Ultra High Shear Mixing Technology

Since most industrial processes don't take place in a beaker, we must always consider the real-world behavior of high-shear batch mixers in large vessels. Thinking on a molecular level, we ask, "How many times does each particle or droplet pass through the high shear zone?" Backing up to see the process from a wider perspective, we ask, "How consistent are my results? How uniform is the distribution of particle or droplet sizes in my batch?" In many applications these are critical questions because they can profoundly influence the properties of your end product.

The daily challenge in high-shear rotor/stator (HSM) mixing is to reach the target droplet or particle size and achieve a satisfactory particle-size distribution in the most cost-effective manner. This

requires a careful balance of rotor/stator design, cycle time at a required batch size, capital cost, and per-cycle operating costs. Any batch mixing process — whether the process goal is particle dispersion, particle-size reduction or emulsification — generates a Gaussian distribution of results. The greater the ratio of product volume to HSM throughput, the broader the distribution will be. Of course, the goal is usually to produce the narrowest distribution possible with an equipment solution that meets the site-specific process and business requirements. The question is simply, "What is the most effective, economical, and practical way to produce the required particle - or droplet size distribution?"

At mixing equilibrium we have reached the target average particle size. Additional processing will gradually narrow the distribution curve, but extending the process for this purpose alone almost always amounts to a substantial waste of time and energy. An alternative strategy is to increase the size of the HSM. This will increase the ratio of HSM throughput-to-product- volume and narrow the curve. But this will also increase both the initial capital investment and the ongoing energy costs. The attractiveness of this solution depends heavily on the value of the product being manufactured, its competitive strength, and the overall business case for investing heavily in equipment.

A radical strategy for narrowing the particle-size distribution would be to use two tanks and a conventional inline HSM. You would pump directly from the first tank, through the inline HSM, and into the second tank. The process would then be reversed: pumping from the second tank, through the inline HSM, and back into the first tank. This cycle can be repeated over and over until the product reaches the desired characteristics. With this method, the shear history of the product could be more closely monitored than in customary batch or batch-recirculation processes. Of course, the expense of purchasing and tying up two tanks is usually prohibitive. This technique would also be extremely time-consuming, and it would require either constant operator intervention or complex automation.

Try a different approach - an ultrahigh-shear mixer

The best solution is often to switch to an ultrahigh-shear inline mixer (UHSM). In select applications, an UHSM can achieve the desired process goals in a single pass, allowing this device to process batches of product in a “terminal” approach (that is, with one single pass of the tank contents through the UHSM, and then on to the next phase of the process). Although the UHSM typically represents a higher capital investment than a traditional single stage HSM, its ability to complete the process in a single pass often allows us to step down to a lower-throughput unit. This reduces initial equipment cost without an unacceptable sacrifice in production.

The single-pass performance of the UHSM is attributable to the extraordinarily high shear it applies and the large number of shearing events to which it subjects the mix material in each pass This also accounts for its ability to produce an exceptionally narrow particle size distribution with a single pass. For products that require great uniformity in a dispersion or emulsion, this can be a decisive advantage. A recent example of this solution involved a manufacturer in the asphalt industry. In this case, a clay filler is added to asphalt at 400°F to boost its viscosity for use as a thixotropic automotive undercoating. After an initial pre-mix using a large-sweep agitator in a 2,000-gal. tank, the material requires mixing under high shear to deagglomerate and disperse the clay so that it develops its thixotropic properties.

An initial test on the benchtop reached the specified endpoint (defined in this case as target viscosity) in 30 minutes. A scale up calculation based solely on mixer flow rate suggested that a

25-hp inline mixer with a 4.5-in.-dia. rotor would be an appropriate choice for production.

Operating at 3,600 rpm, and with a flow rate of 150 gal/min, this would be a logical choice in most applications. But in this case it was impractical. The 30-minute cycle on the benchtop produced roughly 900 tank turnovers. Projecting to full-scale production in a 2,000-gal.tank, the process would require 7,200 minutes — or five days. The best solution proved to be a switch to a UHSM operating at 30 hp with a 6-in.-dia. rotor and a flow rate of 20 gal/min. After the pre-mix, the UHSM successfully dispersed the clay and built up the viscosity in one pass, a batch that required 100 minutes — just 1 hour and 40 minutes. The material was then passed directly to filling equipment, where it was dispensed into final packaging.

Don't assume...test!

Understanding high-energy rotor/stator mixing is a daunting challenge on any level. It is far more complex than traditional low-shear mixing, which makes rigorous modeling and academic study extremely difficult. In the absence of such guidance, operators must rely on the instinct, experience, empirical testing and other technical resources offered by their high-shear-mixer manufacturer to find the most efficient and cost-effective HSM solution.

The best strategy is to consult with a mixer manufacturer that can provide a well-equipped laboratory with quantitative analytical support for a thorough process test. Bring your own ingredients, and specify process conditions carefully to accurately simulate conditions on your process line. Most important, test using a variety of equipment, from traditional single-stage batch and inline rotor/stator mixers to ultrahigh-shear devices. Even with an expert guiding you through the selection process, you cannot possibly know for sure that you have chosen the best equipment for the job until you've tested numerous possibilities.

In most of the CPI, competition is more intense today than ever before. So, even small gains in production efficiency can be vital to build your product's competitive strength. Measure your benchtop results meticulously, because every second counts and projections to full-scale operations can compound the impact of small, lab scale errors. Evaluate your process results quantitatively with appropriate instruments such as particle-size analyzers. Leave nothing to chance or supposition. And above all, project carefully from the benchtop to full-scale production before you buy any scaled-up systems. An extra measure of rigor and diligence at this stage can certainly mean the difference between success and failure on the plant floor and profitability in the marketplace

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