All Shook Up: What You Need to Know About Mixers and Thickeners

Thickeners, already widely used, are being studied to take advantage of their unique properties. This trend, together with advances in mixing technology, suggests that thickeners are becoming even more significant. Here's a guide to understanding them better…

By Christine Angos

Rheology modifiers, commonly referred to as thickeners or viscosifiers, are ever-present in most all modern products. The use of these additives cuts across several process industries including food, pharmaceuticals, cosmetics and personal care, adhesives, textiles, ceramics, paper, detergents, paints, inks and coatings, among others. They serve the purpose of not just altering the viscosity of the formulation but also that of providing specific functionality to the product. This could range from improving "mouth feel," body, texture, moisture retention, and suspendability of soluble ingredients to increasing stability and dry strength, inhibiting syneresis, resisting bacterial attack, preventing shrinkage, and controlling crystal ice formation.

Thickeners come from both natural and synthetic sources. Naturally occurring polymers comprised of polysaccharide or amino acid building blocks are generally water-soluble. Common examples are starch, cellulose, alginate, egg yolk, agar, arrowroot, carageenan, collagen, gelatin, guar gum, pectin, and xanthan gum.

On the other side, synthetic acrylic-based polymers are conveniently grouped into three general classes: alkali-swellable or soluble emulsions (ASEs), hydrophobically modified alkali-swellable emulsions (HASEs), and hydrophobically modified ethoxylated urethane resins (HEURs).

HASEs are modifications of ASEs following an addition of hydrophobic functional groups. These are commonly known as associative thickeners. In the simplest form, an associative thickener is a water-soluble polymer containing several relatively hydrophobic groups.

HEURs also belong to the category of associative thickeners. But unlike HASEs, HEURs are nonionic substances and are not dependent on alkali for activation of the thickening mechanism.

Typically white, fluffy, dry powders, popular varieties of synthetic thickeners include carbomers, sodium carboxymethylcellulose (CMC), and fumed silica.

The Plot Thickens

The VersaMix agitation system consists of a three-wing anchor, a high-speed disperser, and a high-shear mixer.

Rheology modifiers alter a system's viscosity through a combination of mechanisms. Addition of alkali to an emulsion consisting of tightly coiled polymers generates anionic charges along the chains. Like charges repel each other, and the polymers swell and uncoil, occupying more volume within the solution. Also, hydrophobic groups form domains along other water-hating groups, ultimately reducing overall free energy and manifesting as a more structured, less fluid system. Lastly, particle-to-particle interactions between thickeners and charged surfaces of system components bring about changes in rheological properties.
The ease by which thickeners are effectively dispersed or dissolved in the solvent chemically depends on particle size, molecular weight and structure (average number and distribution of hydroxyl groups per compound), and also the presence of a surfactant.

This 100-gallon VersaMix high-shear mixer is equipped with a SLIM induction tube for subsurface introduction of powders right into the high shear zone.

The primary objectives of the mixing step are to provide a homogenous mixture and to expose as much surface area of the additive particles. To achieve this goal

mechanically, the system is subject to high shear mixing conditions. Simply adding powders on top of an agitated batch used to be the only way to introduce thickeners. However, most thickeners, due to their hydrophobic groups, resist wet-out upon contact with water and could float on the surface for hours. Mixing operators are then forced to carefully sift and add powders only as fast as the liquid will take them.

Adding powders slowly into a small batch of vigorously agitated liquid may provide enough time for individual solid particles to hydrate. But in a full-scale production setting, this method of addition is very costly and time-consuming. Moreover, if powders are added too slowly, an uncontrolled viscosity buildup can occur mid-processing, thus preventing the rest of the solids to be fully dissolved.

In contrast, manually adding the powders too fast can cause particles to clump up. The clumps solvate to form a tough outer layer, which prevents complete wetting of the interior particles. This can result in solution defects such as grainy texture, reduced viscosity, or the presence of insoluble particles resembling "fish eyes." The high shear conditions usually needed to break up these agglomerations can also overshear the already hydrated particles, resulting in a permanent viscosity loss.

While thickeners of different varieties and origins offer numerous benefits, their incorporation into any liquid formulation requires certain processing techniques in order to reveal full functionality.

The Multi-Agitator Solution

A multi-agitator mixer can consist of any of three agitators or combinations thereof:
&#149 Anchor Agitator
&#149 High-Speed Disperser
&#149 High-Shear Mixer

The anchor agitator rotates at relatively low rpm, providing radial and axial movement to the batch. Scrapers can be mounted to the arms and wings of the anchor to remove any constituents from the vessel walls. This promotes batch homogeneity and improves thermal transfer when a heating or cooling jacket is used.

The high-speed disperser with modified saw-tooth blade is commonly used to disperse solids into viscous liquid vehicles. In conjunction with the anchor agitator, the high-speed disperser can be used in viscosities up to several hundred thousand centipoise.

The high-shear mixer consists of a four-blade rotor that rotates at high speed and at close clearance to a stationary stator head. The high-speed rotor draws formulation components from the bottom and then expels the components radially through openings in the stator.

Multi-agitator mixers are highly successful at producing high-quality thickened solutions. For example, a Carbopol solution can be produced in a VersaMix agitation system in considerably less time than in conventional mixers. A typical mixing procedure is as follows:
&#149 Water is added to the vessel of the VersaMix.
&#149 Agitators are turned on and speeds are adjusted to create the proper flow patterns and vortex.
&#149 It is essential that the Carbopol powder is drawn immediately below the surface and dispersed by the high-speed disperser and high-shear mixer.
&#149 The rotor/stator is run until all of the Carbopol has been dispersed, and then

it is turned off. Running the high-shear mixer for an extended period of time can damage the Carbopol polymer, reducing its thickening efficiency.
&#149 Vacuum processing techniques can be employed to eliminate air in the finished product.
Some of the recommended features for multi-agitator units used for the dispersion of Carbopol solutions include the following:
1. Vacuum processing capability allows the removal of air from the product, resulting in a smoother air-free gel.
2. Variable speed control of each agitator (mechanical variable speed drives or AC variable frequency inverters) enables the user to fine tune the flow patterns and optimize the vortex for charging purposes.
3. Jacketing of the mix can lets the user control the temperature of the batch. Heating of the water can accelerate the rate of dispersion; however, this also makes the solution more sensitive to agglomeration formation during powder charging. Cooling of the batch can aid in keeping the solution below 70&#176C (158&#176F), the temperature at which a permanent loss of viscosity can occur.
4. Teflon scrapers, staggered on the arms and wings of the anchor, can be hinged or fixed. They're used to scrape materials from the sides and bottom of the mix can. This promotes batch homogeneity and improves heat transfer when the jacket is used.
5. Sight ports and charging ports allow the operator to view the batch and add Carbopol without raising the agitators.
6. A probe-type thermocouple can be used to monitor batch temperature.
7. A flush-mounted ball valve in the bottom of the mix can facilitates the discharge of the Carbopol solution with minimal dead space between the anchor and the bottom of the mix can.
8. Caster wheels on the mix can promote easy movement of the mix can in and out of the mixing position.

The SLIM System

An inline SLIM system is available in both a hopper arrangement (shown) and a hose-and-wand arrangement.

For a long time, improvements to first-generation high-shear mixers have been confined to different stator designs and multi-stage assemblies. Recent advances,

though, take the conventional rotor/stator to a higher level of use and purpose. For instance, Solids/Liquid Injection Manifold (SLIM) technology, based on the standard four-blade rotor and stationary head, has been developed. The rotor and stator mixing arrangement of a SLIM-modified high-shear mixer is specially designed and engineered to create negative pressure (vacuum) behind the rotor, which is used as the motive force to suck powdered (or liquid) ingredients directly into the high shear zone. The resultant powder/liquid mixture is expelled centrifugally through the openings in the fixed stator. Solids are wetted instantly and a smooth, lump-free solution is produced at a rapid and cost-efficient rate. In many applications, the SLIM system shortens mixing cycles by more than 50 percent.

The SLIM technology is available in both batch and inline high-shear mixers. The inline SLIM system eliminates the need to dump solids directly into an open batch vessel and virtually eliminates "dusting," too. This has led to a significant reduction in the volume of airborne particles in plants that have switched to the new induction system. In addition, it does not use an eductor to create the suction, thereby making the inline SLIM more tolerant of flow and viscosity changes.

For batch-style operations, the VersaMix with SLIM system technology is considered one of the most efficient mixing systems. It combines the bulk flow-inducing capability of the anchor agitator, the dispersing action of the saw-tooth blade, and the homogenizing and powder induction functions of the SLIM-modified rotor/stator assembly. Mixing of rheology additives is made simpler and faster, thereby activating full functionality in the end product.

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