Rotor Stator Mixer Design Shifts Into High Gear

A new high-energy, high-shear mixer rewrites the rulebook...again.

A new mixer design has recently pushed high-energy, high-shear rotor/stator mixing into new territory. With an innovative rotor/stator generator developed in the Ross Test & Development Center, the new mixer is capable of ultra-high shear mixing, dispersion, emulsification, homogenization and particle size reduction. But unlike other mixers that apply intense shearing action, this one does not force manufacturers to choose between a high shear rate and a high flow rate. It delivers both.

The revolution continues.

The new mixer – called the *MegaShear** – continues the revolution in rotor/stator design that began in the late 1980s and exploded in the following decade. For equipment users, it means that rotor/stator mixing technology now provides a cost-efficient answer for even more processing challenges. And now, with an inline design that can deliver both high flow and ultra-high shear in a single pass, it addresses other critical needs in production, as well – by providing higher throughput, improved process control, and superior end-product consistency.

But the MegaShear and others in the new generation of rotor/stator mixers haven't made earlier designs obsolete – and that may be the single most remarkable result of the recent revolution in rotor/stator mixing. Instead, they have extended the spectrum of products that can be produced successfully with a rotor/stator mixer. For this reason, the application and value of the newest rotor/stator design is most clearly understood in the context of the entire rotor/stator family.

In the beginning, there were batch rotor/stator mixers…

The basic, single-stage rotor/stator mixer has been around for more than 30 years. Immersed in a mix vessel, a rotor turns at high speed within a stationary stator. As the blades of the rotor pass each port in the stator, they expel material at high velocity into the surrounding mix. They also physically shear particles and droplets – quickly grinding solids and hydraulically shearing droplets. As fast as material is expelled, more material is drawn into the rotor/stator generator from below, which promotes continuous flow and thorough mixing.

With a variety of stator designs, this rotor/stator mixer easily replaces propellers, turbines and high speed dispersers in many applications. Applying intense mechanical and

hydraulic shear, and generating vigorous flow in a low-viscosity batch, mixing cycles are commonly shortened by more than 50%. It is a good choice for applications that require fast particle/droplet size reduction to a threshold of about 4-10 microns – including many foods, chemicals and textile colors.

The inline rotor/stator alternative

A batch mixer operating in an open vessel is easy and inexpensive to maintain, and it can be moved quickly from one vessel to another. But it also presents significant limitations, because batch mixing efficiency is directly related to flow within the vessel. As viscosity and vessel size increase, adequate flow becomes difficult to maintain. "Dead spots" in the vessel prevent homogeneity.

Poor flow also causes an uneven distribution of heat within the vessel. Zones of localized heat can cause thermal degradation, unacceptably high levels of off-spec batches, and – at minimum – slow mixing cycles.

In marginal cases, supplemental agitation can solve this problem, especially when viscosity exceeds 10,000 cps. A shaft-mounted propeller can generate axial flow (and also accelerate the addition of dry solids that require a vigorous vortex). An anchor

agitator can move material from the vessel wall toward the rotor/stator generator. But as vessel size increases, the process eventually becomes prohibitively expensive to run.

A small inline rotor/stator mixer – using a rotor/stator generator similar to the one used in a batch mixer – can handle a batch of virtually any size by recirculating material until the cycle is finished. A supplemental pump is generally unnecessary at viscosities below 10,000 cps, because a single-stage rotor/stator mixer usually produces enough pumping action on its own to recirculate the batch. With a supplemental pump, an in-line rotor/stator mixer can efficiently handle viscosities well beyond the practical limits of a batch system – above 1,000,000 cps.

In-line mixing systems are also versatile on a process line that requires frequent changeover from one product to another. A simple valve can divert the finished product downstream or switch instantly from one source vessel to another. Solids and liquids can also be injected directly into the high shear zone of the in-line mixer. This is much faster than additions in a batch configuration, especially when adding lightweight solids such as fumed silica or viscosity modifiers.

Today, many process engineers are looking for more control and greater accuracy than a batch system can provide. The in-line system meets this challenge, because product sampling is easier and more reliable, and recirculation is more closely controlled.

In-line viscometers, temperature probes, flow meters and other instruments all feed data to the control system, which manages the cycle at a high level of accuracy.

Multi-stage generators multiply the shearing events per pass

Until the arrival of "multi-stage" rotor/stator generators, the drive to produce products with smaller particle/droplet sizes was answered mainly with prolonged recirculation. This certainly produced more homogeneous batches, but even lengthy recirculation cannot increase the shear rate of a single-stage rotor/stator generator.

This threshold was broken when "multi-stage" rotor/stator generators were introduced. With 2-4 rotor/stator pairs nested concentrically, mix material moves outward from the center of the multi-stage unit, and it is subjected to a quick succession of shearing events.

Multi-stage rotor/stator mixers are excellent choices for many high-quality dispersions and emulsions. They are also extremely versatile, since the rotor/stator head

can be changed to accommodate a variety of product requirements. Results typically include a fast mix cycle and end-point particle/droplet sizes in the range of 1-5 microns in most applications.

The "X" factor – and a quantum improvement

The design of early rotor/stator generators followed a predictable path. Batch mixers got bigger. Inline mixers recirculated longer. Single-stage generators evolved into multi-stage generators. Shear rates went up and particle/droplet sizes went down. But the first *quantum* advance in several decades of rotor/stator mixing didn't arrive until the late 90s. By applying *far* more intense shear, the new kind of generator – dubbed the "X-Series" by its creators at the Ross Test & Development Center – began to produce sub-micron dispersions and emulsions that rival those produced with more expensive equipment such as colloid mills.

The new generator does not include a rotor (or several rows of rotors) with conventional blades. Instead, the rotor and stator are comprised of many concentric rows of intermeshing teeth. The mix material begins at the center of the generator and moves outward through radial channels cut in the rotor/stator teeth.

As the mix material migrates toward the outlet, passing through many concentric rows of teeth, it is subjected to intense mechanical and hydraulic shear – and thousands of shearing events in each pass.

The total shear applied is further intensified because this generator operates at extremely high tip speeds – up to 18,000 fpm. (Tip speed is commonly used as an indicator of shear and overall rotor/stator performance. Conventional single-stage rotor/stator mixers generally operate with tip speeds in the range of 3,000 – 4,000 fpm.)

X-Series units are appropriate for applications in which sub-micron particle/droplet size is essential to achieve the desired product stability, visual appeal and texture. Applications typically include such products as mayonnaise, mustard, greases and lubricants, silicone elastomers and silica dispersions.

The X-Series rotor/stator generator generally operates with an unaided flow rate of 30-50 gpm, and some units reach 125 gpm. Because all of its power is focused on high-energy shearing rather than pumping, an auxiliary pump is often required for recirculation and for moving the mixed material downstream.

***MegaShear* increases the shear *and* the flow – all in one pass**

In terms of rotor/stator generator design, the *MegaShear* represents an ingenious step forward. But in operation, it is a hybrid – the first to combine:

- High flow rates: up to 500 gpm without an auxiliary pump
- high tip speeds: over 11,000 fpm
- Ultra-high shear: comparable to that of an X-Series High Shear Mixer

The combination of high flow and high shear is an important improvement over previous rotor/stator designs, because gains in throughput can produce direct gains in overall production, operating efficiency, and bottom-line profitability. Even for those who are already using an ultra-high shear rotor/stator mixer to produce sub-micron emulsions and dispersions, the MegaShear offers many manufacturers a tool to produce *more* end-product, faster.

But perhaps the most significant advantage that the *MegaShear* offers is its ability to disintegrate large particles and droplets in a single pass. With virtually 100% particle/droplet disintegration on the first pass, the MegaShear produces an exceptionally uniform particle/droplet size distribution – which is critically important for many fine

emulsions and dispersions. A extremely narrow size distribution contributes to superior product stability and texture, faster solubilization, greater efficacy in the case of pharmaceuticals, and greater efficiency for catalyzed chemical reactions.

By eliminating the need for inline recirculation, the mixer also delivers an important improvement in process control. Unlike recirculating systems, in which passes through the rotor/stator were estimated statistically, the MegaShear operates with exactly *one* pass through the rotor/stator – a statistical certainty.

The MegaShear is especially well-suited for applications that include high-quality chemical dispersions, emulsions, suspensions and solutions. Food applications include condiments, sauces, dressings and marinades.

Making sense of all the choices – test!

Today, there are more choices in rotor/stator mixing than ever before. In many applications, more than one rotor/stator design will do the job. The question is, which meets your process requirements (for mean particle/droplet size and uniformity, for example) and matches your business priorities (for cost vs. performance).

The only way to know for certain is to test a wide variety of designs in a well-equipped laboratory. Don't rely solely on intuition to judge performance: test using your own ingredients in the lab, and *measure* the results with analytical equipment.

The next step is usually to test in your own plant. Reputable manufacturers will invite you to rent the equipment you plan to purchase for an in-plant trial before you buy it. Ultimately, this is the best assurance you can get that your mixing solution will meet *all* of your goals for production and profitability.