New directions in *high speed* solid-liquid mixing

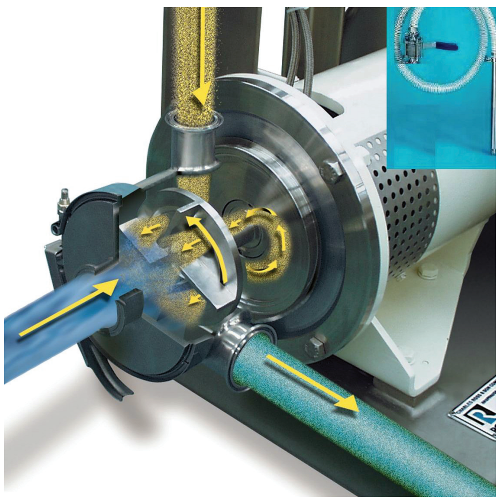
Instead of adding powders from the top of an agitated batch, why not introduce them sub-surface?

By Christine Banaszek

Mixing solids and liquids in today's process industries remains both art and science. Inevitably, empirical testing, experience and creativity are needed to solve problems and optimize processes.

Depending on solids and liquid vehicle properties, mixing can be a straightforward batch or continuous process, or it can proceed through several stages and require different mixer types.

Suspending fine particles in a slurry, dispersing fillers into a viscous composite, dissolving solid polymers into a blend of solvents, wetting out hydrophobic powders or breaking up agglomerates of pigment particles — any of these operations may require minutes or hours of high- or low-shear agitation, under atmospheric or vacuum conditions, low or high temperature and many other variables. Almost no two mixing cycles are exactly alike.



Charles Ross & Son Co. says its SLIM technology overcomes solids-liquids mixing challenges associated with eductor-type systems using a rotor/stator mixer that also executes the functions of both a pump and the eductor.

Given the wide range of mixing equipment available, it rests with process engineers to match the most efficient method to a particular application.

The trouble with solids

Solids are mixed into liquid as powders, pellets, granules, flakes, crystals, fibers and other geometries. Solid size and shape affects the mixing outcome, but, in general, equipment selection first and foremost takes into account the material's viscosity and shear-level requirements.

Starting viscosity of the liquid phase; maximum viscosity reached by the mixture during processing; and final end-product viscosity — if different from maximum viscosity — must all be considered. Note that percent solids, which normally refers to the non-volatile materials or inorganic components of a mixture, is not always a reliable gauge since low and high solids compositions take on a wide range of viscosities.

Shear level, on the other hand, is dictated by, to put it simply, the ease with which solids dissolve or disperse to form an acceptable size distribution. For instance, solids dispersion into a low viscosity liquid is accomplished by a variety of mixers, from simple single-shaft agitators to more sophisticated high-shear homogenizers. Low-speed agitators such as propellers, pitched-blade turbines, paddles, impellers and anchor stirrers, which provide relatively gentle agitation, are used with solids that readily disperse or dissolve. Because they easily wet out, powders require very low energy input per unit volume. Good mixing is simply based on adequate batch turnover within the vessel. Tank and blade geometry, as well as mixer speed, are the main design parameters.

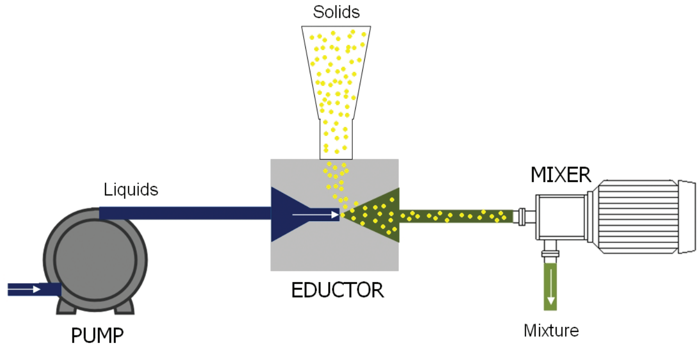
When mixing substantial amounts of powders into a large batch, it is not uncommon for manufacturers to install a recirculation line equipped with an inline rotor/stator mixer to accelerate the mix cycle.

Combining with liquids

More challenging solids require not only high-shear mixing, but also an effective method of combining them with the liquid phase. This largely depends on how the solid particles interact with each other and with the liquid component. For instance, many gums and thickeners are difficult to disperse because they resist wetting out. When mixed with a slow-speed agitator, they float stubbornly for hours on the surface of the batch. Even when processed using high-speed devices such as rotor/stator mixers and saw-tooth dispersers, certain powders still take a long while to hydrate completely. Individual solid particles, instead of being wetted by the liquid, group together as agglomerates and form "fish eyes," which are very hard to break apart. Fish eyes are agglomerates of partially hydrated powders characterized by a tough outer layer that prevents the complete wetting of particles within the interior. Some operators are left to contend with carefully sifting and slowly adding solids into the batch.

On the other hand, some formulations cannot tolerate very slow powder addition because as the batch starts to thicken, remaining solids become even more difficult to mix into an already viscous solution. In extreme cases, solids are intentionally overdosed and the un-dispersed agglomerates are simply filtered out. Moreover, while extended agitation breaks lumps in the batch it can also over-shear already hydrated or dispersed particles, resulting in a permanent viscosity loss and damage to the product.

Another approach is to pre-blend the problematic powder with other dry ingredients to keep the particles as apart from each other as possible before being added into liquid. Solids may also be pre-dispersed into a different liquid that is miscible with the solvent. These techniques reduce the lump formations but increase production time, labor and raw material costs.



First generation eductor-based powder injection system.

In answer to these challenges, mixing engineers tackled the question: Instead of adding powders from the top of an agitated batch, why not do it sub-surface or in a line outside the tank, for maximum contact with the liquid phase?

Inline powder injection

Early powder injection technologies operated based on the Venturi principle: a pump accelerates liquid into an eductor, creating a vacuum; powder fed through an overhead tube is drawn by this vacuum into the eductor where it joins the liquid flow; finally, a rotor/stator device mixes the powder and liquid, and propels the flow downstream.

Eductor-based systems minimize dusting and eliminate the problem of floating solids in batch mixers. They also offer more control over the mixing process. In fact, while the theory is sound, in practice balancing the performance of the pump, eductor and mixer is often difficult. Routine clogging causes long downtimes. Systems can be temperamental and require the attention of an experienced operator. Most set-ups can only handle thin liquids below 100 cP with low solids concentration. Elevated viscosities result in a weak vacuum in the eductor and lead to poor mixing. Finally, with three separate devices in series, clean-up and maintenance are intensive.

New generation rotor/stator designs, such as Ross Solids/Liquid Injection Manifold (SLIM) Technology, address the above limitations using a specially designed rotor/stator mixer that also executes the functions of both the pump and the eductor. The ported rotor generates an intense vacuum that draws powders right into the high-shear zone of the mix chamber, where they are dispersed instantly into the liquid stream. Without the need for an auxiliary pump and eductor, operation is simpler and more straightforward. This technology also simplifies material handling, accelerates dispersion, reduces dusting and improves operator safety.

In a SLIM system, solids are combined with the liquid and immediately subjected to intense shear. They meet at precisely the point where flow is most turbulent, preventing agglomerates from forming. Dispersion is virtually instantaneous and complete. The same process is also suitable for high-speed size reduction and dissolution requirements. This type mixer works optimally at solid loadings as high as 70% depending on the application and covers a wide viscosity range — from water-like to up to 10,000 cP during powder injection.

Solids may be fed manually or metered into a hopper sitting on top of the mixer. Since the mixer is usually installed at floor level, operators no longer climb up mezzanines carrying heavy bags of powder. Alternatively, a "hose & wand" attachment may be used for dipping into bulk bags or containers to conveniently induct lightweight powders without creating a dusty environment. After adding all solid ingredients, the powder induction valve is closed and the mixer continues to re-circulate or pump the mixture like a regular rotor/stator device.

Other batch-style solids injection mixers are suitable for use in fixed or portable tanks. As for the inline configuration, powders may be manually fed into a hopper, drawn through a hose or delivered by a feeding device. By itself, a batch SLIM mixer can process low-viscosity mixtures up to around 500 gallons. It is also commonly used in combination with other top-entering agitators to increase capacity and extend viscosity range.

Christine Banaszek is an application engineer at Charles Ross & Son Company, maker of specialty mixing and blending equipment. She received her B.S.Ch.E. from the University of the Philippines – Diliman, where she also subsequently served as instructor of chemical and environmental engineering. She has published many articles and whitepapers on mixing and blending technologies, applications and best practices.

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