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➤ Planetary mixers have undergone some major improvements in recent years in response to evolving process needs.

Advanced **Planetary Mixer Options**

by Christine Banaszek, Application Engineer, Charles Ross & Son Co.

The rapid development of technical ceramics and ceramic-based composites is pushing manufacturers to seek new and improved methods of production. Different products vary in the ways they are handled, formed and finished, but at the heart of the process is the mixing procedure, which commonly takes place in planetary-style mixers.

Comprised of agitators that move around the vessel while turning on their respective axes, planetary mixers have undergone some major improvements in recent years in response to evolving process needs. Given today's intensely competitive market, R&D managers and process engineers that have not already done so have more incentive to give mixing a closer look.

Despite the many end uses and applications—from bioceramics and cutting tools to advanced filters, membranes, aerospace, and automotive components—many ceramics and composites are batched as high-viscosity pastes, slurries or doughlike materials in planetary-style mixers. Within this mixer category, the three main designs are double planetary mixers, planetary dispersers and planetary dual dispersers.

PowerMix planetary disperser.

Double Planetary Mixers

Double planetary mixers consist of two identical stirrer blades that rotate on their own axes while orbiting the vessel. The stirrers provide a thorough mixing action regardless of product rheology. Unlike mixer blades with a fixed axis of rotation, planetary stirrers do not rely on the product's ability to flow toward them. Instead, both blades continuously advance along the periphery of the mix vessel and contact fresh product all the time, removing material from the walls and transporting it toward the inte-

Planetary dual disperser.

rior. Batch components are constantly recombined and physically moved from one area of the vessel to another until a homogenous state is achieved.

R&D labs using commercially available kitchen-style single planetary mixers realize that these devices are limited to small volumes and do not offer a clear path to scale-up. In addition, single planetary mixers cannot effectively handle highly viscous applications, especially materials that are too sticky, thick, or heavy, or have a tendency to hang on to the stirrer.

For these reasons, the more robust and scalable double planetary mixer is more practical and reliable, offering enhanced agitation by way of the blade-to-blade interaction that is not present in a single planetary mixer. Since double planetary mixers can be built for vacuum operation (and most of them are), the product may be conveniently de-aerated right in the mix vessel. Vacuum mixing helps to reduce porosity and optimize strength in engineered ceramic composites.

For many years, rectangular paddle-shaped stirrers were the standard blade design for double planetary mixers. When processing relatively low-viscosity materials, these blades impart low-shear agitation, which is ideal for abrasive formulations. As needed, abrasion-resistant coatings can be applied to the mixer blades and vessel sidewall surfaces. Some of the most commonly used coatings are aluminum oxide, chromium oxide, polyvinylidene fluoride (PVDF), nylon and tungsten carbide. Other surface treatments include electropolishing, boronizing and hard chrome plating.

When mixing at high viscosities, the planetary blades deliver the greater shear necessary for creating finer solid dispersions. Typically, as product viscosity approaches 2 million cP—the high end of the viscosity range for this machine—shear in the batch increases steadily, agglomerates disintegrate and average particle size drops quickly. In fact, it is common procedure for operators to artificially raise the viscosity of a batch by withholding some portion of the liquid binder or solvent to accelerate dispersion. Once all the solids are mixed in and the desired level of dispersion is achieved, the batch is then let down to its final viscosity.

Due to their geometry, rectangular stirrers rely on centrifugal forces and gravity to keep product within the mixing zone. At elevated viscosities, some products tend to climb up the vertical flights of each stirrer and out of the mix vessel. This characteristic migration of batch material reduces mixing efficiency, necessitates additional cleanup and can even increase contamination risks.

In recent years, many ceramic manufacturers have gained tremendous improvements to the operational capabilities of their double planetary mixer by simply upgrading to a new helical blade design with no bottom crossbar. Stirrers such as the Ross High Viscosity "HV" Blades (U.S. Patent No. 6,652,137) prevent the "climbing" problem commonly experienced with traditional rectangular stirrers. These blades feature a precisely angled helical contour that generates a unique mixing action—the sweeping curve firmly pushes batch material forward and downward, keeping it within the mixing zone at all times. This enhanced control over batch level ultimately leads to improvements in mixing efficiency, cleanup time and product purity.

Another important benefit to the helical blade design is that it extends the double planetary mixer's operating viscosity range to up to approximately 6 million cP. The open paddle design of traditional rectangular blades features a bottom crossbar, which makes it difficult to raise or lower the blades through a highly viscous batch. The vertical flights of the rectangular stirrers also sometimes tend to generate a power spike as they pass each other at very close tolerances. In contrast, the HV blades' helical contour causes the agitators to pass each other in a slicing motion, so that even at the same close tolerances, the sudden spike in power experienced with rectangular blades is eliminated. The absence of horizontal crossbars also allows the helical agitators to be easily lifted out of a viscous batch.

Typical applications of the double planetary mixer include dental composites, bone graft substitutes, injection molding feedstock, refractory cements, potting compounds, polymer concrete, screen printing pastes, microsphere-filled composites, thermal management materials, ceramic dispersions in wax, dilatant materials, lubricants, investment casting slurries, and electrode pastes for fuel cells, among others. When equipped with helical blades, a double planetary mixer can even handle some extremely viscous applications that previously required a more expensive horizontal sigma blade mixer.

Aside from their primary use in compounding high-viscosity formulations, double planetary mixers are also used for vacuum drying requirements. The photo at right shows a 40-gal double planetary mixer that produces thoroughly dried tungsten carbide powders from a tungsten carbide/heptane slurry. Heat is applied throughout the mixing cycle, and the solvent is gradually removed under vacuum. As the mixture is transformed into a paste and finally to a flowable powder, batch temperature is carefully monitored. The HV blades continuously sweep through the vessel and prevent the formation of localized zones of dangerously high heat. Efficient heat transfer is extremely important since the powder is flammable. At the end of the vacuum drying cycle, more than 95% of the solvent is reclaimed.

This mixer replaced conical tumbling driers, which handled much smaller batches—less than 20% the capacity of the double planetary mixer—and took 6-8 hours per cycle. The double planetary mixer drastically reduced drying time to just over an hour and required less cleaning and preparation between batches.

The final granulation is extremely uniform in terms of size, moisture content and encapsulation. Uniformity in all these aspects is crucial because the slightest flaw in the granulation can lead to failure of the finished part.

Double planetary mixer with high-viscosity blades.

Planetary Dispersers

Some highly filled compounds require a two-step approach to ensure a properly dispersed batch. For example, after mixing all ingredients in a double planetary or sigma blade mixer, the batch is carefully let down and transferred to a high-speed, saw-tooth disperser to provide the extra shear needed for completion. This method, while effective, can be time consuming and labor intensive.

A more efficient procedure is one-pot processing in a planetary disperser. Equipped with both low- and high-speed agitators, a planetary disperser accomplishes mixing tasks normally done by two or more devices. In this configuration, a rectangular or helical stirrer blade rotates on its own axis while orbiting the mix vessel. At the same time, a saw-tooth disperser blade also revolves around the batch while turning on its own axis at tip speeds of around 4,000 ft/min. This high-speed blade quickly disperses powders, fibers, pellets and other solids into liquids (low or high viscosity).

As the slower planetary blade orbits through the mix can in a circular manner, it continuously sweeps the vessel walls, as well as the vessel bottom, and carries material toward the disperser. The close tolerance sweeping action of the planetary stirrer also ensures that heat created by the disperser blade is evenly distributed throughout the batch. Each agitator is controlled independently, allowing the operator to fine-tune flow patterns and shear rates at any point during the mixing cycle.

Ceramic applications processed in planetary dispersers are similar to those batched in double planetary mixers, but have a lower peak viscosity (up to around 2 million cP) and benefit from high-speed agitation (i.e., not extremely abrasive or shear sensitive). For example, a manufacturer of specialty ceramics was using a double planetary mixer with rectangular blades to produce a plug cement material. The machine was reliable and generated an adequate dispersion, but the company decided to investigate more vigorous mixer systems that could possibly shorten the cycle time.

The viscosity of this particular ceramic cement goes down as the level of dispersion increases. A thin slurry is advantageous as it allows for easier application and more uniform coating on the substrate. In the double planetary mixer, viscosity drops to around 210,000 cP after 50 min of mixing. Mixing trials on a Ross PowerMix planetary disperser proved that cycle time can indeed be reduced and an even greater degree of dispersion can be achieved.

Powders consisting of talc, kaolin clay, silica and graphite are loaded into the planetary disperser, followed by the liquid component. The combination of high-speed mixing and planetary stirring produces the same dispersion quality as the control sample in less than half the time it takes in the double planetary mixer. In less than 40 min, a better-quality slurry with a viscosity of 120,000 cP is completed in the planetary disperser.

Planetary Dual Dispersers

Faced with increasingly more demanding applications, manufacturers are finding a need for more powerful and shear-intense mixing equipment. For high-viscosity materials, one solution is the planetary dual disperser equipped with two planetary stirrers and two disperser shafts.

In this system, solid additions can be made in larger quantities and shorter intervals. Each disperser shaft is typically equipped with at least two saw-tooth blades such that any agglomerates in the batch are disintegrated faster and material turnover is even more rapid than in a regular planetary disperser. This mixer configuration also offers a unique processing flexibility: both disperser shafts are removable, allowing

Mixing has a direct correlation to the performance, strength and durability of specialty ceramics and composites.

the mixer to be operated as a classic double planetary mixer.

Planetary dual dispersers are typically operated under vacuum. In the preparation of advanced thermal interface materials, liquid resins are first heated in the vessel and blended under vacuum. Ceramic fillers and other solids are then added in increments. For each powder addition, deep vacuum is established and maintained for 5 minutes before the planetary stirrer blades and high-speed dispersers are turned on. This mixing procedure consistently produces high-quality, uniform and air-free pastes from one batch to the next.

Test Before You Buy

Mixing has a direct correlation to the performance, strength and durability of specialty ceramics and composites. In low-volume niche markets, the right mixing system can help propel existing products to increased profitability while ensuring a flexible and agile production that can easily adapt to new requirements.

Cover all bases and be prepared to test a variety of equipment and techniques. Ask your mixer supplier about proof-of-concept demonstration services and trial/rental programs. The latter will allow you to perform mixing experiments and production runs in your own facility without the commitment of a capital purchase. Empirical testing is the single best way to confirm the most efficient high-viscosity mixer for your particular application.

For more information, contact the author at Charles Ross & Son Co., P.O. Box 12308, Hauppauge, NY 11788; call (631) 234-0500; or visit www.mixers.com.