Choosing the right mixer: Six factors to consider

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If you want to avoid mixing problems like material degradation, poor mixture quality, time-consuming product changeovers, and high operating costs, you need to select a mixer that's suited to your material and process requirements. The six selection factors covered in this article can help you make the right mixer choice.

Often more than one type of mixer can handle your application. But how do you choose the best mixer for the job? Before starting the selection process, you need to decide what your mixing process must achieve. This requires considering not only the characteristics of the materials you'll mix, but your process and production conditions and requirements. The following sections cover this information in the form of six factors to consider when choosing a mixer.

1 Consider your material characteristics

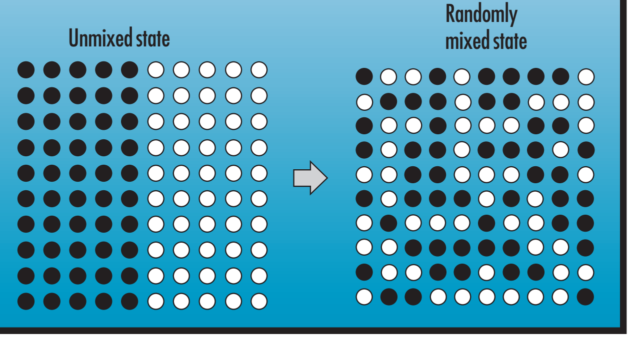
Your materials can have low or high particle strength and any of several flow characteristics. These characteristics will help you determine which mixing scale — macro or micro mixing — is best for your materials. [***Editor's note:*** Describing individual mixers is beyond the scope of this article; for more mixer information, see the later section "For further reading."]

Macro mixing. Free-flowing, coarse materials with a mean particle size greater than approximately 75 microns are typically best suited to macro mixing, also called *convective mixing* or *low-shear mixing*. Macro mixing transfers the material from one mixer location to another during processing. As the mixing progresses, the mixture becomes more randomly ordered. Eventually, the mixture reaches a randomly mixed state and is considered a well-mixed product, as shown in Figure 1.

Free-flowing materials are well-suited to macro mixing because they have minimal interparticle forces and are considered relatively easy to mix. Putting the particles in motion during mixing requires low energy input, and the particles can quickly reach an optimal mixed state.

Figure 1

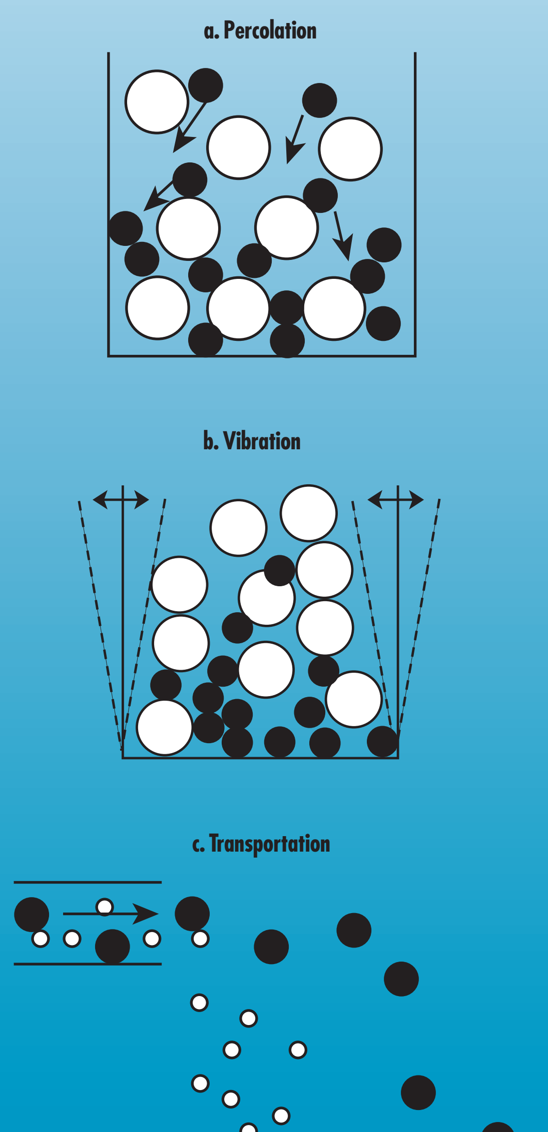
Macro mixing progression



However, the final macro-mixed product isn't consistent or stable. Differences in particle size, shape, and density can cause the mixture to segregate during mixing or discharge. The segregation mechanisms typically are percolation, vibration, and transportation, as shown in Figure 2. In *percolation segregation* (Figure 2a), gravity causes small particles in a packed powder bed to sift downward through the voids between large particles, which is more likely when the particles have widely different sizes. In *vibration segregation* (Figure 2b), small particles in a vibrating powder bed gradually settle below the large particles. In *transportation segregation* (Figure 2c), differences in particle trajectories, caused by size, shape, or density differences in the particles, separate the particles during discharge or conveying.

Figure 2

Segregation mechanisms



Micro mixing. More consistency and stability in the final mixed product can be achieved with finer, more cohesive materials. In fact, this benefit is driving the increased use of cohesive materials — those with particles smaller than 75 microns or that contain a liquid binder — in mixing applications. However, because these materials have strong interparticle forces that tend to produce agglomerates, they're more difficult to mix. When macro mixed, such fine, cohesive particles form agglomerates, as shown at the left in Figure 3, that can't be broken up by the method's mild transportation mechanism. This prevents the particles from becoming randomly mixed. Instead, these fine particles are best handled by micro mixing, which applies impact or shear to intensify mixing and minimize agglomerates, as shown at the right in Figure 3.

In most micro mixing equipment, called *intensive mixers,* impact-force devices such as knives or other sharp-edged elements break up the agglomerates, as shown in Figure 4. The devices can quickly and efficiently distribute the cohesive particles. However, because the impact-force devices simply cut the agglomerates into pieces, the fine particles from the broken agglomerates can easily form other agglomerates or randomly adhere to other particles.

Other micro mixers for cohesive powders use high shear force at a relatively low speed to move particles with a rolling motion, as shown in Figure 5. The particles' rolling motion deforms the agglomerates, causing them to break up and allowing the fine particles to directly encapsulate the larger rolling particles. This creates a nearly ideal mixing distribution. High-shear mixing is especially well-suited to achieving high-quality mixtures of fine cohesive powders, such as pigments, flow agents, or active ingredients. In pigment-mixing applications, for instance, high-shear mixing makes the final pigment color more intense. Higher-shear (called *ultrahigh-shear*) mixing can be used for mechanochemical processing and for producing advanced materials, such as nanopowders and special alloys.

Figure 3

Micro mixing to break up agglomerates

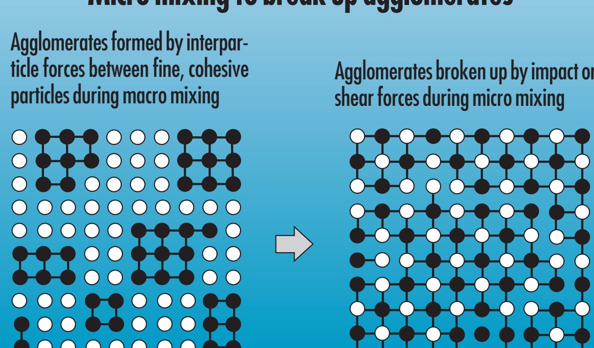


Figure 6 compares mixing results for macro (convective) and micro (intensive — impact, high-shear, and ultrahigh-shear) mixing.

2 Consider your process conditions and requirements

Because your mixer will be an integral part of your process, you need to consider how it will fit into your production line and what process conditions and requirements will affect it.

Safety. To avoid exposing your workers to hazardous conditions, make safety your top priority as you select the mixer and integrate it into your process. Determine how well the mixer's design and construction comply with safety regulations in your area and how the mixer can contribute to or limit dust explosion risks in your process. If your material or process is hazardous, consider how well the mixer will handle your material's hazards (such as toxicity or explosivity) or limit the potential for hazardous emissions. Also find out whether the mixer generates heat or pressure during mixing and whether the mixer uses any gas or solvents that can increase emissions or ignition risks.

Feeders. Although it may seem unrelated to mixer selection, choosing feeders that can accurately charge raw materials into your mixer is critical to mixing success. Off-spec raw material ratios in the mixer will always result in poor mixture quality. Accurate feeders can ensure that your mixer contains the correct amount of each material before mixing starts. As part of choosing your mixer, select feeders that are suited to handling your raw materials'

Figure 4

Knives applying impact forces to break up agglomerates during micro mixing

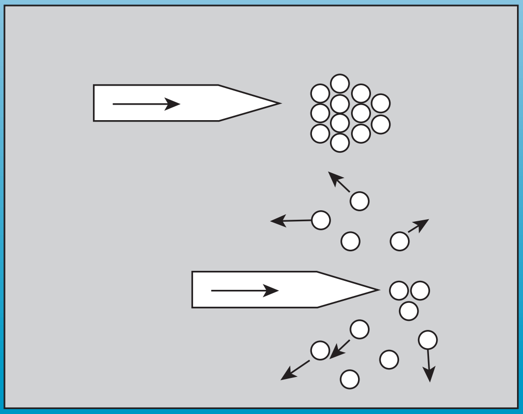


Figure 5

High shear force moving particles with a rolling motion to break up agglomerates during micro mixing

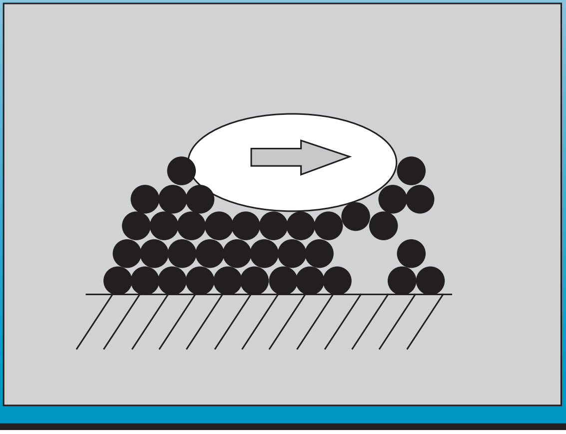
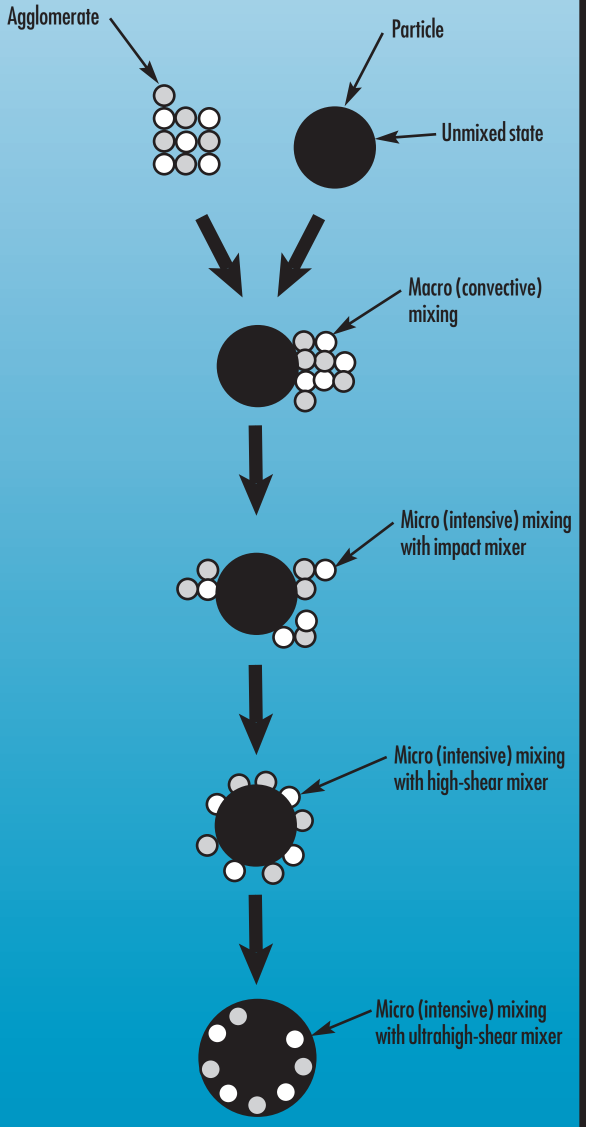


Figure 6

Comparison of mixing results for macro and micro mixing



flow characteristics and that can control feeding with the accuracy your mixture requires.

Operating mode. Deciding whether your mixer will operate in batch or continuous mode depends on several factors. While your required production capacity is the first factor to consider, in general, the more demanding your mixing requirements, the more likely you'll need a batch mixer. Consider these items when choosing the operating mode:

- *Capacity:* If your process will produce less than 1 ton of material, choose a batch mixer.
- *Regulatory requirements:* You'll need a batch mixer to comply with recipe-reporting rules in some industries, such as pharmaceuticals or foods.
- *Microingredients:* Choose a batch mixer if your final mixture will contain very small quantities (less than 1 percent of the total quantity) of several additives.
- *Flexibility and cleanability:* If you'll mix a sanitary product or make frequent product changes, choose a batch mixer. It's easier to empty and clean, and unlike a continuous mixer, it won't be connected to upstream or downstream equipment that also must be cleaned.

Combining process steps. Some mixers can combine mixing with other process steps, such as grinding, drying, coating, and liquid addition. For instance, adding lump breakers or intensifier bars to the mixer can allow it to mix as well as reduce particle size. A conical screw mixer can be equipped for both mixing and vacuum drying, and a high-shear mixer is often equipped to both mix and agglomerate powders. If your final product requires process steps in addition to mixing, you can simplify your process and minimize material handling in your production line by choosing a mixer that can handle the steps.

Capacity. Your desired production capacity compared with the total mixing time is also a factor in picking a mixer. The time it takes to load the raw materials into the vessel, complete the mixing cycle, discharge the final mixture, and clean the mixer can be relatively long or short, depending on the mixer. Be sure to evaluate the mixer based on how these time requirements will affect your desired production capacity.

3 Consider the mixer's cleaning requirements

In some industries, a mixer requires only infrequent cleaning. In others, a mixer must be cleaned regularly to maintain high product quality or provide processing flexibility for multiple formulations. To choose a mixer for a frequent-cleaning application, focus primarily on how easily and quickly the mixer can be cleaned. Better yet, choose a mixer that can help you avoid or minimize mixer cleaning. Such a mixer has a vessel design, surface finish, mixing-element-to-wall clearance, and seal design that minimize material buildup and facilitate fast, easy cleaning.

If your process requirements and material characteristics make it impossible to avoid mixer cleaning, choose a mixer that allows you to use the fastest, most effective cleaning method. Mixer cleaning can be done manually or automatically, by dry methods (using gas flow, brushing, vacuum, or ultrasonics) or wet methods (using water, solvents, disinfectants, steam, or ice to wash the mixer down). Cleaning devices such as stationary or rotating nozzles for spraying gas or liquids into the mixer are usually integrated into the mixer vessel or cover. In some cases, a more costly retractable cleaning lance is designed to fit more than one machine so that an operator can move it from one to another when cleaning is required.

Manual or automatic wet cleaning produces waste liquid that's contaminated with your final product and cleaning chemicals. Because environmental regulations require that you recycle this liquid or treat it so it can be safely discarded, it's best to choose a mixer that allows you to control the amount of waste liquid produced by wet cleaning.

Automated dry and wet cleaning can automatically control and even validate the cleaning cycle and minimize waste product and liquid. For instance, you can use a robotic, programmable cleaning system to clean a mixer with a complex interior geometry. Such a system can provide gas or liquid cleaning in many vessel types, and the gas or liquid flow can be adjusted to match the mixer's contamination level so that cleaning doesn't create excess waste.

Consider how much waste product a mixer will generate, how you'll need to handle the waste, and how much cost this may add to your process. For instance, if a batch mixer will repeatedly make similar batches, often any product residue remaining in the mixer can be left and mixed into the next batch without affecting mixture quality. In some applications, such as pharmaceuticals, the mixer must be completely cleaned, and you must either recycle the waste product back into your process or discard it, which increases the mixer's operating costs.

4 Consider your required mixture quality

Consider these basics when determining which mixer will provide the mixture quality and accuracy you need:

- Mixture quality is measured by more than the mixture's "deviation from the optimum" distribution of different materials in the batch. Depending on your product, the final mixture's flowability, smell, texture, and color can be just as important.

- Not all mixtures require nearly perfect mixing precision. For instance, a mixed product that will be discharged into a process in a larger volume, such as a bulk bag, doesn't require high mixing accuracy.

- While mixture quality is often measured by taking samples from inside the mixer, the mixture's quality when it's inside the mixer isn't necessarily the same as its quality after discharge. Regardless of which mixer you choose, you'll need to closely monitor the mixture's discharge characteristics to detect and avoid segregation as the mixture exits the vessel.

- When taking mixture samples, remember that there's a direct relationship between the required mixture quality and the correct sample size. For instance, consider what mixture quality you will find if you take a 1-liter sample of a 1-liter batch containing 18 powder ingredients. Because the sample is so large, it will indicate that the mixture is nearly perfect, regardless of the true mixing results. Taking smaller samples or samples close in size to the final product's size — such as 400-milligram samples from a pharmaceutical mixture that will be pressed into 400-milligram tablets — will provide a much more accurate measure of your mixture quality.

5 Consider how to control temperature rise in the mixer

One factor that's commonly overlooked during mixer selection is product temperature rise during mixing. Part of the energy input required for mixing will cause the product temperature to increase. In some cases, the mixing process is designed to make use of this temperature rise. But often the temperature rise is an unwanted outcome of the mixer's operation, and it can lead to material degradation, such as melting, or even ignition.

Because the greater the mixer's mixing energy, the faster the temperature rise, it's especially important to consider temperature rise when selecting a micro (intensive) mixer. In a high-shear intensive mixer, temperature rise is especially hard to avoid, making temperature control critical in this unit.

Although a macro (convective) mixer generally uses the least mixing energy, this mixer has a large volume that can lead to more intense reactions. Often, this makes uncontrolled temperature rise more risky in a convective mixer than in an intensive unit. In a convective mixer, heat is frequently generated in areas where added friction occurs between bearings or in seals where product residue accumulates. Ways to help control this problem include selecting a mixer with seals and bearings above the product level in the vessel, using air-lubricated mechanical seals in the mixer, and reducing the mixing element's rotation speed.

6 Consider the mixer's operating cost

Pay attention to factors that will contribute to the mixer's operating cost, and keep these in mind to select a mixer that will operate economically in your plant. The factors include:

- Power consumption.
- Required number of operators.
- Maintenance costs.
- Scheduled and unscheduled maintenance downtime and subsequent production losses.
- Supplier's technical service capability and availability and spare parts availability.
- Cleaning costs (for the mixer alone if it's a batch unit, or for the mixer and upstream and downstream equipment if the mixer is continuous).
- Quantity of waste product between batches.
- Mixer's predicted service life.
- Mixer's residual value after its predicted service life ends. (Although your mixer's book value will probably be zero 7 to 10 years after you buy the unit, changing out the machine's wear parts — belts, bearings, seals, rotor, and mixing elements — can keep it operating for many more years.) **PBE**

For further reading

Find more information on mixers in articles listed under "Mixing and blending" in *Powder and Bulk Engineering*'s comprehensive article index at www.powderbulk.com and in the December 2003 issue.

Additional sources include:

N. Harnby, *Mixing in the Process Industries,* Butterworth & Heinemann, 1992.

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