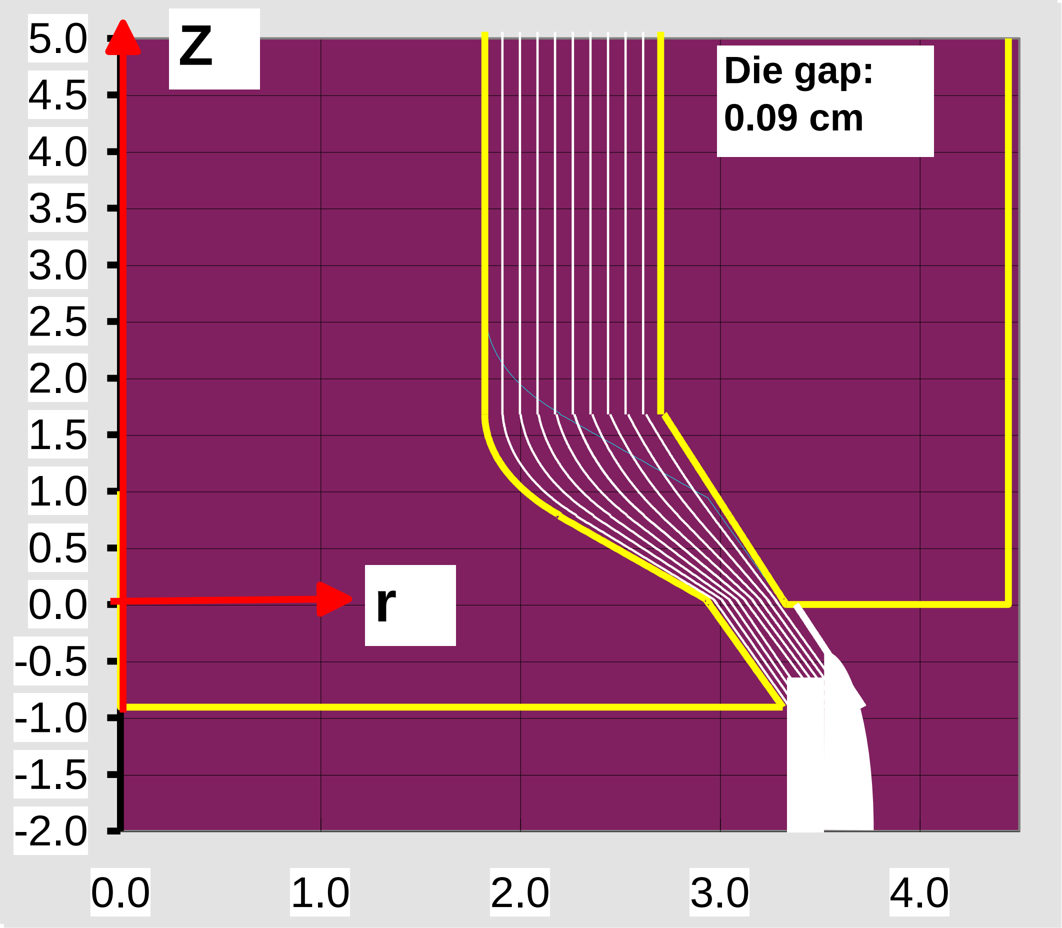
# Blow Molding by Extrusion

- More competitive for the most part of the 16 oz recipients.
- Low cost for the initial mold.
- Easy to produce bottles with handles.
- More eficient with rigid PVC.
- Able to produce irregular-shape products.

# Blow Molding by Injection

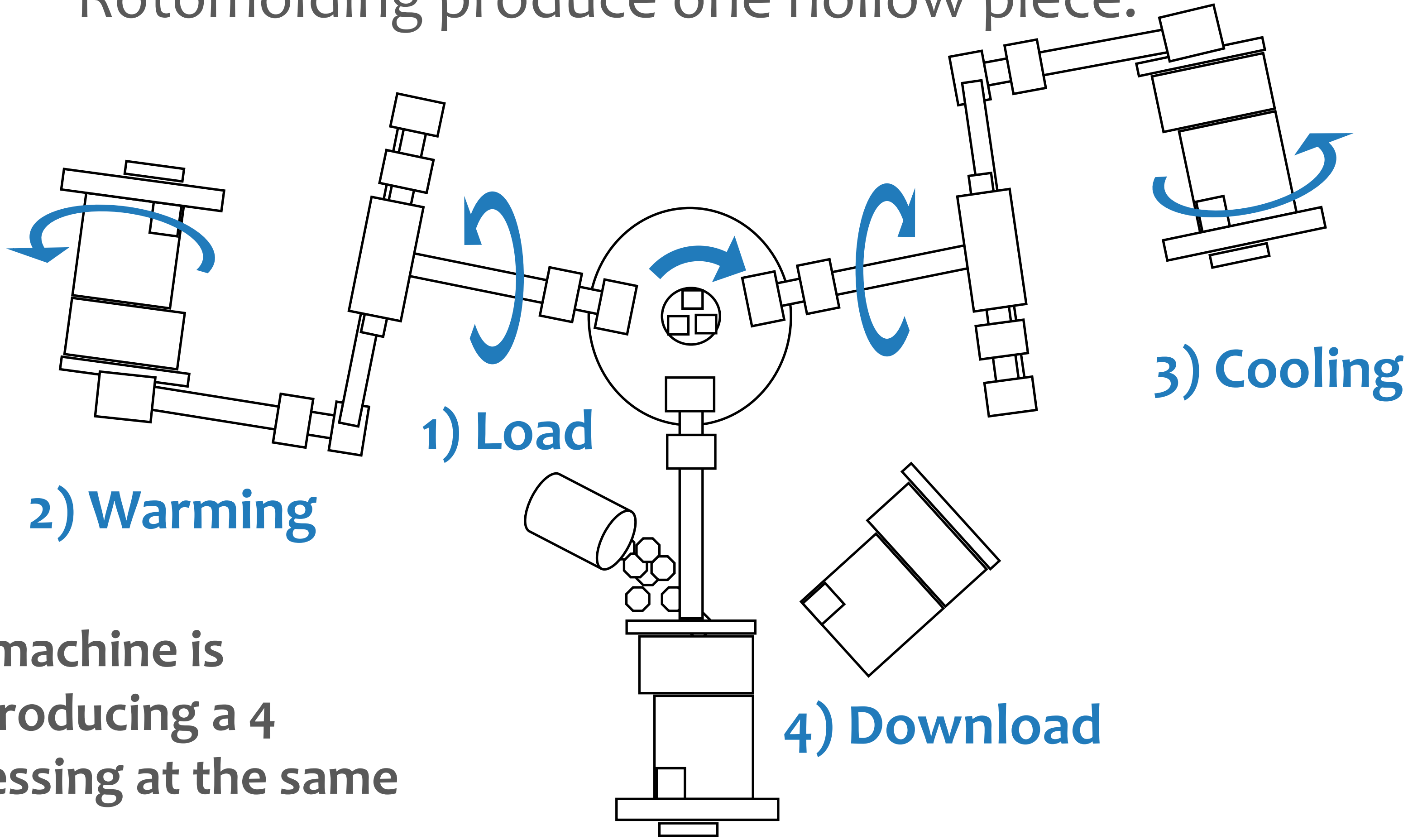
- More competitive for recipients less than 12 oz.
- Easy to produce special finishings (unbreakable closures).
- Do not need finishing processing.
- Better performance without wastes.
- More efficiency with rigid materials (PS and Policarbonate).

# Modeling the flow for Blow Molding



# Molding Covering: Rotomolding

Rotomolding produce one hollow piece.




**A multiarm machine is capable of producing a 4 stages processing at the same**

Dr. Jaime Bonilla Ríos

Tecnológico de Monterrey