High Speed Mixers for Paints, Inks & Coatings
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Abstract

This white paper provides an overview of the different types of high speed mixers utilized in the manufacture of paints, inks and coatings. These machines accomplish a range of processing objectives which sometimes overlap. The recommendations discussed in this paper are geared towards proper mixer selection based on Ross’ experience as a provider of specialty mixing equipment to the coatings industry for over 170 years.

Introduction

Regulatory requirements in the past few of decades have prompted the coatings industry to move its focus from conventional low-solid, solvent-based formulations to waterborne systems, high-solids coatings, energy-curable inks and other low-VOC technologies. This important environmentally-responsible shift coincided with exciting developments of new functionalities as a response to changing customer needs. Now faced with a growing demand for specialty and high value-added coatings, manufacturers are taking a closer look at their processing methods, particularly the mixing and milling steps. The question “What can we do better?” is asked more earnestly as coatings producers strive to improve performance and compliance while managing costs.

Infused with thermochromatic, fluorescent, color-shifting, rust-inhibiting or other novel properties, modern paints, inks and coatings may contain unique combinations of innovative raw materials but at heart they remain to be formulations that rely on good mixing. The degree of mixing and dispersion applied to a certain product invariably affects its color, gloss, conductivity, stability, adhesion properties, curing rate, weatherability and other performance characteristics. Thus, it only makes good business to optimize one’s mixing procedures. The fact is even traditional products and well-established processes can benefit from a strategic reassessment of the mixing operation.

As illustrated in the following sections, various dispersion tools are employed in the production of paints, inks and coatings. Some of these technologies are relatively new solutions to age-old processing issues. Mixer selection is based on a number of factors including viscosity profile, shear requirement, order of addition and throughput.
High Speed Dispersers

The High Speed Disperser, also previously called High Speed Dissolver, is a standard workhorse in the coatings industries. An economical and relatively simple piece of mixing equipment, its primary purpose is to incorporate powders into liquid and break down loose agglomerates to produce an acceptable level of dispersion prior to milling.

Running at tip speeds up to around 5,000 ft/min, the open disc blade of the High Speed Disperser creates vigorous turbulent flow within a low viscosity batch. It also generates a characteristic vortex into which dry ingredients can be added for quick wet-out. The disperser blade may be located on- or off-center depending on the depth of the vortex (an off-center blade produces a smaller vortex and reduces air entrapment). As the batch thickens or increases in volume, blade speed is adjusted to maintain the vortex and rate of material turnover. A few other basic guidelines are typically followed in the sizing and operation of the High Speed Disperser, including:

- Normal operating viscosity range: water-like to around 50,000 centipoise (cP)
- Motor specification: 1 HP for every 10 gallons of product
- Disperser blade diameter: approximately 1/3 of vessel diameter
- Disperser blade location: 0.5 blade diameter off the vessel bottom – 1.5 blade diameter below the liquid surface.
- Full holding capacity of mix vessel: at least 30% greater than the size of the batch to provide sufficient freeboard above the product level.

While many manufacturers still rely on High Speed Dispersers for pre-mix operations, a good number have started to integrate more powerful mixers that go beyond simple powder wet-out. The rationale behind this is if a pre-mixer is able to disperse agglomerates as close as possible to the desired specifications – in other words, mimic the early stages of milling – it can reduce the number of passes through the mill and even allow the use of smaller grinding media for milling finer solids. This presents an opportunity for a tremendous increase in efficiency as well as a reduction in cycle time. Some of these mixer alternatives include new-generation High Shear Mixers and Ultra-High Shear Mixers which are discussed in the following chapters.
**High Shear Mixers**

High Shear Mixers are rotor/stator agitators used for more challenging solid-liquid dispersions and emulsions which High Speed Dispersers cannot adequately process. This type of mixing device typically features a four-blade rotor turning at high speeds within a stationary stator. As the blades rotate, materials are continuously drawn into the mixing head and expelled at high velocity through the openings of the stator. The resulting hydraulic shear promotes fast homogenization, deagglomeration and emulsification. Rotor tip speeds between 3,000 and 4,000 ft/min are typical.

Because of the restriction provided by the stator, this mixer offers higher shear but less pumping capacity than an open-disc saw-tooth disperser blade. For the same reason, its viscosity limit is lower – around 10,000 to 20,000 cP.

Another distinction is that the rotor/stator mixer is available in both batch and inline (continuous) designs. An inline High Shear Mixer behaves like a centrifugal pump. It is not self-priming and requires static pressure (gravity-feeding) or positive pressure (pump-feeding) to introduce materials into the mix chamber. In most cases, gravity feeds product into the rotor/stator assembly as the mixer is typically positioned on the floor or on a platform below the liquid level of the recirculation tank. Standard inline models will easily move flowable products up to around 10,000 cP, depending on the formulation’s shear-thinning properties. With an auxiliary pump, moderately viscous coatings, pre-mixes and intermediates can be processed in a High Shear Mixer. For large tanks (>500 gallons), the inline configuration is often more practical compared to a batch rotor/stator mixer or other top-entering high-speed agitator which requires a high-horsepower motor and a relatively large blade to generate adequate circulation. An inline High Shear Mixer, on the other hand, can recirculate product through a 2,500-gallon stirred tank as easily as in a 25-gallon vessel. In fact, with appropriate piping, a single inline mixer can serve multiple batch tanks of various sizes. Typical installations utilize simple valves to divert finished product downstream or switch instantly from one source vessel to another.

When large amounts of powders need to be added quickly into liquid or when hard-to-disperse solids take too long to completely incorporate, a High Shear Mixer with built-in sub-surface powder induction capabilities is highly worth considering. Eductor-based powder injection systems, while effective in terms of eliminating floating solids and offering more precise control over the mixing process, do suffer from frequent clogging and intensive maintenance issues. In addition, these systems require an experienced operator to perform the often difficult task of balancing the performance of three separate devices in series: the eductor, pump and mixer. High Shear Mixers with an integral mechanism for powder injection are more reliable and easier to operate.
High Shear Mixers with SLIM Technology

Ross High Shear Mixers equipped with the Solids/Liquid Injection Manifold (SLIM) Technology offer a method of sub-surface powder induction that is more operator-friendly and easier to maintain than eductor-based systems. A key advantage to the SLIM design is that it does not require centrifugal pumps or eductors to create the suction for powder injection.

The SLIM features a unique rotor/stator capable of generating a powerful vacuum that draws and injects powders directly into the mixer’s high shear zone. Because solids and liquids are combined at precisely the point where intense mixing takes place, the formation of lumps and “fish eyes” is greatly reduced, if not eliminated. In a SLIM process, powders can be delivered to the batching tank in a way that reduces “dusting” (the release of airborne particles into the mixing area), giving way to simpler clean-up and faster changeovers. This is accomplished through the use of a hose & wand attachment — a flexible hose is connected to the solids inlet port and the other end, a stainless steel wand, is dipped into bulk bags or containers to conveniently induct lightweight powders without creating a dusty environment. Less problematic solids are fed into a hopper for rapid induction aided by gravity.

The SLIM Technology is available in both batch and inline designs which makes it simple to retrofit into most existing processes. It routinely handles solid loadings as high as 70%, depending on the application, while operating within a wide viscosity range: from water-like to up to 10,000 cP during powder injection.

**Batch SLIM.** As the rotor reaches operating speed, the SLIM valve is opened and powders are quickly drawn into the batch by virtue of the powerful vacuum generated by the ported rotor.

**Inline SLIM.** The liquid stream (1) enters the mixer and immediately encounters the powder injection (2) at the high shear zone of the rotor/stator assembly. The resulting dispersion (3) is expelled centrifugally through the stator openings at high velocity.

Some common powders injected through the SLIM:

- Acrylic Polymers
- Algimates
- Bentonite and Kaolin Clays
- Boric Acid
- Calcium Carbonate
- Carbomers
- Carbon Black
- Carrageenan
- Carboxymethylcellulose
- Dye Powders
- Flyash
- Fumed Silica
- Graphite
- Guar
- Gum Arabic
- Iron Oxide
- Latex Powders
- Magnesium Hydroxide
- Metal Chlorides
- Pectin
- Potassium Sorbate
- Precipitated Silica
- Pulp Dust
- Rosin Ester Resin
- Sodium Carbonate
- Sodium Gluconate
- Starch
- Talc
- Titanium Dioxide
- Xanthan Gum
Ultra-High Shear Mixers

In addition to eductor-less powder injection systems, other rotor/stator technologies have been developed to enable coatings manufacturers to wet out powders while also accomplishing some level of grinding and deagglomeration right in the same mixing vessel.

One such design is the Ross PreMax Ultra-High Shear Mixer, a top-entering batch mixer equipped with the patented “Delta” rotor/stator (US Patent No. 6,000,840). Supplied with a wear-resistant Stellite bushing, the rotor turns at tip speeds up to 5,000 ft/min and is uniquely contoured for high pumping capacity. Product is expelled radially through the stator slots at high velocity while new material is continuously being drawn from above and below the mix chamber. This generates upper and lower vortexes allowing for extremely efficient powder additions and rapid turnover rates. The PreMax is typically used as a stand-alone unit and does not require supplemental agitation for products up to 50,000 cP. For more viscous products, it can be used in combination with an anchor sweep or other type of low-speed agitator. The PreMax is also offered with a SLIM option for sub-surface powder injection.

This Ultra-High Shear Mixer has been shown to generate higher levels of dispersion than other batch-style mixers including saw-tooth blade type dispersers, traditional rotor/stators and immersion mills. Mixing in a PreMax produces results comparable to one or two passes through a media mill. Manufacturers are therefore able to achieve their target particle size distribution with fewer mill passes, and in some cases, eliminate milling entirely.

Sample Application:

A manufacturer of UV-curable coatings used to disperse titanium dioxide powders at 40% loading into a low-viscosity epoxy resin in a tank equipped with a high speed disperser. The rough dispersion was then pumped to a ceramic bead mill and milled for four hours before being transferred to a downstream holding tank. Simulation trials on a PreMax Ultra-High Shear Mixer revealed that the coating can be batched and finished in a single tank with no milling required. The Delta rotor/stator of the PreMax quickly wets out the pigment powders and, in 30 minutes, produces identical results as the previous milling process: a number 8 on the Hegman gauge or an “off the gauge” dispersion.

PreMax Batch Ultra-High Shear Mixer with “Delta” rotor/stator (US Patent No. 6,000,840).
Ross Series 700 Inline Ultra-High Shear Mixers

Ross also offers inline Ultra-High Shear Mixers capable of even more intense deagglomeration than the batch-style PreMax. These are the Series 700 Mixers which are available in three rotor/stator designs and designed to run at tip speeds over 11,000 ft/min.

The **X-Series** (US Patent No. 5,632,596) consists of concentric rows of intermeshing teeth. The product enters from the center of the stator and moves outward through radial channels. The combination of extremely close tolerances and very high tip speeds subjects the product to intense shear in a single pass. The gap between adjacent surfaces of the X-Series rotor and stator are adjustable for fine-tuning shear levels and flow rates.

The **QuadSlot** generator is a multi-stage rotor/stator with a fixed clearance. Capable of high pumping rates, the QuadSlot is typically used in general purpose applications where aggressive mixing is required but precise control of shear is not important.

The **MegaShear** (US Patent No. 6,241,472) is capable of the highest peak shear and throughput levels. Product is forced by high velocity pumping vanes into semi-cylindrical grooves in the rotor and stator. Multiple streams are induced within these grooves and collide at high speed before exiting the mix chamber.

Similar to a regular single-stage inline rotor/stator mixer, the Series 700 Ultra-High Shear Mixer behaves like a centrifugal pumping device. Materials are fed by gravity or pumped to the mixer. When an auxiliary pump is used, this machine can process viscosities up to around 200,000 cP.

Many manufacturers have successfully replaced high-maintenance high pressure homogenizers and colloid mills with an X-Series, QuadSlot or MegaShear. A comparably-sized Series 700 Mixer costs considerably less than a high pressure homogenizer while being less sensitive to clogging and changes in viscosity. In almost all applications, it delivers greater particle size reduction and throughput compared to a conventional colloid mill.
Multi-Shaft Mixers

Multi-Shaft Mixers equipped with two or more independently-driven agitators working in tandem are robust systems that deliver both high shear agitation and laminar bulk flow within a wide viscosity range: from water-like to several hundred thousand centipoise.

The simplest design is the Dual-Shaft Mixer which features a low-speed anchor and a high-speed saw-tooth disperser blade. The wings of the anchor agitator usually include adjustable scrapers for wiping the vessel bottom and sidewalls. This allows for tighter temperature control in addition to enhanced product turnover.

Another typical configuration is the Triple-Shaft Mixer which includes an additional rotor/stator assembly. This configuration is popular for formulations wherein the final particle size distribution is critical. As discussed earlier, using a saw-tooth blade to incorporate powders into liquid results in acceptable levels of dispersion but applying a more shear-intensive mechanism such as the rotor/stator mixing typically results in a finer and more uniform particle size distribution.

The SLIM Technology is an option available for Ross Triple-Shaft Mixers with a working capacity of 4 gallons and larger. During powder injection, the liquid vehicle must be under ~10,000 cP but after all the solids are added, product viscosity may continue to climb. The latter part of the mix cycle may rely on just the anchor agitator and disperser if product flow through the rotor/stator assembly becomes too restricted.

Aside from the improved capability of Multi-Shaft Mixers over single-shaft devices from a viscosity and heat transfer standpoint, another design advantage is that they are closed systems and can offer benefits in vacuum mixing. Processing under vacuum eliminates unwanted air voids that agitation under atmospheric conditions can produce but just as importantly, it helps certain formulations to develop higher densities and possess better properties as a result of improved shearing and contact of the different components.
SOME MULTI-SHAFT MIXER CONFIGURATIONS

Lab-scale explosion-proof Triple-Shaft Mixer, 2-gallon capacity.

50-gallon Dual-Shaft Mixer with a thermoprobe installed on the mixer cover.

Triple-Shaft Mixer with SLIM Technology. The 10-gallon mix vessel is supplied on a raised base.

1000-gallon Triple-Shaft Mixer with dual-post hydraulic lift.

Fixed-tank design 600-gallon Dual-Shaft Mixer supplied with VFD-driven pumps, high accuracy flow meters and PLC recipe system.
Planetary Mixers

Specialty paints, inks and coatings that undergo very high viscosity peaks (above 1 million cP) are better prepared in Planetary Dispersers and Double Planetary Mixers. These machines feature two or more blades which rotate on their respective axes while revolving around the mix vessel. In other words, all agitators continually advance into the batch and contact fresh product all the time.

Combining slow-speed planetary agitation with an orbiting high speed disperser, the Ross PowerMix Planetary Disperser (US Patent No. 4,697,929) quickly incorporates powder additions into a thick liquid base. Each agitator is independently controlled so flow patterns and shear rates are easily fine-tuned with every change in batch rheology. Since the disperser is constantly moving through product, the PowerMix is able to deliver shear to high viscosity materials with minimal heat build-up.

For very challenging formulations, a Planetary Dual Disperser may be utilized. This mixer consists of two disperser shafts (each having two saw-tooth blades) and two planetary stirrers.

The classic Double Planetary Mixer (DPM), on the other hand, is ideal for melting and kneading semi-solid materials or highly viscous pastes. While not considered a high speed mixer, the DPM is equipped with two identical stirrers which impart increasing levels of shear as the batch gains considerable viscosity. A common processing technique in this very robust machine is mostly high viscosity mixing to ensure satisfactory solids dispersion (from 2 million cP up to around 6 million cP), followed by a let-down step towards the end of the cycle.
MIXER SNAPSHOT:
100-gallon PowerMix Planetary Disperser Designed for Ink Production

Features:

• Working capacity: 40 to 100 gallons.

• Stainless steel 316 wetted parts.

• Viton elastomers.

• Liquid seal barrier protects the gearbox drive assembly from all product contact (particulate matter, dust, solvent vapors) and helps prevent cross-contamination from batch to batch.

• Mixer is supplied with two (2) interchangeable mix cans each featuring a 15-psig jacket, sidewall thermocouple and 4” flush tank ball valve.

• Rectangular Stirrer is driven by a 15 HP explosion-proof motor to 25 rpm.

• 12” Disperser Blade is driven by a 20 HP explosion-proof motor to 1400 rpm. The saw-tooth blade is adjustable anywhere along the disperser shaft to accommodate different batch volumes.

• Ross SysCon NEMA 7&9 Operator Station mounted to the mixer for starting/stopping the agitators, setting agitator speeds and viewing batch temperature. The 15 HP and 20 HP Variable Frequency Drives are mounted in a NEMA 12 Control Panel shipped loose for installation in a non-hazardous location and designed to work in conjunction with the local explosion-proof Operator Station.