Choose the Right Inline High Shear Mixer for Your Process

A White Paper Prepared By

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Choose the Right Inline High Shear Mixer for Your Process

Abstract

Throughout the process industries, manufacturers rely on high shear mixing to produce emulsions, dispersions and solutions. Many of today's chemicals, adhesives, pharmaceuticals, foods, plastics, coatings, composites and other products can no longer be made efficiently using traditional batch mixers such as propellers, turbines and saw-tooth dispersers. This can be attributed not only to new raw materials and formulations but also to the increasingly competitive market which puts a high value to process efficiency and lean manufacturing. The long mix times, multiple transfer steps, batch-to-batch variations and other issues that manufacturers were simply dealing with have become unacceptable. As a result, newer mixer designs such as inline high shear rotor/stator devices have become more in demand and have undergone significant developments in terms of features and functions.

This white paper presents some ideas for selecting the right inline high shear mixer for your process. The recommendations discussed in this paper are based on the company's collective experience as a mixing equipment provider to the process industries for over 170 years. Mixer testing and simulation trials are encouraged to confirm the suitability of a specific mixing strategy.

Introduction

Rotor/stator mixers, also called high shear mixers, are comprised of a rotor turning at high speeds within a stationary stator. As the blades rotate, materials are continuously drawn into one end of the mixing head and expelled at high velocity through the openings of the stator. The resulting hydraulic shear promotes fast mixing, breaks down solid agglomerates and reduces the size of suspended droplets.

Although high shear mixers were first developed as batch-style, top-entering mixing devices, they are now just as widely used in an inline configuration wherein they behave like a centrifugal pump. An inline rotor/stator mixer is not self-priming and thus requires static pressure (gravity-feeding) or positive pressure (pump-feeding) to introduce materials into the mix chamber. Gravity usually feeds the product into the rotor/stator assembly since the mixer is typically positioned on the floor or on a platform below the liquid level. Most inline high shear mixer models will easily move materials up to around 10,000 centipoise (cP), depending on the formulation's shear-thinning properties. With an auxiliary pump, moderately viscous products can be processed in a rotor/stator mixer.

Inline high shear mixers are practical solutions for batch tanks equipped with gentle-blending devices. The supplemental shear and agitation they provide can dramatically reduce cycle time. One main advantage to an inline mixer is that it is easily installed without disturbing pre-existing equipment. Its configuration eliminates the difficulties of trying to squeeze a top-entering mixer into a vessel along with pre-existing agitators, baffles and other obstacles.

Unlike a batch mixer, which requires a high-horsepower motor to generate adequate circulation in a large vessel, an inline mixer can handle a 2,500-gallon stirred tank as easily as it handles a 25-gallon batch. In fact, with appropriate piping, a single inline mixer can serve multiple batch tanks of various sizes. Typical installations utilize simple valves to divert finished product downstream or switch instantly from one source vessel to another.

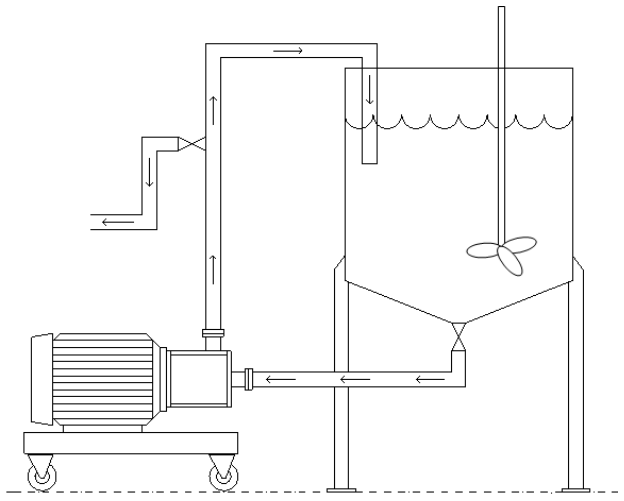
Traditional rotor/stator mixers

The basic single-stage inline high shear mixer consists of a four-blade rotor that turns at high speeds within a stationary stator. Rotor tip speeds between 3,000 to 4,000 ft/min are typical.

Rotor/stator mixers are offered with a variety of interchangeable stator designs to fine-tune particle size reduction, deagglomeration, emulsification, flow rate and temperature rise.

The Disintegrating Head, featuring round holes or large squares, is excellent for general purpose mixing and generating vigorous flow. It can quickly reduce the size of relatively large solid particles hastening dissolution. The Slotted Head provides the most popular combination of high shear and efficient flow rates. It is well-suited for emulsions and many medium-viscosity mixing applications. The Fine Screen Head applies the highest peak shear of all single-stage high shear mixers. Depending on the size of the mixer and its use, the openings on this type of stator can be made of a reinforced screen or fine holes. It is generally used for lower viscosity emulsions and fine dispersions.

(1) Four-blade rotor; (2) Fine screen stator head; (3) Round hole disintegrating stator head; (4) Slotted stator head; (5) Product inlet



Inline high shear mixer piped to a batch tank for recirculation and pumping downstream.

Liquids and solid raw materials may be combined in a batch tank then recirculated through the inline rotor/stator mixer. When the desired level of dispersion and homogenization is reached, the recirculation line is closed and the mixer serves as a transfer pump, moving the finished mixture to a nearby collection tank or downstream process.

Another method of delivery which applies to liquid-liquid and gas-liquid applications is to meter the ingredients to the high shear mixer for a truly continuous operation. Standard models are offered with only one main inlet connection, so be sure to discuss with your mixer supplier if you intend to introduce another liquid or gas stream.

Ross Sanitary Inline High Shear Mixers (400 and 400S Series) are 3A-certified.

Single-stage inline high shear mixers are available in laboratory (left) and production (left) models up to 100HP. At relatively low viscosities and volumes, the recirculation vessel does not normally require any additional batch agitation.

Q: Can single-stage rotor/stator mixers produce fine dispersions and emulsions with submicron particles or droplets?

A: Yes, standard high shear mixers are capable of producing submicron droplets or particles. But in large part, this is also highly dependent on the formulation itself. Apart from mixing intensity, several other factors affect particle or droplet size reduction including inherent properties of the raw materials, their interaction or chemistry, presence and type of surfactant, operating temperature, shear-sensitivity, etc. For this reason, particle size distribution can only be accurately determined through mixer trials wherein the actual raw materials are used and real process line conditions are simulated as closely as possible. In certain cases, even the same raw material sourced from a different supplier can yield significantly different results.

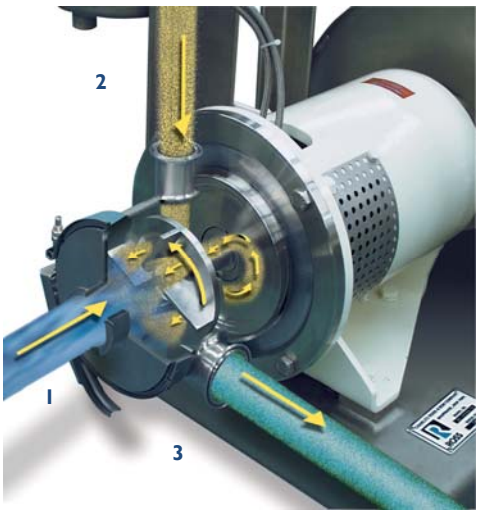
Inline mixers designed for fast powder injection

When large amounts of powders need to be added quickly into liquid or hard-to-disperse solids take too long to completely incorporate, an inline high shear mixer with sub-surface powder injection capabilities is extremely worth considering.

In earlier powder injection systems, a pump would propel the liquid stream into an eductor, creating a vacuum. Powders fed through an overhead tube would be drawn by this vacuum into the eductor where it joined the liquid flow. The resulting 'pre-mix' moved on to a rotor/stator mixer which then applied shear and mixing action, breaking down agglomerates and transporting the mixture downstream. In its day, this system offered a useful tool for powder induction. The inline system eliminated the floating solids problem of batch systems, and it offered a more precise control over the mixing process. But this set-up also presented some serious limitations. With three separate devices in series, maintenance — in terms of labor, required expertise and spare parts — was intensive. Balancing the performance of the pump, eductor and mixer was often difficult, and in many applications, downtime was quite high.

Today's inline rotor/stator mixers with integral powder injection capability are more operator-friendly and low-maintenance in design. These new generation high shear mixers no longer require the use of centrifugal pumps or eductors to create the suction for powder injection. One of the pioneers in this technology is the Ross Solids/Liquid Injection Manifold (SLIM) System.

Aside from being easy to operate and maintain, the SLIM also offers significant gains in terms of optimizing the usage of raw materials and reducing cycle time by as much 80%, based on user experiences. The shear levels that a SLIM mixer imparts are similar to a standard rotor/stator but its ability to combine solids and liquids right at the region where intense mixing takes place makes a significant impact on dispersion quality. The majority of agglomerates and "fish eyes" that would normally be found when solids are added from the top of the batch are prevented from forming in the first place.

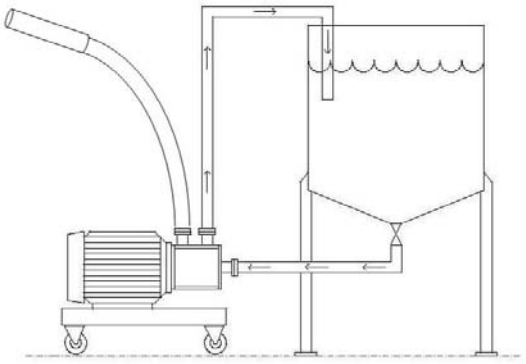


How an inline SLIM mixer works: The liquid stream (1) enters the mixer and immediately encounters the powder addition. Drawn by a powerful vacuum generated by the ported rotor, powders (2) are injected directly into the high shear zone and dispersed instantaneously. The resulting mixture (3) is expelled centrifugally through the stator openings at high velocity.

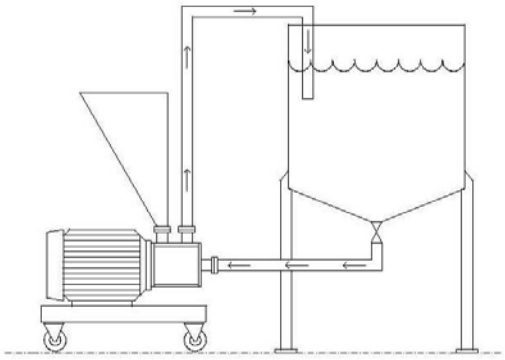
Ross Inline High Shear Mixer with SLIM (Solids/Liquid Injection Manifold).

Powders may be drawn from out of the original bag or packaging using a flexible wand connected to the solids inlet port of the SLIM. This technique is particularly useful in reducing dusting in the mixing area and suitable for powders that are relatively lightweight and free-flowing. Another method is to transfer powders into a hopper directly above the mix chamber. This configuration facilitates the highest rates of powder induction.

Flexible Hose & Wand Attachment



Hopper Attachment



Some common powders injected through the SLIM:

Alginates	Alumina	Bentonite clay
Boric acid	Calcium carbonate	Carbomers
Carbon black	Carrageenan	Citric acid
Cellulose gum / Carboxymethylcellulose (CMC)	Dye powders	Granulated sugar
	Guar	Gum Arabic
Hydroxyethyl cellulose	Milk	Potassium sorbate
Pectin	Rosin ester resin	Starch
Sugar	Talc	Vanilla powder
Titanium dioxide	Whey	Xanthan gum

Ultra-high shear mixing

For processes requiring extremely fine particle or droplet sizes, conventional high shear rotor/stator mixers running at tip speeds around 3,000-4,000 fpm can fall short in delivering the desired level of dispersion or emulsification. The next viable alternatives worth investigating are inline ultra-high shear mixers which are designed to run over 11,000 fpm.

Aside from higher tip speeds, another major difference is the rotor/stator design. In an ultra-high shear mixer, the clearances between the rotor and stator surfaces are tighter and the flow patterns generated are more complex and turbulent. The combination of these factors results in finer particle sizes, more stable emulsions and highly uniform distributions.

The Ross Series 700 Mixers belong to this class of inline ultra-high shear mixers. Offered with three rotor/stator sets namely X-Series, QuadSlot and MegaShear (see box on Page 8 for a detailed explanation of each set), the Ross Series 700 Mixers are high-throughput, low-maintenance machines capable of reducing particle or droplet size faster and to a greater extent compared to traditional single and multi-stage rotor/stators. In most applications, ultra-high shear mixers deliver better size distribution results than colloid mills. When used as a pre-mixer prior to high pressure homogenization, an ultra-high shear mixer can reduce the number of homogenizer passes required to reach the target particle size and in some single pass requirements, it can eliminate the high pressure homogenizer entirely.

In a typical process set-up, a batch mixer is used to combine the raw materials and the resulting slurry, paste or emulsion is then passed through the inline ultra-high shear mixer. More challenging formulations require multiple passes and due to the intense energy that this process imparts to the product, temperature must be closely monitored. Like a regular rotor/stator mixer, an X-Series, QuadSlot or MegaShear mixer behaves like a centrifugal pumping device. Materials are fed by gravity or are pumped to the mixer. When an auxiliary pump is used, the inline ultra-high shear mixer can process thick pastes, gels, creams and other products with viscosities up to 200,000 cP.

Production-size Ross Series 700 Inline Ultra-High Shear Mixers. Direct-driven and belt-driven models are available depending on the model and horsepower.

Ross Series 700 Inline Ultra-High Shear Mixers

X-Series

The X-Series head (US Patent No. 5,632,596) consists of concentric rows of intermeshing teeth. The product enters at the center of the stator and moves outward through radial channels in the rotor/stator teeth. The combination of extremely close tolerances and very high tip speeds (11,300 fpm or higher) subjects the product to intense shear in every pass through the rotor/stator. The gap between adjacent surfaces of the rotor and stator are adjustable from 0.010" to 0.180" for fine-tuning shear levels and flow rates.

QuadSlot

The QuadSlot mixing head is a multi-stage rotor/stator with a fixed clearance. It produces high pumping rates and intense hydraulic shear energy.

MegaShear

The MegaShear head (US Patent No. 6,241,472) is capable of the highest peak shear and throughput levels. It consists of parallel semi-cylindrical grooves in the rotor and stator towards which product is forced by high velocity pumping vanes. Different streams are induced within the grooves and collide at high frequency before exiting the mix chamber.

Conclusion

Developments in rotor/stator mixing technologies such as those discussed in this paper offer opportunities for manufacturers to upgrade efficiencies, improve product quality, reduce costs and revitalize R&D efforts. Whenever practical, perform mixer simulation trials using your own raw materials to confirm which type of inline high shear mixer is best suited to your process. Ask your mixer supplier about testing and demonstration services or rental equipment which you can use for trial production runs in the convenience of your own plant.