Mixing and more: The continuous co-rotating, overlapping twin-screw mixer

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Continuous Mixing. Continuous Expertise.

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Equipment that performs several process steps can not only reduce the number of machines in your operation, but cut your labor requirements as well. One example is a continuous co-rotating, overlapping twin screw mixer, which can provide several process steps in addition to mixing. The mixer's operation can be fine tuned to closely control the effects of shearing, heating, and cooling on your viscous mixture. After discussing some basic mixing principles and twin-screw variations, this article explains how the co-rotating, overlapping twin-screw unit operates, examines the mixer's processing stages, and details several applications. Related information discusses the importance of selecting a continuous mixer before - not after - your product's development.

Traditionally, the goal of mixing is to uniformly distribute or blend one (or more) ingredient with another, For instance, in batch mixing,ingredient A is mixed with ingredient B and blended until the mixture has uniform consistency.

This sounds simple, but several mechanisms occur during this process - in both dry and wet mixing reactions - that can profoundly impact the final product. Two of the mechanisms are shearing and heating.

Shearing occurs when, as the ingredients are mixed, one ingredient breaks down and disperses throughout another. In batch mixing, shearing is uneven because of the mixing vessel's large size. Some particles are readily dispersed, while others aren't dispersed until the mixing cycle ends.

Because the shearing times are uneven, product quality also becomes uneven. Once a particle is sheared and homogenized, heat can begin to build up in it. So the particles sheared early in the cycle can be at a higher temperature than those sheared at the cycle's end.
You can gauge the effect of shearing and heating on the final mixed product by looking at the products shear-heat history. The history is established by taking samples of the mixture at intervals over the mixing cycle and recording sample changes that indicate shearing (or homogeneity) and temperature changes. The longer the batch is mixed, the broader its shear-heat history will be.

Batch mixing is often suited to small quantities or to mixtures that require long reaction times. Batch mixing larger quantities within a reasonable time is difficult because it takes a long time to turn over the batch's entire volume. In obtaining a homogeneous mixture, the large-volume batch process also develops a very broad shear-heat history. As a result, you lose valuable control over the final product.

With continuous mixing, you can achieve more control of the mixing process. Instead of averaging the properties of the ingredients, as batch mixing does, continuous mixing allows you to observe the ingredients' sensitivity to shearing, heating and cooling. This lets you make subtle adjustments to the mixture's physical and chemical properties to achieve the product quality you need.

The other major advantage of continuous mixing is that mixing and other process steps take place in one self-contained vessel. Explosive or toxic dusts and vapors are enclosed in the vessel, making the process safer for the workers.

Several types of continuous mixers are available. This article concentrates on one type of continuous twin-screw mixer - the co-rotating, overlapping unit - which commonly handles pastes and other relatively high viscosity mixtures. The mixer, available from several manufactures, provides blending and other processes simultaneously. By incorporating other processes into the mixing step, the mixer can improve process control, product quality, consistency, and throughput rates.

Twin-screw mixer basics

A continuous twin-screw mixer has a horizontal vessel shaped like a closed figure eight that's machined to fit very closely around two screw agitators. While the mixer includes some of the basic components of extruders and other mixers (the pug mill, double arm kneading mixer, and high-intensity Banbury mixer), the twin-screw mixer extends these machines' capabilities by providing continuous operation and the intimate mixing that can achieve various chemical and physical reactions required for other processes. Ingredients can be dry, liquid, or a combination. The mixer is suited to a wide range of mixture viscosity's, with some models handling syrup-like viscosity's as low as 20,000 centipoise. Production rates can be as low as 5kg/h and as high as several hundred metric tons per hour.

The vessel can be equipped with a thermal jacket, in which a heating or cooling media circulates to provide precise temperature control in the mixer to aid processing. In some large models, the screw agitators are hollow and filled with a heating of cooling medium.

The screw agitators can co-rotate or counter-rotate and can be overlapping (intermeshing during rotation) or tangential (meeting only at a tangent during rotation). While this article concentrates on the mixer with the more common co-rotating, overlapping agitators, understanding its mixing operation will be easier if we first consider how it differs from mixing with counter-rotating, tangential agitators.

Counter-rotating, tangential screw agitators rotate at different speeds in opposite directions. The first section of each agitator has flights designed to provide conveying; the second section has flights that provide mixing. In operation,ingredients are fed continuously into the agitators' screw section, which transfers the material towards the mixing section. The flights on the agitators in the mixing section draw material toward the agitators, forcing it into the nip point between them. Some material is carried through the nip point and experiences high shear, while the material that doesn't pass through the nip experiences relatively low shear. As a result, the tangential agitators provide limited shear control. The tangential agitator design can also result in dead spots during mixing.

Co-rotating, overlapping twin-screw mixing

A twin-screw mixer with co-rotating, overlapping screw agitators is shown in figure 1. On most models, the agitators consists of individual screw or paddle elements as shown in figure 2. The elements slide onto each agitator shaft in several orientations to provide a precisely tailored shear-heat profile that meets process requirements. The agitators rotate at a consistent speed as ingredients are fed at various points along the vessel's length; the location of each ingredient's feed point (which is typically an injection port) depends on the nature of the product being processed. The agitator elements intermesh and wipe each other throughout each agitator revolution, keeping the material in motion at all times and eliminating dead spots where material can lodge.

Figure 1

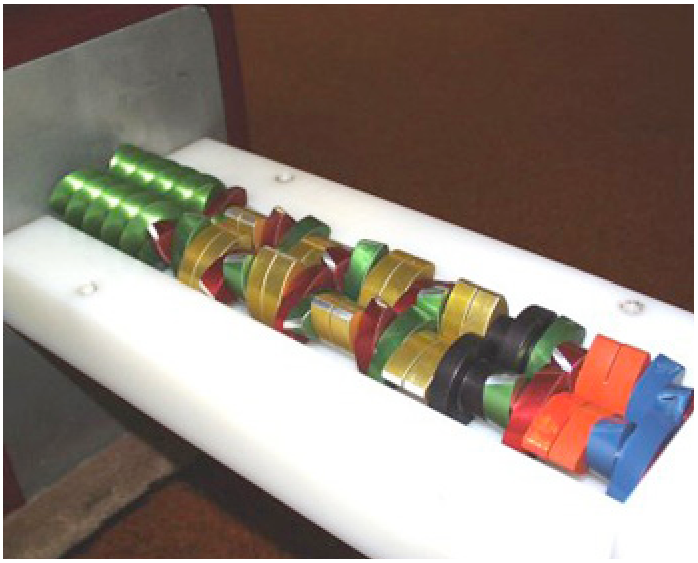

Figure 2

The mixture passes through a series of compression and expansion zones as it travels along the vessel's length. each zone is created by the screw agitator configuration in that part of the vessel: Compression is created by the agitator's paddle elements, which increase shear on the material and intensify the mixing action. Expansion is created by the agitator's screw elements (or an area on the shaft that has no elements), which apply low shear for gentle (or no) mixing. These elements can be arranged and the agitator speed, heating and cooling, and other process conditions can be varied to match application requirements and give the final product its desired physical and chemical properties. Adjusting these variables can enable the mixer to provide other process steps, such as deagglomerating, dispersing, or defibrillating.

Depending on the application, the mixture is extruded through a die plate or exists through a conventional discharge in a downward direction. The agitators' wiping action cleans the screw and paddle elements, assisting mixer evacuation and cleaning.

A closer look at the mixer's processing stages

A few basic stages control the final product's form in a co-rotating, overlapping twin-screw mixer; blending and homogenization, shearing with temperature control, and - in some cases - extruding.

In seconds, the mixer's screw elements blend ingredients until they're completely and thoroughly distributed - that is, microscopically homogenized. That makes the mixture's shear-heat history extremely short.

After homogenizing, the mixture is sheared as it passes through the paddle elements. Each paddle's type and placement can be adjusted to fine-tune the shearing and obtain the product's desired physical and chemical properties. the heating or cooling medium circulating through the vessel walls (and, if so equipped,through the hollow paddles) controls the temperature as the paddles shear the mixture. The close paddle-to-paddle and paddle-to-wall clearances provide uniform shearing and a self-cleaning action that heats the mixture rapidly to reduce processing time. After homogenizing and shearing achieve the product's desired properties, the mixture can be extruded by fitting a die plate over the discharge to produce various product sizes and shapes.

Applying the mixer to more than mixing

The co-rotating, overlapping twin-screw mixer can be customized for a range of applications. In one application the unit can work as a crystallizer, while in another it can work as a shearer-cooler. Depending on the variables you select - the screw and paddle element configuration, agitator rotation speed, and heating and cooling zones - the mixer can accomplish several process steps in one cycle to meet your product requirements. The following applications illustrate the co-rotating, overlapping twin-screw mixer's versatility.

Crystallizing artificial sweeteners. The mixer is often used to crystallize artificial sweeteners (and other super-saturated solutions) and precisely control their crystalline structure. For this process, the mixer first creates a super-saturated solution of sweetener. After applying shear, the mixer crystallizes the product - that is, forms its crystalline structure - and then cools the product to solidify the crystalline structure.

Homogenizing and shearing chocolate. Unlike for other confections, the goal for mixing chocolate (made up of a combination of dry and wet ingredients) is to preserve the chocolate's crystalline structure throughout the process. Chocolate easily overheats and is destroyed at temperatures above 80 degrees C, so the mixer handles it in a regulated, multi-step process that homogenizes and shears the material quickly to form a thick liquid or paste. The mixer can also handle a related application - conching chocolate - in which the chocolate is processed for hours with low-speed agitation to achieve a creamy texture.

Grinding, defibrillating, and agglomerating friction materials. Friction materials such as automobile brake pads include polymers, fibers of various sizes and shapes, and various curing agents. The mixer homogenizes these materials by grinding large chunks and unbundling fiber strands into individual strands (called defibrillating) so they can be evenly distributed throughout the mixture. The mixer can also provide the precise amount of heating required to partially or completely cure the curing agents, thus agglomerating the mixture.

Compounding toners.The first step in compounding toners is to finely grind the pigment to micron and submicron particle size. Next, the finely ground pigment is dispersed into molten resin. Then any agglomerates formed between the finely ground pigment and molten resin are sheared. The co-rotating, overlapping twin-screw mixer's shearing and heating abilities achieve superior dispersion of the pigment with a fear shorter shear-heat history than that of many batch mixers or extruders.

Pelletizing controlled-release materials. Pelletizing a material, which is popular with controlled-release applications such as fertilizers, herbicides, and pharmaceuticals, requires wet-massing the material first. This step is a chemical reaction in which dry particles are coated with a liquid. Then the coated material is extruded and spheronized - that is, formed into uniform spheres. This mixer can handle the wet-massing and other steps in one vessel. It can also handle large throughput rates, unlike a batch spheronizer, which processes only relatively small amounts of material at one time. The mixer also simplifies process automation and reduces the high labor costs associated with batch pelletizing.

Tip: Make mixer selection part of your product's development.

When choosing a continuous mixer, it's important to consider mixer selection at the very beginning of your product development or improvement process rather than later.

The problem is, however, that during product development small trial quantities of your product are mixed in batches. typically only after you've perfected the product formula do you consider large-volume, continuous production. But, by this point, all those batch-mixing trials have compromised the roles of shearing and heating in mixing your product.

By making mixer selection an integral part of product development, you can directly affect your product formula. Conduct tests in various continuous mixers not only to determine whether producing your formula is feasible in each, but to uncover distinctive properties of your product.

Such tests are typically run in a mixer manufacturer's test lab using samples of your ingredients in several test mixers. This process can take as little as 1 or 2 days, and the tests can be videotaped to document all stages in the mixing process.

Your presence during the tests is essential. By participating, you'll learn even more about your product, including variables during mixing and how the variables affect your final product.

References

1. Dr. Gregory Zeigler and Carlos Aguilar. "Research probes conching in continuous processing." Candy Industry, May 1995.
2. Marvin J. Sack, John T. Shelton, and Deepak S. Phadke,"Evaluation of a continuous processor for wet massing a placebo formulation for pelletization," Pharmaceutical Development, Marion Merrel Dow Inc., Kansas City, MO.

Suggestions for further reading

Find more information on the co-rotating, overlapping twin-screw mixer and related equipment in "Paste and viscous-material mixing, "Chapter 18, Perry's Chemical Engineers' Handbook, seventh edition, ed. Don W. Green, McGraw-Hill, 1997.

For more information on continuous mixing, check articles listed under "Mixing and blending" in Powder and Bulk Engineering's cumulative" Index to articles," December 1998.

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