Mixing equipment and applications in the food industry

At the heart of transforming raw ingredients into food for human consumption is the mixing operation. Its main task, which other food processing steps also share, is to establish consistency. Whether a food product requires small-scale mixing by hand or high volume blending of multiple ingredients, at-home cooks and food process engineers alike know the importance of proper mixing. Even with the right amount of ingredients and flavors, a great recipe will not transform into good food unless the components are well-mixed. Taste, texture, color, appearance – these are all crucial parameters intimately influenced by the mixing process. Consumers expect that the food products they patronize will be exactly the same as the one they had last. It is easy to understand that within the food industry a high level of consistency is required not just batch-to-batch but facility-to-facility. In this market, consistency is the backbone of consumer loyalty.

Various types and styles of mixing equipment are utilized within the food industry. Their use and application are determined by the phases being mixed (liquid-liquid, solid-liquid, or solid-solid) as well as physical characteristics of the end product (like viscosity and density). Advances in mixer and blender designs have contributed to the growing success of food companies, meeting the requirement for consistency and developing new products while also lowering production costs. This white paper discusses both traditional and new specialty mixing technologies available to food manufacturers today.

Dry Blending

The **Ribbon Blender** is well-proven type of equipment popularly used in the food and beverage industries. A ribbon blender consists of a U-shaped horizontal trough and an agitator made up of inner and outer helical ribbons that move material in opposite directions. The ribbons rotate up to approximately 300 fpm, and move materials both radially and laterally.

This blender design is very efficient and cost-effective for dry mixing of such applications as cake and muffin mixes, flour, bread improvers, cereals, trail mixes, snack bars, spices & herbs, tea (leaves or iced tea powders), coffee (whole or ground beans), and other beverage blends including whey protein shakes, chocolate drinks, powdered juices, energy drinks, etc.

When dry blending food products, relatively small amounts of liquid may be added to the solids in order to coat or absorb coloring, flavoring, oils or other additive solutions. Liquid ingredients can be added through a charge port on the cover but for critical applications, liquid addition is best accomplished through the use of spray nozzles installed in a spray bar located just above the ribbon agitator. The spray bar is connected to a pressure vessel. Liquid flowrate, as well as blender speed, are fine-tuned during liquid addition to avoid flooding or formation of wet clumps of powder.

Although dry blending is its more popular function, the ribbon blender is also used in the preparation of flowable slurries or pastes, say in food extrusion operations. Food extrusion is a processing technology employed for a wide variety of end products, from pasta to ready-to-eat cereals, from snack chips to pet food. The function of the ribbon blender in the extrusion process is to homogeneously mix two or more grains, flours, oil, sugar, emulsifiers, extrusion aides and other powders. Once the constituents are blended, water is usually added to the batch in order to raise the existing moisture content to the proper level for extrusion.

For blends that require a gentler mixing action, the **Paddle Blender, Vertical Blender or Tumble Blender** are considered by food manufacturers.

The horizontal paddle blender runs at about 2/3 the tip speed of a comparable ribbon blender, providing lower shear and less heat development.

In comparison, the blending action of a vertical blender's slow turning screw is far gentler than that of a horizontal blender. The blending screw orbits a conical vessel wall while it turns and gently lifts material upward. The materials are then thrust at the upper most batch level towards the center of the vessel, and then move slowly back down the center, while mixing with materials being moved upward by the orbiting screw.

The tumble blender is a rotating device that commonly comes in double-cone or V-shaped configurations. Asymmetric vessels designed to reduce blend times and improve uniformity are also available. Generally, tumble blenders operate at a speed of 5 to 25 revolutions per minute. Materials cascade and intermix as the vessel rotates. Mixing is very low-impact.

High Shear Mixing and Emulsification

High Shear Mixers (HSM's) utilize a rotor/stator assembly which generates intense shear necessary to puree solid ingredients in the preparation of dressings, sauces and pastes. This type of device is also used in the food industry for the production of syrup solutions, beverage emulsions and dispersions.

Available in batch (vertical) or inline (horizontal) configurations, high shear mixers are comprised of a rotor that turns at high speed within a stationary stator. As the rotating blades pass each opening in the stator, they mechanically shear particles and droplets, and expel material at high velocity into the surrounding mix, creating hydraulic shear. As fast as material is expelled, more is drawn into the rotor/stator generator, which promotes continuous flow and fast mixing.

A major development in HSM design is the SLIM (Solids/Liquid Injection Manifold) Technology, a high speed powder induction system available on Ross High Shear Mixers. The modified rotor/stator assembly is specially designed to create negative pressure (vacuum) behind the rotor, which can be used as the motive force to suck powdered (or liquid) ingredients directly into the high shear zone.

The SLIM is particularly useful in inducting hard-to-disperse gum and thickener powders such as CMC, xanthan gum, gum Arabic, guar, carrageenan and alginates into a liquid phase. These powders are notorious for driving up processing costs. Even with a strong vortex in an open vessel, they resist wetting out and often float on the surface for hours. Using the SLIM, solids are combined with the liquid stream and instantly subjected to intense shear. In other words, solids and liquid meet at precisely the point where positive mixing takes place. When solids and liquids are combined and mixed simultaneously, agglomerates are prevented from forming because dispersion is virtually instantaneous.

The inline configuration of the SLIM is a great improvement in design compared to earlier venturi or eductor systems. In these systems, the process liquid is pumped at high velocity into a venturi chamber and passes into the inline mixer. The combination of the pump, venturi and the pumping action of the mixer creates a vacuum in the venturi chamber. Powder fed through an overhead hopper is drawn by this vacuum into the eductor where it joins the liquid flow. A rotor/stator then mixes the powder and liquid, and propels the flow downstream.

While this set-up eliminates the dusting and floating issues of batch systems, it also presents serious limitations. With three separate devices in series, maintenance – in terms of labor, required expertise and spare parts — is intensive. Balancing the performance of the pump, eductor and mixer is often difficult, and in many applications, downtime is quite high. But the most serious limitation relates to the inherent operating limitations of the venturi or eductor. Clogging is routine. The system is temperamental and requires a lot of operator experience and attention to operate successfully. Since the feed rate of the eductor relies on the vacuum created by a fast-moving stream, it is also extremely viscosity-dependent. As the viscosity of the stream rises, velocity falls and the efficiency of the eductor drops offs steadily until it finally stops.

The Ross SLIM design is a breakthrough based on one simple idea — eliminate the eductor.

In the older powder induction designs, solids are combined with the moving liquid stream in the eductor, and then mixed farther down the line. That distance between the eductor and the mixer is critical. Material that had been combined but not yet mixed intimately could clog the pathway before reaching the rotor/stator mixer where agglomerates could be disintegrated and small particles are forced into a dispersion that could flow quickly without problems. In addition, clumps produced in the venturi chamber could solvate to form a tough outer layer which prevents complete wetting of the interior particles. While product can be recirculated several times to improve initial dispersion, the high shear conditions usually needed to break up tough agglomerates can also overshear already hydrated particles resulting in a permanent viscosity loss.

Food companies are not only faced with the challenge of dispersing gums, flavors and other ingredients into a liquid stream. Another common and critical requirement is the need to reach a high level of solids loading in the final batch. Because the SLIM system combines and mixes solids and liquids simultaneously, it is able to operate at extremely high feed rates without choking.

Ultra-High Shear Mixing (Continuous Process)

Higher energy HSM designs are available such as the **QuadSlot, X-Series and MegaShear** offered by Ross**.** With tip speeds up to 18,000 feet/second, these ultra-high shear mixers are ideal for emulsions and dispersions that otherwise would require more expensive homogenizers or colloid mills. Submicron droplet or particle size distribution is possible with these devices. Typical applications include sauces, condiments, dressings, juice concentrates and flavor emulsions.

For example, in the processing of oil-in-water emulsion food products, users of Ross X-Series mixers experienced the following improvements over traditional colloid mills:

- Increased throughput. One X-Series unit replaced as many as four colloid mills. Consequently, processing became much simpler. It reduced the cleaning, running, and balancing of four colloid mills into managing just one machine.

- Increased energy input. A single pass through the X-Series produces a lower oil droplet size and duplicates the texture and viscosity of a product that required a higher oil content when processed in a colloid mill. This translates to a tremendous amount of savings in raw material.

- Convenient control of shear. Rotor speed of the X-Series is controlled electronically through a variable frequency drive. Speed control is an essential parameter which enables the user to fine-tune texture and viscosity.

- Improved cleaning and disinfection procedure. The X-Series can be cleaned and disinfected in place by performing a series of quick steps: pumping warm cleaning solution, rinsing and draining. The shorter cleaning time equates to not just a faster changeover procedure but also to longer intervals between cleaning cycles (longer production runs).

- Ability to entrain inert gas. The X-Series makes it very easy to add nitrogen into the emulsion formulations, something which was not achieved in the colloid mills. The inert gas helps in the preservation and stability of the products.

High Viscosity Batch Mixing

Dual-Shaft and Triple Shaft Mixers are used in the food industry for the batch manufacture of medium to high viscosity applications such as candy syrups, beverages, nutraceuticals, sauces, pastes, peanut butter, and other spreads.

This type of mixing system is comprised of two or more independently-driven agitators working in tandem. A low speed anchor compliments one or two stationary high shear devices, such as an open disc-style disperser blade or a high shear mixer rotor/stator assembly. On its own, a disperser blade will produce acceptable flow patterns in batches up to around 50,000cps; the rotor/stator up to around 10,000cps. Hence, for higher viscosities, there is a need for a supplemental agitator to improve bulk flow, deliver material to the high speed devices and constantly remove product from the vessel walls for better heat transfer.

The most common low speed agitator designs are the two-wing and three-wing anchor. For added efficiency, especially in terms of axial flow, a three-wing anchor can be modified to feature helical flights in between wings. In combination, stationary high shear devices and an anchor will process food products as high as 500,000cps.

One user of a Ross Dual-Shaft Mixer produces fortified peanut butter. The process starts with shelled and roasted peanuts. Vegetable oil is added to the whole peanuts and the two ingredients are creamed together in the Dual-Shaft Mixer equipped with a two-wing anchor and a high speed disperser blade. Powdered milk, vitamin and mineral mix and sugar are added through a charge port and mixed into the paste. The fortified peanut butter is then passed through an inline rotor/stator mixer to reduce the size of the peanuts and granular sugar, producing a very smooth paste. This method of mixing not only ensures homogeneity but also prevents separation during storage. During discharge, the finished product is pumped by the inline mixer into large plastic drums and packed into plastic bottles for distribution.

Another example is a viscous fruit candy application previously manufactured using double arm sigma blade mixers; the gum dispersion was often inadequate and this resulted to fish eyes (lumps) in the finished product. Lab tests confirmed that a Triple Shaft Mixer can properly disperse the gum ingredient and create a smoother, better quality product. Conventional propeller or turbine mixers simply cannot achieve the same level of dispersion nor could they handle this extremely tough mixing application.

Due to the thickness and stickiness of the material, discharging by gravity presents an obvious bottleneck. A heavy-duty Discharge System complemented the sanitary Triple Shaft Mixer by providing the ability to quickly and cleanly press out the finished candy product. A stainless steel platen is lowered hydraulically into the vessel positioned underneath the discharge system. An O-ring on the platen rides against the vessel walls wiping them clean. Product is forced out through a valve on the side or bottom of the vessel, or through the top of the platen. The very small amount of product remaining, mostly on the vessel bottom, is easily cleaned by flushing warm water and doing a quick scrape down.

Double Planetary Mixing

As product viscosity continues to build up, a multi-agitator mixing system will eventually fail to produce adequate flow as can be characterized by an anchor simply carving a path through the batch (instead of pushing product away from the walls and into the center) or by high-temperature zones right near the disperser and rotor/stator assemblies. At this point, stationary agitators no longer suffice and a move to a planetary mixer is recommended. The agitators of a planetary mixer 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.

While single planetary mixers are commonly utilized for processing viscous food applications such as dough, their use has certain limitations when it comes to products that are too sticky, too heavy, or those that tend to climb up the stirrer. In these cases, the double planetary is a more practical choice. It can be equipped with traditional rectangular stirrer blades, finger blades or High Viscosity "HV" blades. The latter is a patented Ross blade design which generates a down-thrust action owing to its precisely angled helical contour. This sweeping curve firmly pushes the batch material forward *and downward*, a unique mixing action that solves the 'climbing' problem commonly experienced when processing highly filled materials. In addition, the HV blades do not have a lower crossbar so they can be cleanly lifted off a very viscous batch and can pierce right through it just as easily.

One such double planetary mixer installation produces gourmet organic cheese tortas. Ross test and development laboratory engineers were tasked to identify the optimal mixer design for this delicate product. The need for short mixing cycle was stressed -- in order to maintain quality standards for purity and freshness, minimum handling during processing was important. Beating the product too much makes it lose its fresh taste and texture. A traditional, single-planetary mixer required a long mixing cycle to soften 30-pound blocks of cold cream cheese and blend it with butter and other viscous ingredients. In contrast, a multi-shaft, high-shear mixer would whip air into the cheese. After testing a variety of mixers and agitator designs, the Ross team came to the unconventional conclusion: a sanitary double planetary mixer equipped with helical "HV" blades mixed the cheese torta ingredients quickly and met the customers' exacting specifications. Compared to their old process, the Ross mixer enabled them to create five times the volume in half the time with less labor. The efficiency of this process is attributable to the HV blade design with a trailing slope and helical geometry. The angled blades continuously push ingredients down into the batch, while they also move material from the walls toward the center of the vessel. This motion promotes complete top-to-bottom homogeneity and close control of temperature within the batch. Once the mixing cycle ends, the operator rolls the 40-gallon vessel to a Ross Discharge System to transfer the mixed products into packaging equipment. Meanwhile, a clean vessel, fully charged with ingredients, is rolled into place to start the next batch. With multiple mix vessels on hand, cleaning, mixing and discharging can all proceed simultaneously in a virtually continuous process.

Other food applications processed on double planetary mixers include syrups, gels, pet food, candies and other viscous formulations.

High Speed Planetary Mixing

Some highly filled and highly viscous formulations benefit from a hybrid planetary mixer which combines the traditional thorough mixing action of a planetary mixer with the added advantage of a high speed disperser. Both the planetary blade and the high speed disperser rotate on their own axes while revolving around a central axis. The planetary blade orbits through the mix can continuously sweeping the vessel walls, as well as the vessel bottom, and carrying material toward the high speed disperser. The close tolerance sweeping action of the planetary blade also insures that the heat which can be created by the disperser blade is evenly distributed throughout the batch. Variable speed allows precise control of shear rates to minimize the degradation of any shear-sensitive components. Sausage casing gels, viscous gum solutions and starchy mixes are some examples of applications processed in hybrid planetary mixers.

Conclusion

Evolutionary improvements in mixing technologies as discussed above present an opportunity for food companies to periodically update processes, upgrade efficiencies, improve product consistency and strengthen R&D efforts. It is recommended to plan a thorough testing program with a reliable and experienced equipment manufacturer before even committing to a specific type of mixer system. Confirm your mixing strategy by trying a variety of potential candidates utilizing your own raw materials and simulating operating conditions as close to your actual process as possible. The rewards are sweet and fulfilling.

Author: Christine Banaszek
Charles Ross & Son Company
710 Old Willets path
Hauppauge, New York 11788