Plastic Behavior In The Compounding Twin Screw Extruder

Lesson 4

I. Screw Terminology

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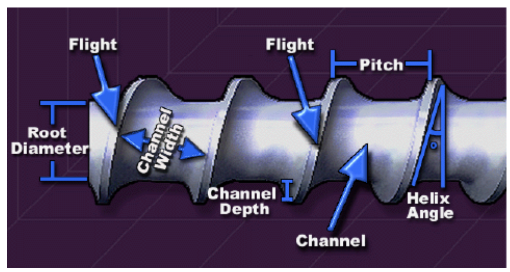
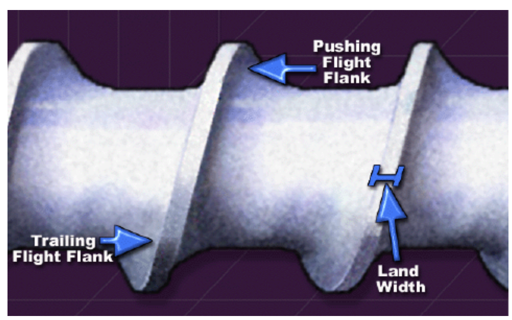




A. Length to Diameter Ratio (L/D ratio)

1. The L/D ratio is the length of the flighted portion of the screw divided by the screw diameter.
2. *Example:* The length of a flighted portion of a screw is 48 inches. The screw diameter is 2 inches. 48 divided by 2 equals 24. Therefore, the screw's L/D ratio is 24 to 1.
3. Typical L/D ratios for twin extruder screws are between 20 to 1 and 40 to 1.

Notes

II. Screw Design Elements

Twin screws can be counter-rotating or co-rotating, intermeshing or non-intermeshing, one-piece or modular.

A. Pumping Elements

1. Forward flighted elements used to convey the raw material forward.
2. Used to pump the melt past openings such as vents, feed ports and drains.
3. Used to build up pressure in the melt to force it out the die openings.

B. Mixing Elements

1. Mixing elements such as kneaders, pin mixers, vane mixers and slotted mixers are used to mix the raw material.
2. Mixing element designs depends on the type of mixing desired.
3. Two types:
   a. Distributive mixing
      - Raw material mixture is evenly distributed to obtain a uniform blend of the material.
      - Divides the melt into smaller flow streams, then recombines them.
      - *Example:* Narrow kneaders and combing mixers

   b. Dispersive mixing
      - Breaks down larger particles of gels or pigments and disperses or spreads them within the melt by forcing the plastic over restrictive barriers and through thin openings.
      - Causes high shear
      - *Example:* Wide kneading disks

C. Zoning Elements

1. Zoning elements are used to separate the mixing, pumping and venting processes in the extruder.

Notes

2. *Example:* A melt seal zoning element placed before a vented section will create a "melt seal" to allow for adequate removal of volatiles from the melt.

3. Zoning can be forward flighted, neutral or reverse flighted.

D. Location of Screw Elements

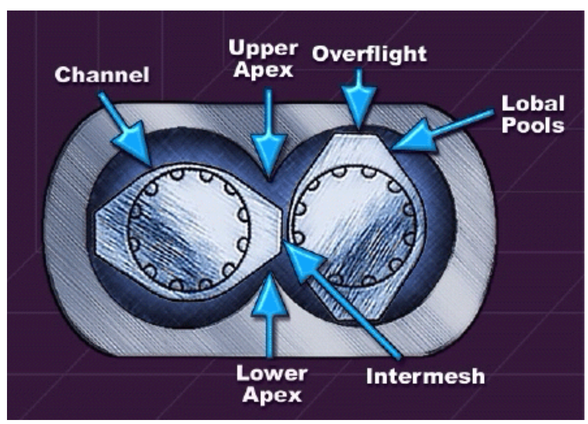
1. Twin screws are made up of two or more combinations of pumping, mixing and zoning elements.

2. The arrangement of the screw sections will determine:
   a. How much and what type of mixing is accomplished.
   b. Pumping capability of the extruder.
   c. Amount of shear energy going into the plastic.
   d. Length of time the melt is in the extruder (residence time).

III. Five Mass Transfer Regions

A. Five Transfer Regions within each Screw Element

Five Mass Transfer Regions



1. Channel
   a. Area of *low shear* in which the amount of material fed into the extruder affects the rate of mixing.

Notes

b. The more raw material in the extruder, the more material in the screw channel, resulting in less shearing and mixing of the plastic.

2. Overflight
   a. Flow between the top of the flight or mixing element and the barrel wall.
   b. Area of *very high shear*.

3. Lobal pools
   a. Pools of raw material captured by the pushing flight flank or "lobe."
   b. Area of *very high shear*.

4. Apexes
   a. Regions around the intersections of the barrel walls.
   b. There is an upper and lower apex region.
      1) Co-rotating twin screws rotate only one screw flight into the apex region at a time. The melt moves around the upper and lower apex regions in the same manner.
      2) Counter-rotating twin extruders rotate both screws into one apex region at a time. For example, when the screws both rotate into the upper apex, that region is more active than the lower apex region. When the screws rotate into the lower apex, then the lower apex region is more active than the upper apex.
   c. Area of *high shear*

5. Intermesh
   a. Region where the two screws nearly meet.
   b. Intermeshing twins are more shear intensive in this area than non-intermeshing (tangential) twin screw extruders.

B. Flow & Mixing Characteristics

1. The flow and mixing characteristics in all the regions except the channel, are independent of the degree of fill of the twin screw extruder.
2. Regardless of the amount of raw material in the extruder, the same rate of mixing will occur in the lobal pools, overflight, apexes and intermesh regions.

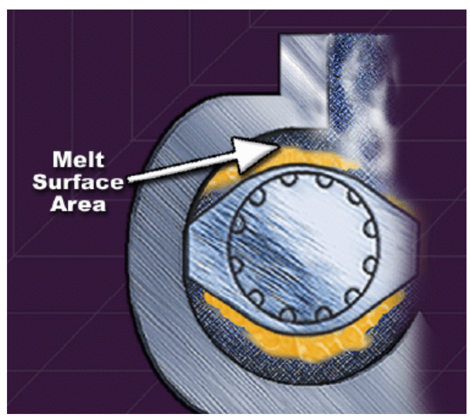
Notes

IV. Feeding the Compounding Twin Screw Extruder

A. Starved-Fed Method

1. Raw material is fed to the extruder screws at a controlled rate, as opposed to being gravity or flood fed.
2. Dosing feeders are used to meter out a predetermined amount of plastic raw material from the hopper into the feed section.
3. Extruder output rate depends on the feeder input rate to the extruder.
4. In a starved-fed extruder, some sections of the screw can be fully filled with material while other sections are "starved' or partially filled. This occurs because some screw elements convey the melt forward more effectively than others.
5. Increases shearing and venting

Starved-Fed Method



Starved-feeding increases shearing and venting of the plastic material because of the decrease in the amount of plastic melt in the flight - more of the melt's surface area is exposed to the various mixing and venting sections.

B. Effect of Screw Speed on a Starved-Fed Extruder

1. Under normal conditions, twin screw extruder output is independent of screw speed - increasing screw rpm does not increase output in a starved-fed extruder.