GET INTO THE THICK OF THINGS

SUCCESSFULLY MIXING HIGH-VISCOSITY MATERIALS POSES UNIQUE CHALLENGES

BY BILL ALHOFEN, CHARLES ROSS & SON CO.

IN MOST PARTS OF THE CHEMICAL INDUSTRY, viscosities are on the rise. This is a universal response to demands such as those to cut levels of volatile organic compounds and to improve onsite performance of high-solids water-borne products. As this trend accelerates, many manufacturers are finding that the mixing equipment they have relied on for years is now inadequate.

To adapt, many are moving from simple dual-shaft mixers to more robust triple-shaft units. Others are upgrading to double planetary mixers and hybrid planetary designs or opting for an agitator that can obviate a double-arm kneader.

Many equipment options are available today for high-viscosity mixing and dispersion. Equipment suppliers offer several major classes of mixers and numerous agitator designs, and these can be combined in many ways. Unfortunately, no simple equation pinpoints which mixer and agitator are needed for any particular purpose. There are too many variables in each application, and each presents a unique set of goals and constraints. However, this much is certain: The need to process higher-viscosity materials will continue to increase and, as product formulations ramp up, most chemical manufacturers will soon be faced with the need to find mixing alternatives.

For many, this will present a fresh set of challenges and require a step into a new world of equipment specification. The question is where should you start?

New challenges emerge

Mixer specification should always begin by matching an agitator design to a desired mixing function and result, such as particle/droplet size reduction, dispersion or emulsification. For low-viscosity materials that are made in small batches, we consider such variables as the target shear rate, the volume of additions required, the number of batch turnovers needed to achieve homogeneity and the material's tolerance to heat.

As batch volume increases, the scale-up process becomes

Mixer applicability

Design/configuration	Minimum viscosity, cP	Maximum viscosity, cP
Multishaft mixer with three-wing anchor	1	350,000
Multishaft mixer with helical ribbon added to anchor	1	500,000
Planetary/disperser hybrid mixer	20,000	2 million
Double planetary mixer with traditional rectangular blades	50,000	2 million
Double planetary mixer with HV blades	50,000	8 million
Kneader/extruder	500,000	10 million+

>> Rotor/stator designs

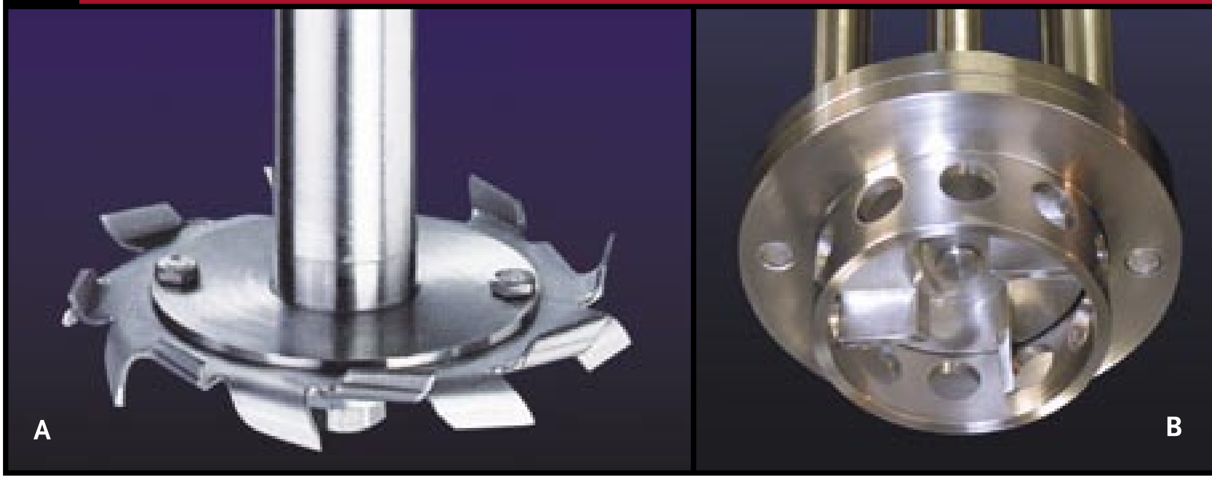

Figure 1. A high-speed disperser (A) is a good choice when moderate shear and high flow are needed, whereas a rotor/stator mixer (B) applies more intense shear than a disperser, but generates less flow.

more complex. We often suggest additional agitators to provide supplemental shear and to stimulate radial and axial flow. Because low-viscosity materials flow readily, an anchor agitator usually is the logical choice to induce flow from the vessel walls inward. However, certain high-shear agitators, such as high-speed dispersers and rotor/stator generators, also promote vigorous flow by expelling materials at high velocity into the surrounding batch (see *CP*, April 2004, p. 31-39).

As viscosity rises, we soon cross a threshold into a different realm of mixing technology, and a variety of new design challenges emerge. For example:

- Materials that do not flow easily cannot be moved satisfactorily with an anchor agitator. When pushed away from the vessel wall, they do not keep moving. So, you must use special agitators that rotate and travel through the mix vessel, passing through *every* point within the batch, not just along the periphery. Highly viscous materials must literally be carried from the vessel wall to the batch interior.
- Materials that are heavy, thick and sticky — especially those highly loaded with fibrous fillers — can ball up, climb the agitators and avoid being mixed.
- Nonflowing materials fail to carry heat away from high-shear zones efficiently. If these materials also are heat-sensitive, they can slow the mixing cycle to a crawl.
- The lack of sufficient flow makes it tricky to accurately monitor batch temperature. Because heat is not dispersed evenly throughout the batch, a probe might be located in a zone of abnormally low (or high) heat, and thus give a misleading reading.
- Drives must be specially designed to handle the immense load of a high-viscosity product and provide constant torque throughout the speed range, even at very low rpm.
- Agitators also must be designed and fabricated specifically to accommodate these dense materials and high-torque requirements. This is critical for effectively mixing the products within a short mixing cycle.

The list of special challenges in high-viscosity mixing goes on and on and underscores the importance of using equipment designed for the task.

The First step

To select the right unit for a high-viscosity mixing application, begin by focusing on the basic agitator designs. Consider each agitator's motion within the vessel, its impact on the batch material and its effectiveness in high-viscosity applications. Here's a brief rundown:

Stationary high-shear agitators and a slow-speed anchor. High-shear devices, such as high-speed disperser blades and rotor/stator generators (Figure 1), are useful in many high-viscosity applications — up to about 500,000 cP for the disperser with a helical anchor, and up to about 200,000 cP for the rotor/stator generator. These high-speed agitators suit fast particle/droplet size reduction, powder wet-out and dispersion.

Dual- and triple-shaft mixers combine stationary high-shear devices and an anchor agitator. They rely on the slow-turning anchor to push material from the vessel wall and bottom to the high-shear device. While the stationary high-speed devices impart high shear, the anchor slowly revolves around the vessel wall and stimulates mass flow.

Equipped with a three-wing anchor, the dual-shaft mixer handles viscosities up to about 350,000 cP (table). With a helical ribbon added to the anchor (Figure 2), the triple-shaft mixer suits viscosities up to about 500,000 cP. In both cases, the inherent flow characteristics of the material being mixed limit the effectiveness of the anchor and, thus, of the high-shear agitators.

Mixers operating with multiple stationary agitators are exceptionally versatile, but are limited to mid-range viscosities. Their versatility — especially in the case of the triple-shaft mixer — mainly results from their independently controlled drives. The agitators can be engaged in any combination and at any speed for any interval during the mixing cycle. Yet, the drive system is comparatively simple even for a mixer with several agitators. This largely explains why the multi-agitator mixer often is an economical choice.

In addition, this flexibility frequently enables a single multi-shaft mixer to consolidate mixing processes that otherwise would be conducted in two separate units. For example, a single triple-shaft unit can handle rapid pre-mixes and subsequent fine dispersions.

Orbiting planetary agitators. When the batch material becomes too heavy to flow freely to the agitators, the logical design alternative is to move the agitators through the batch. That is the forte of the double planetary mixer, which is one of the classics of mixer design. Figure 3 shows its agitator movement.

This mixer operates at viscosities as low as 50,000 cP, but works most efficiently at higher levels. As the viscosity of a heavy paste approaches 2 million cP, shear in the batch increases steadily, agglomerates disintegrate and average particle size drops quickly. For this reason, manufacturers often artificially raise the viscosity of a batch to accelerate dispersion and mixing and then let it down to the desired final viscosity when the cycle is complete.

The mixer comes with a variety of blade designs (Figure 4). For instance, the HV Blade, introduced a few years ago, features a trailing slope and helical geometry; as the broad, flat-sided blade moves forward through the batch, it constantly forces material downward. This enhances top-to-bottom mixing, even in extremely heavy materials. It also prevents the climbing that often occurs with heavy and sticky materials. Even difficult materials, such as silicone sealants, remain in the batch and mix quickly. HV Blades can handle jobs that otherwise would require a double-arm kneader or kneader/extruder and can provide significant capital cost savings while also typically offering 30% faster batch times.

Because the double planetary mixer can mix high-viscosity products while applying low shear, it especially suits applications involving abrasive materials and delicate microspheres. The double planetary is also the mixer of choice in many applications including battery pastes, sealants and caulks, dental composites, metallic slurries, syntactic foams and plastisols, and metal powders.

When higher shear is needed, a disperser/planetary hybrid can be used. It features a high-speed disperser and a planetary blade; both orbit as each turns on its own axis (Figure 5). With this design, even at viscosities up to 2 million cP, the disperser blade can apply intense shear without cavitating in the thick material. The planetary motion of the two agitators also eliminates the risk of localized heat buildup near the high-shear zone and, with it, the chance of degrading sensitive materials. The hybrid can handle applications from about 20,000 cP to at least 2 million cP. Typical applications include thick film inks, plastisols and sheet molding compounds, conductive and security inks, propellants, adhesives and sealants, and many slurries.

Double-arm kneader/extruders. For materials over 8 million cP, the kneader/extruder remains the mixer of choice. Two close-tolerance sigma blades revolve in a trough, tear materials like solid rubber apart, and knead

>> Triple-shaft mixer

Figure 2. This unit features a helical ribbon attached to the anchor to enhance top-to-bottom flow.

>> Blade movement

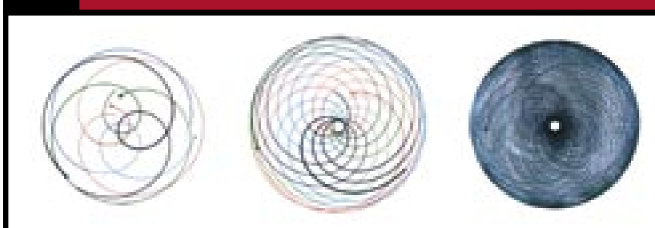

Figure 3. In a double planetary mixer, the orbital motion of blades is both predictable and efficient.

>> Blade types

Figure 4. Choices include traditional rectangular (left) and finger blades (center), as well as the newer HV Blades (right).

>> Hybrid design

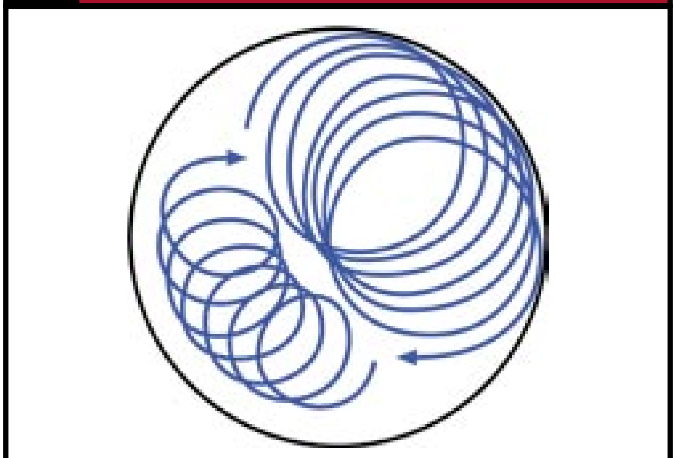

Figure 5. Both the high-speed disperser and planetary blade orbit through the vessel, but turn independently on their own axes.

them quickly. When the process is finished, an extrusion screw in the trough discharges the heavy material automatically. Materials like ceramics, bulk molding compounds, heavily loaded sealants and hot melts require enormous power, and the kneader/extruder responds without difficulty. For instance, using a kneader/extruder instead of a paddle mixer can cut the time needed to disperse rubber into polymers, resins and fillers from 18 hours to 2 hours. The product is highly consistent, has a uniform honey color and no entrained air.

Auxiliary equipment

To maximize the value of high-viscosity mixers, you need to choose the right auxiliary equipment. Here are some items worth considering.

Change cans. Rolling, interchangeable mix vessels are the simplest investment any manufacturer can make in productivity. They can minimize downtime for both equipment and plant staff.

Consider a typical setup using four change cans per mixer. As one can is being loaded with raw materials, the second is midway through the mixing process, the third is being discharged remotely and the fourth is being cleaned. As each step is completed, the vessels simply roll from one position to the next.

Change cans can also be equipped with a pneumatic sled that operates like a hovercraft to allow easy transportation in the plant. They suit batch sizes up to about 750 gal., depending upon the weight of the product.

Automated discharge systems. With high-viscosity materials, discharging by hand can be slow and cumbersome. An automated method for handling finished materials can provide significant advantages. For instance, a follower-plate system can discharge a heavy batch in a fraction of the time required to scrape it out by hand. Plus, less direct labor means fewer injuries and more time on the job. Discharge systems can be manually controlled or fully automated, hydraulically or pneumatically actuated, and fitted with discharge valves to accommodate downstream filling equipment. They come in a variety of configurations.

Test for success

Once you have surveyed the equipment options for handling a high-viscosity formulation, the next step is to test. Theory and experience are vital for speeding up the specification process, but any experienced mixing engineer will tell you that until you test in a well-equipped laboratory, you don't know for sure that you've found the best possible mixer for your needs.

Test in a laboratory under controlled conditions. Use your own ingredients. Make sure to apply quantitative analysis to the results. And, most importantly, try a variety of mixer and agitator designs at various levels of viscosity.

Finally, the most conclusive test will be on your own process line. Many suppliers offer on-site testing as an option prior to purchase; take advantage of this opportunity. Even if you need to rework your budget to afford an in-plant rental, it's the least expensive insurance you will ever buy. **CP**

Bill Alhofen is product manager, high viscosity mixers, for Charles Ross & Son Co., Hauppauge, N.Y. E-mail him at balhofen@mixers.com.