Going to Extremes: When Size Matters More Than Chemistry

Viscosity, droplet, and particle size have a lot to do with how paint, water sealant and other coatings perform. Paints may need to go on thick. Pigment solids should be small and evenly dispersed. Monomer droplets need to be small and uniformly emulsified. In today's high tech coating applications, often it's only the smallest particle, the smallest droplet, or the most dispersed or homogenized liquid that meets manufacturers' requirements. In the case of paints, small, evenly dispersed pigment particles can mean higher particle surface area — therefore more brilliant color and a smoother finish. In the case of monomer emulsions, smaller droplet sizes can result in polymers that are stronger, more uniform, and more metallic in their appearance. That can mean higher gloss in finishes and top coats. Water repellents, meanwhile, should be as "thin" as possible so they will penetrate further into and bond tighter on the surfaces to which they are applied. Smaller particle (and droplet) size means the sealant can more easily penetrate wood and concrete porous surfaces and bond tighter to those surfaces.

In each case, the key to success is the manufacturer's ability to achieve extreme results — smaller, more uniform, more dispersed, etc. — in a process that is also cost-effective and reliable. Today's high value added applications not only have to push the envelope, they have to push it everyday.

Traditionally, paint companies were more limited in terms of how small, dispersed, or emulsified materials can be made. Changing chemical formulations to change viscosity or particle size often meant sacrificing other essential product characteristics. And mechanical-based strategies like grinding mills or homogenizers simply didn't work very well. Results were variable, weren't very scalable from the lab to the production floor, and opened the door to potential contamination from grinding media. Thanks to the Microfluidizer® processor, however, things are starting to change. Paint companies are achieving the extreme results they require — and also achieving some very successful products as well.

In paint performance, where pigments are involved, particle size is typically a key factor. When they arrive at the factory, pigments are typically packaged in 50 lb. drums with particle sizes of 50 microns and above. Even at this size, however, particles are small enough that they must be premixed — i.e. wetted with a surfactant so that they will not clump together when added to a carrier. They are also then run through equipment that mechanically disperses the particles in the premix and reduces the size of pigment particles even more. The smaller and more evenly dispersed the pigment particles, the higher the quality of the paint. Properties affected by the particle size can include the richness of the color, the smoothness of the paint, and even the drying time. A uniform dispersion also means that the entire batch will have the same consistency.

In finish and top coats, the goal is to create strong polymer chains. These products start as emulsions of small droplets of monomers in concentrates. The monomers at this point are in the form of very small molecular chains with an amorphous (i.e., irregular) structure. It is in the polymerization phase (through the addition of heat, pressure, and chemicals) where these monomers are transformed into the longer polymer chains that give coating products their durability and appearance. Successful polymerization, however, also depends on the size and size distribution of the droplets in the monomer concentrate prior to polymerization. Very small droplets (micron size and below) and more uniform droplets with higher surface area will produce a more efficient and effective polymerization reaction — i.e., longer, more consistent chains.

The key concept is this: Forcing two product emulsion (dispersion) streams against each other within a chamber of fixed geometry under constant pressure with high energy. We call this product collision technology.

In the production of water sealants, mechanical dispersion and particle size reduction is also an important part of the production process. Here, the issue may be reducing the size of the already-formed active ingredient and thoroughly dispersing the particle. This will result in better penetration of the sealant inside wood or concrete and a tighter bonding of the sealant with the material it is protecting.

In all three of these examples, the key issue for the manufacturer is this: for the properties I'm trying to achieve, how small should the particles (droplets) be? In working with dozens of paint and coating makers over the past 10 years, it is our experience that there is only one way to fully answer this question — trial and error. That implies that you are able to reduce the size of emulsion droplets and dispersion particles as much as you want — both during product development and then during manufacture. (So, it helps if the process you ultimately use on the factory floor is a straight scale-up of the one you used on the laboratory workbench.) How does this new class of mixers give you the required salability and control? The key concept is this: forcing two product emulsion (dispersion) streams against each other within a chamber of fixed geometry under constant pressure with high energy. We call this collision technology.

In Microfluidizer® equipment, a fluid stream of product material is divided into two paths, sent under extreme pressure through passageways of very small size (about the cross section of several human hairs) within an interaction chamber of fixed geometry. Here the streams smash against each other with incredible force. Given a pressure of 20,000 psi, forces can be on the order of $2x10^7$ watts/kilogram — and there is some product-collision equipment that can sustain pressures of 40,000 psi. Although particles and droplets colliding against each other is not the only force at work here. Other forces are the impact of the streams against the walls of the chamber and the shear of the streams against the walls of the passageways. Also a factor: the rapid acceleration of the product stream as it is forced through the small passageways (analogous to connecting a firehose to a straw). This acceleration causes a rapid lowering of pressure which creates bubbles in the product stream which then collapse — in other words, the acceleration causes cavitational forces. The fixed geometry of the interaction chamber and the passageways guarantees that not only particles (droplets) will be small but that size distribution will also be small and that the emulsion (dispersion) will be highly consistent. This is particularly important in the paint and coatings market where consistency is a major objective.

Using the product material itself as a collision medium has other benefits — one of which is that more of the energy can be applied to the product. By contrast, in a grinding mill a lot of energy is wasted moving the grinding media around. An even bigger advantage is in the time it takes to achieve these results — typically minutes to a few hours for Microfluidizer® processor technology versus multiple days for a grinding mill.

A similar situation exists in a traditional homogenizer, where the product is mixed at lower pressures as it is forced through a small opening and impacted against a valve that opens and closes in response to the force of the stream. The movement of the valve means that particle (droplet) sizes and particle size distributions are large. Minimum particle (droplet) sizes produced by conventional homogenizers fall in the range of 1 to 20 microns.

But homogenizers, grinders and other traditional mixing equipment have a more serious problem when it comes to high-performance paint applications — they can't achieve concentration of high energy that a product collision can with its fixed geometry and constant pressure. Less force means larger particles in suspension, less stability, and ultimately lower product performance.

When compared to traditional methods, the benefits of Microfluidizer® processor technology include:

- Much smaller particle and droplet size
- Much more uniform particle and droplet size distribution
- Faster processing times (> 2 orders of magnitude in some applications)
- Better control of the amount of energy applied
- Much higher energy (up to 40,000 psi sustained)
- Complete scalability from small batches to continuous production
- No moving parts
- Virtually self cleaning in many applications
- Virtually no contamination
- Uniform dispersions and emulsions
- Highly repeatable result from run to run or batch to batch

In summary, collision technology affects the material being processed in three ways. 1) by crushing forces of the material particles hitting each other; 2) by shear forces on the particles within the interaction chamber and 3) by cavitational forces due to extreme velocity and pressure changes in the material stream. Crushing forces are created (and doubled) by breaking the stream in two and redirecting it against itself.

All of these forces are the direct result of applied mechanical pressure — the amount of which can be easily adjusted simply by changing the pressure of the fluid stream. You might want to change the pressure and force of the fluid stream if you were processing more (or less) viscous liquids, or an application that called for more (or less) mixing or dispersing action. Regardless of the amount of force applied, however, the geometries of both the passageways and the interaction chambers remain fixed. All materials experience the same forces assuring the most uniform distribution of particle (droplet) size of any mixing process.

“Not only is product collision technology highly controllable, it is also extremely flexible . . .”

Geometry is not the only reason that forces can be large, uniform and constant. Another reason is the use of an intensifier pump. This is the pump that responsible for forcing the mixture through the microchannels and the interaction chamber. It can be driven by either air pressure or hydraulic fluid. A conventional piston-driven triplex pump applies force in a series of spurts in response to its push/pull cycle (in which a check valve prevents the fluid from going backward in the pull part of the cycle). By contrast, an intensifier pump applies a constant pressure throughout its complete cycle. Furthermore, this process can be easily adjusted simply by incrementally (and with great accuracy) adding or subtracting pneumatic or hydraulic pressure. And even though intensifier pumps can be set to a broader range of pressures than conventional pumps, once set, their pressures stay constant over the entire process stroke.

A Strategic Weapon

Not only is Microfluidizer® processor technology highly controllable, it is also extremely flexible — allowing manufacturers to tackle a range of applications almost as broad as the paint and coatings market itself. Flexibility is possible due to the extreme pressures achieved (up to 40,000 psi sustained) and extreme particle size reduction (less than a micron).

Consider the variety of just these three scenarios:

• A water sealant manufacturer wants to reduce the size of the special wax in its product formulation — thereby allowing the protectant material to better penetrate wood and concrete and form tighter bonds while changing from a solvent to aqueous carrier.

• A maker of ink jet inks needs to produce dispersions containing extremely small and uniform particles of carbon black capable of being propelled through 1800+ dpi ink jet print head.

• A maker of high-performance clear coatings for cars needs extremely high gloss and high brightness. Reducing size of monomers in suspension will allow subsequent polymerization to form extremely uniform and durable polymer chains.

You may wonder, when looking at these, why we don't mention the companies names. The answer is we can't — our customers who use this technology consider it their "secret weapon." In the paint and coatings business, the ability to control particle size in a dispersion or droplet size in an emulsion is a major competitive advantage.

Microfluidics™

30 Ossipee Road
Newton, MA 02464-9101 USA
617-969-5452
800-370-5452
Fax 617-965-1213
info@mfics.com
www.microfluidicscorp.com
A DIVISION OF MFIC CORPORATION

European Office
c/o Freudenberg, Bau 42
Höhnerweg 2-4
D-6945 Weinheim, Germany
+49 (0) 6201-80-6670
Fax +49 (0) 6201-88-6679
microfluidics@t-online.de
www.microfluidicscorp.com