Processing of Compounded Materials in Single or Twin Screw Extrusion - Suggestions for Optimizing the Process

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Background

When processing compounded materials, what type of mix is expected from the extrusion process will determine what screw geometry and end of screw components should be used.

The following is an overview of various mixes and screw geometries intended to give the reader insight into how their particular compunding process can be optimized.

Types of Mixtures

There are three general categories of mixtures:[1]

1. *Homogeneous mixtures of compatible polymers*, which includes mixtures such as the polyamides PA6 and PA66.

2. *Single-phase mixtures of partly incompatible polymers*, which includes mixtures such as polycarbonate (PC) and polybutylene teraphthalate (PBT).

3. *Multi-phase mixtures of incompatible polymers*, which includes mixtures such as polypropylene (PP) and polystyrene (PS).

One way of acheving these mixtures is distributive mixing (laminar mixing of liquids). This results in large strains on the system and increases the interfacial area between the two or more phases. This process is further impacted by the strain rate of deformation.[2] Distibutive mixing can be thought of as spreading or wiping materials into a mixture.

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[1] Osswald, Tim A., and Georg Menges. *Materials science of polymers for engineers*. München: Hanser, Carl, 2012. Print.
[2] ibid.

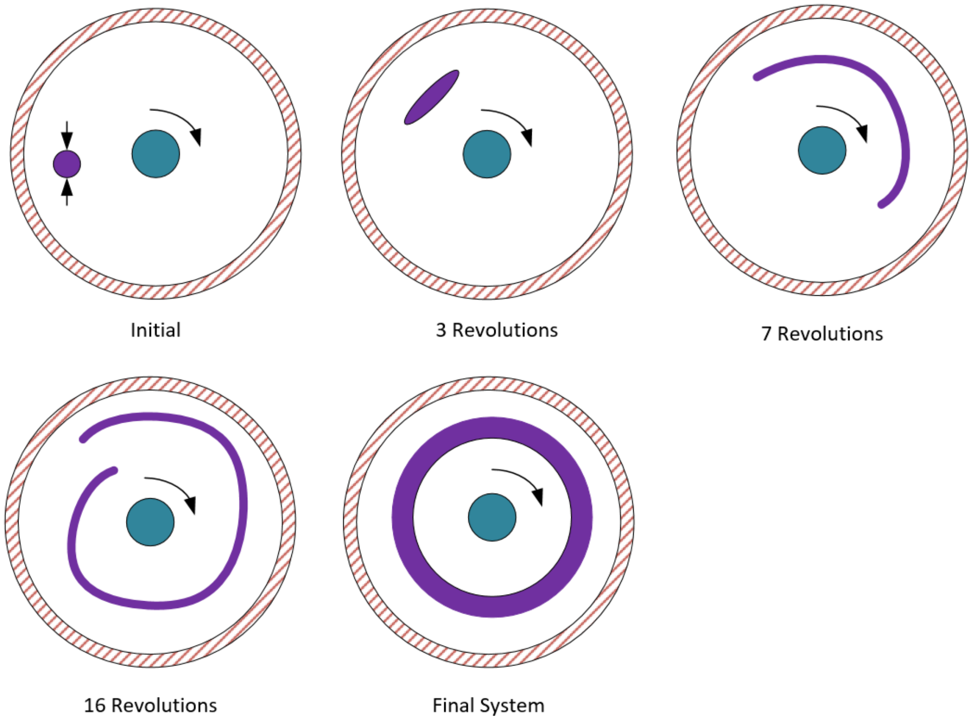

Figure 1: Distributive mixing process

Another method of mixing compounds is dispersive mixing. This involves the breaking of an agglomerate of solid particles or immiscible fluid and dispersing them throughout a matrix[3]. This can be thought of as breaking materials apart.

[3] Ibid.

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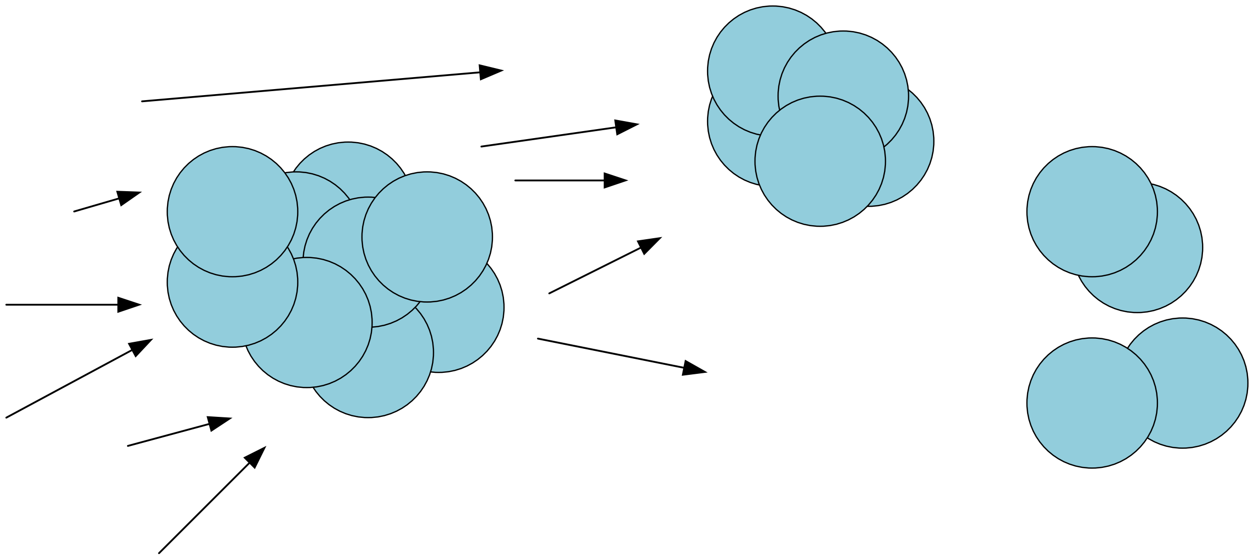
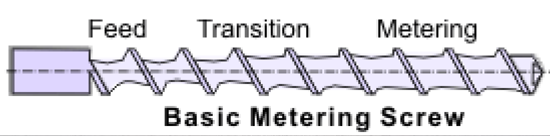


Figure 2: Dispersive mixing process

Screw Geometry Impact – Single Screw

The design and geometry of an extrusion screw is critical to acheiving either form of mixing, and different geometries will produce different mixing effects.

The three basic segments of a single metering screw are the feed, transition and metering sections, and each section is important for optimizing compounding results.



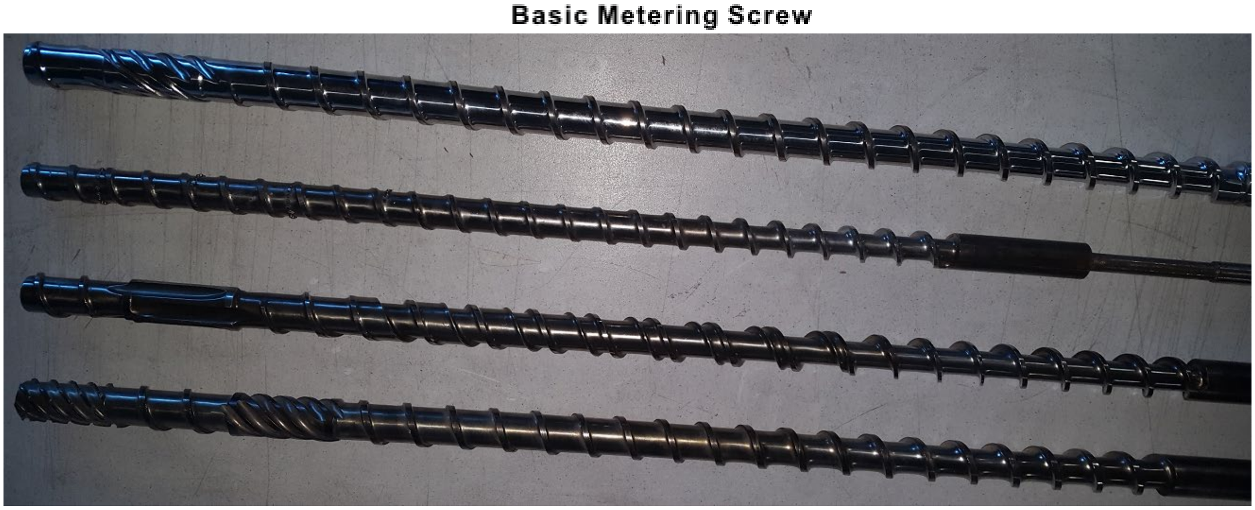


Figure 3: Metering screw diagram and examples

Feed Zone

The cross sectional area of the root of the screw is critical for this zone. Torsional strength is lowest at this point. The flow resistance against the fed material must be as low as possible and the transport must be independent of the die back pressure. In addition, it must be able to effectively transport against a pressure gradient as there is constant pressure buildup in a properly designed screw.

Figure 4: Feed section of a screw

Feed zone depth, material consistency, and a uniform cut are important. This allows for pellets to be packed tighter together. A tighter pack allows for higher bulk density (less empty space between pellets), which is critical for reducing screw slippage and creating lower zone temperatures.

It can be helpful to increase the length of the feed section for materials that feed poorly or require significant heating. For example, it can be helpful to increase the length of the feed to 10-12 turns when material requires heat to be absorbed prior to being melted.[4]

Remember that when it comes to screw geometry, flight channel size does not change and that temperature control is typically static. Therefore, one cannot wait for the channel to fill, and this depends on the hopper or operator.

Compression/Transition Zone

This zone allows for the venting of air in the granular bed back thru the hopper and prevents material damage through a careful melting process.[5]

[4] TWWomer and Associates, LLC
[5] White, James L., Helmute Potente, and U. Berghaus. *Screw extrusion: science and technology*. Munich: Hanser, 2003. Print.

In considering this section of the screw, one must take into consideration the bulk density versus the melt density. This is regularly called compression ratio (C/R). However, the term is frequently not used precisely: 0.375/0.125 = 3:1 CR and 0.300/0.100 = 3:1 CR, but these two screws will give significantly different results. The CR does not indicate the length of the zone, which is critical for optimizing the melting of the polymer without plugging or breaking up the melt pattern.

Figure 6: Compression/transition zone

Another element of the compression/transition zone is the barrier zone. This acts as a filter for granules so that the material in the melt channel is free of unmolten particles.[6] When the melt overflows the barrier, it creates a separated and homogenized melt channel.[7]

Figure 7: Barrier zone

Metering Zone

This zone is critical in controlling pressure build-up and transporting. It reduces or eliminates the pulsation of melt in the screw from being presented to the die. The section may have various devices on the end to force or choke the flow that results in the mixing of polymer(s) and additives.

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[6] ibid.

[7] TWWomer and Associates, LLC and White, James L., Helmute Potente, and U. Berghaus. *Screw extrusion: science and technology*. Munich: Hanser, 2003. Print.

Figure 8: Metering section

Screw Considerations When Processing Filled Polymers

First, consider the bulk density versus the melt density. Fillers affect these properties and may result in high pressures and temperatures, leading to a lower lower output.

Consider the differences between lower melt components and higher melt components. Failure to do so may negatively impact the work you did in compounding the materials.

Remember that clearances in mixing sections can result in solid bed break-up or melt block. This may create more shear and degradation of your additive or solid with the wrong clearance.

Be sure to sample first with a constant taper at a moderate rate. Try a sample on the screw with only the main carrier resin. Quantify the base material before sampling with a filled or additive compound.

Figure 9: Assorted screw designs

End of Screw Components

Breaker Plates

Breaker plates transition the flow of the polymer from a radial flow to a linear flow. They further create a seal between the extrusion barrel and the product die or crosshead.

The plates contain a seat for screen packs to be placed.

Keep in mind that the plates create back pressure on melt in the screw, which can result in increased viscous heat generation in your polymer.

There are no real standards or design constraints for breaker plates, which can be slotted, inverted, or have different diameter holes in the same plate. A spacer ring without a breaker plate is sometimes used for highly filled compounds. A compression ring can be used to reduce the inner dimension at the middle of the plate, which results in higher shear.

Figure 10: Breaker plates

Screen Packs

Screen packs provide a method to filter resins and resins and polymers. Screens can create a number of process variables, such as an increase in back pressure, and increase in melt temperature and possibly a lower extruder output.

In terms of screen sizes, 20 mesh to 200 mesh is typical. That is, 20=0.0331” (0.841mm) and 200=0.0023” or (0.074mm).

Screen mesh comes in different weaves, such as square and dutch weaves, which have different effects. Dutch weave allows for fine filtration with multiple thin screens and has thicker wire running through one axis.

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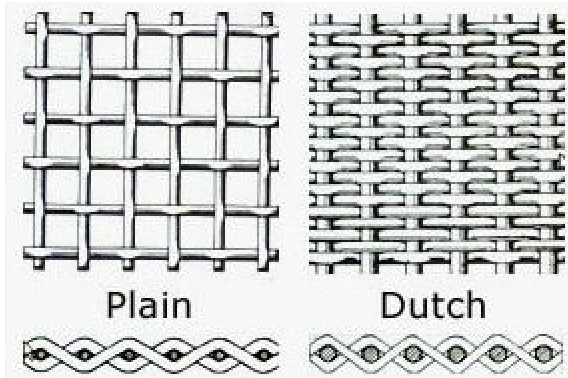

Figure 11: Screen packs weave type

When it comes to choosing a screen base material, remember that metal screens can rust. Stainless steel is ideal for PVC-type applications, and nickel alloys for fluoropolymers and PVDC where corrosion is more likely. In addition, consider whether the particulate size you are using greater than the smallest screen size.

During installation, screens can be sandwiched to protect the smaller mesh screens. For example, a sandwich might include the following sequence: 20 mesh, 40 mesh, 80 mesh, 80 mesh, 40 mesh, 20 mesh. When using screen packs, watch the pressure rise over-time. Sometimes frequent changes or even a screen changer are required.

Suggested Practices for Using Screen Packs

Be sure to confirm the impact the identified combination of screw, breaker plates, and screen packs has on the melt temperature and head pressure in the base resin.

In highly filled composites, it is best to eliminate the screen pack and only use a breaker plate. Modify the holes in the plate to help build and maintain the desired pressure. You can always run lower output with increased barrel temperatures, assuming there is no impact to the active or additives.

For more information, please contact Steve Schick.