Answers to some common mixing questions

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Mixing dry powders thoroughly but efficiently is a challenge in many bulk solids processing plants. In this article, a powder technology professor gives practical answers to questions he's often asked about mixing problems.

If you're concerned about whether you're adequately mixing your dry ingredients, how your mixer's design and operation affect your mixing efficiency, and how to keep your final mixture well-blended after it leaves your mixer, you're not alone. Find practical information on these and other common mixing topics in the following sections.

Q *Is my mixing time too long?*

A It's surprising how often mixing practitioners are unable to give an objective reason for why they use a given mixing time in a process. Usually, a particular mixing time — say, 20 minutes — is used because it's always been used with that mixing process, not because there's any underlying scientific basis for such a mixing time. To compound the problem, many mixers don't have a sampling port — a critical component for monitoring mixing progress. The result is that very few people monitor their mixing rate as processing continues.

The good news is that if you do monitor the rate at which your powders are mixed, you may be able to cut your mixing time by a factor of at least 2, which will prevent overmixing and speed your process. The ability of effective monitoring to reduce mixing time was demonstrated in a recent study in which a sample of a proprietary explosive powder mixture was taken from a paddle mixer for analysis during the mixing cycle.[1]

In the study, the mixer was stopped halfway through the cycle, and a pneumatic sampling lance, as shown in Figure 1, was inserted through the mixer's access door to remove a sample from the mixture.[2] The sampling lance consists of two concentric tubes, one inside the other. As the lance is inserted into the mixture, air flows at low speed through both tubes into the material. This facilitates the lance's movement to the desired location in the mixture and, by preventing the lance from disturbing or compacting the material as it's inserted, helps ensure that the sample will be representative of the mixture. Then the airflow through the central tube is reversed and its velocity is increased so the airflow can withdraw a sample of material from the mixer. The sample enters the central tube and is stopped by a filter, which allows only the air, not the particles, to flow back out of the tube. The filter can be moved up or down the tube to adjust the sample volume. After the sample is taken, the lance is withdrawn from the mixer, and air continues to flow back up the central tube during this process to keep the sample in place. Then the airflow through the central tube is reversed to discharge the sample for analysis in a particle sizing instrument.

The sample volume for the study was 1.0 gram, and the sizing instrument was an aerosol spectrometer.[3] The instrument produced particle size data in about 1 minute, which allowed the researchers to quickly decide whether the mixing process needed to continue.[4] The size data indicated that the sample was adequately mixed just halfway through the mixing cycle, so the mixing was stopped, cutting the total mixing time in half.

Q *Is there enough room in my mixing chamber to provide turbulent particle movement for efficient mixing?*

A To some extent, it depends on your mixer and application. In the food industry, mixture homogeneity isn't always critical. For instance, a cake mix must have a uniform texture, but this requires less homogeneity than a typical pharmaceutical mixture that contains a tiny amount of an active drug. The pharmaceutical mixture must be very homogeneously mixed to ensure that each of the small final tablets contains the right amount of the drug. So in pharmaceutical and other applications requiring maximum homogeneity, a mixing chamber with enough room to allow turbulent particle movement is critical.

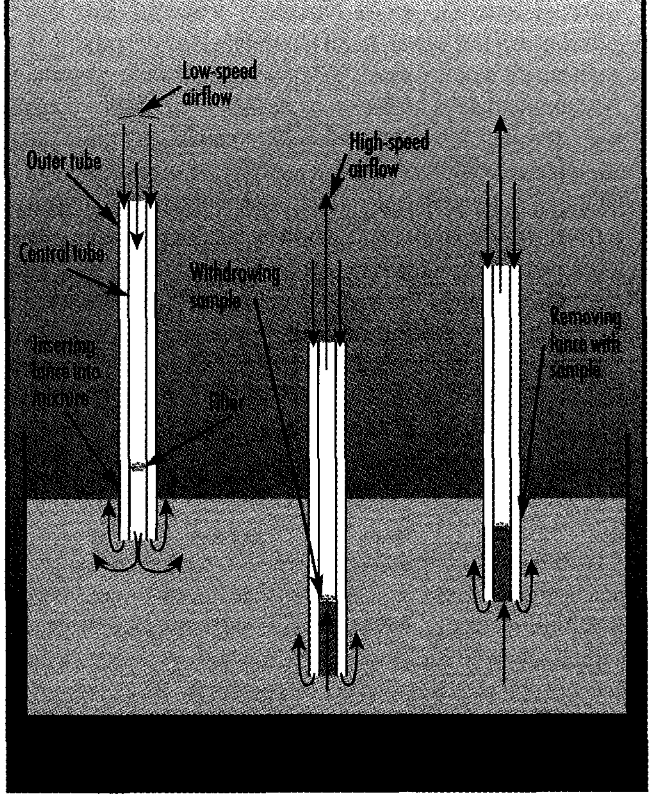
A ribbon mixer is often used to mix foods and other products with less stringent homogeneity requirements. The mixing chamber is typically three-quarters full of material, which prevents particles from moving rapidly and randomly inside the chamber. The mixer has a horizontal, stationary, trough-shaped vessel and an internal rotating shaft that's mounted with ribbon-like blades. The ribbon mixer's action produces a somewhat leisurely, continuous folding-in of the ingredients, which is well-suited to applications requiring less thorough mixing.

By contrast, the V (also called *twin-shell*) blender, as shown in Figure 2, is typically used for mixing very homogeneous foods and other products. It has a V-shaped vessel that rotates (Figure 2a), and the mixing chamber is typically less than half full of material. This allows more room for fast, random particle movement. When the blender turns over, the falling particles intermix in a turbulent motion (Figure 2b), ideally creating a transient fluidized bed.

You can further improve the V blender's efficiency by adding *randomizing rods* (Figure 2c) to the vessel. During mixing, particles contact and are deflected by the rods, adding to the turbulent motion. However, the number of rods you can add is limited by your cleaning requirements: The more rods, the more difficult the blender will be to clean. If you will frequently change products and must prevent cross-contamination, use fewer rods to avoid major cleaning costs and long production delays.

Figure 1

Pneumatic sampling lance's operation[a]



Q *Can premixing some of my ingredients improve my mixing efficiency?*

A Because ingredients in a mixture can segregate when the mixture is moved, try to mix ingredients with similar particle sizes. An ingredient whose particle size differs from the other ingredients' particle sizes by a ratio greater than 1:3 can cause segregation. For instance, at a 1:9 size ratio, chronic segregation occurs as the smaller particles sift downward through the mixture when it's moved.

For some applications, such as pharmaceuticals, a random mixture may not be intimate enough.

Depending on your application, you sometimes can prevent segregation by premixing the finer ingredients and then granulating them by adding a liquid to them with a spray bar. This forms larger-size particles that more closely match the particle size of the mixture's other ingredients. For instance, in a cement mixing process, small amounts of very fine hardening agents had to be added to coarse ingredients to produce an industrial cement mixture. To prevent segregation, the finer ingredients were first granulated in a small offline mixer and then added to the larger mixing process.

Sometimes you can prevent segregation by purchasing ingredients that have more suitable particle sizes. For instance, your material supplier may be willing to separate a material into fine and coarse fractions so that you can purchase the coarser material for your mixture. This also allows the supplier to sell the finer material at a premium price. Or you can create particles of uniform size by microencapsulating coarse particles with fine particles by one of various methods.[5]

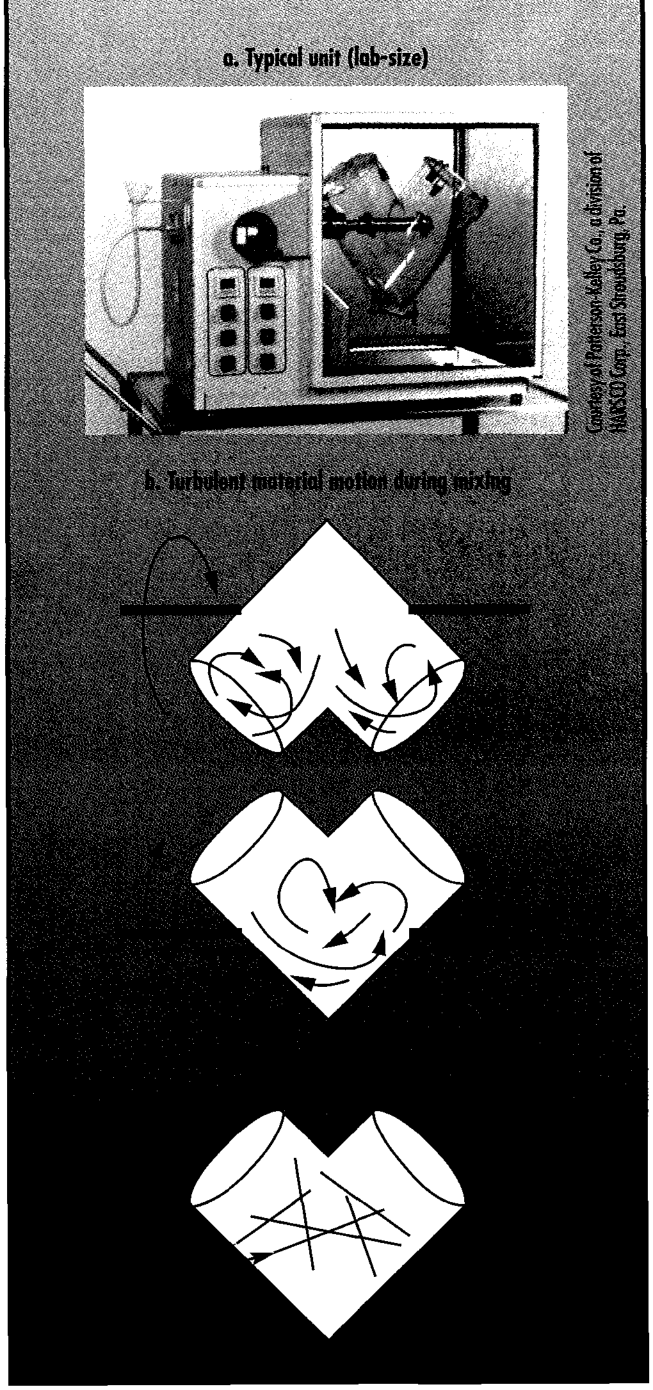


Figure 2

V blender

Q *How can my mixer achieve the intimacy my mixture requires?*

A The level of intimacy (that is, extreme homogeneity) your mixture requires depends on the scale of inspection your final product will be subjected to. For instance, premixing color ingredients for a plastic molding mixture requires intimacy at a level where ingredients are intermingled at the scale of the ingredients' particle size: This will produce final molded products of uniform color. Achieving this level of intimacy means the premix must be blended in a mixer that achieves a high shear rate in some zone of the mixer.

In some cases this high intimacy level can be achieved in a ribbon mixer by reducing the ribbon-to-wall clearance to create a narrow shear zone between the ribbon and the mixer wall. However, processing the whole mixture through this narrow zone can be time-consuming. Instead, it may be better to premix the ingredients in a V blender, which can provide primary randomization for the ingredients, and then discharge the mixture to a pin mill. In the pin mill, pins mounted on the mixer's rotating shaft create a high shear rate that can produce the required mixture intimacy.

You need to recognize that such mixture intimacy can't always be achieved in your available processing time or your mixer, so you may have to live with slight consistency variations between batches. In a case where slight variation isn't acceptable, you can blend a premix at a high shear level. For instance, to produce a color premix for a plastic molding mixture, you can blend the color premix ingredients in a mulling mixer. In this mixer, large rotating wheels and a set of scrapers compress the material against the pan-shaped vessel's bottom, producing very high shear for maximum intimacy. Then you can mix small quantities of the color premix into a large quantity of the plastic molding mixture for each batch of plastic products to ensure that the products have consistent color.

Q *Is a random mixture good enough?*

A In a random (or *randomized*) mixture, ingredients are distributed in a random way so that, by chance, some particle clusters of an ingredient will exist in the mixture, making it less homogeneous. Even when you mix at a high shear rate, at best you probably will achieve only a random mixture.

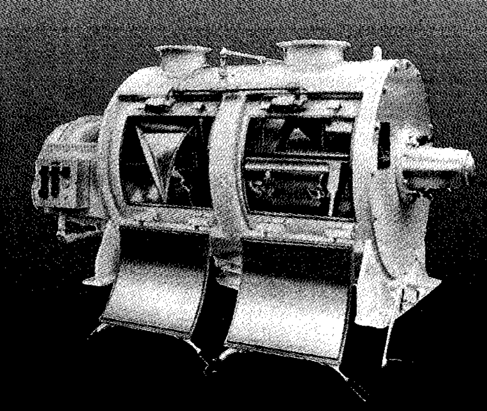
For some applications, such as pharmaceuticals, a random mixture may not be intimate enough. In this case, you must achieve a structured mixture, in which the particle-to-particle structure ensures high intimacy. This can be accomplished in one of two ways: You can microencapsulate a coarse ingredient with fine ingredients, or you can choose ingredients so that one ingredient will be attracted to another by electrostatic forces generated when the particles rub against each other during mixing.

Q *How can I prevent my mixture from segregating as it exits the mixer?*

A Discharging or loading a finished mixture can cause the ingredients to segregate. In one recent case, a food powder mixture was efficiently mixed in a high-speed paddle mixer, as shown in Figure 3, in which rapidly rotating paddles created a fluidized zone. After mixing, the food powder was discharged through a wide chute to a packaging machine on the floor below. The powder was to be packaged in 1-ounce packets. However, air currents in the chute segregated the powder as it flowed downward, causing fines to build up near the packaging machine's inlet. The result was that the final 1-ounce packages didn't contain the right proportion of ingredients. To solve this problem, the mixer was moved to the same floor as the packaging machine so the final mixture flowed over a shorter distance, eliminating the opportunity for ingredients to segregate before packaging.

Figure 3

High-speed paddle mixer



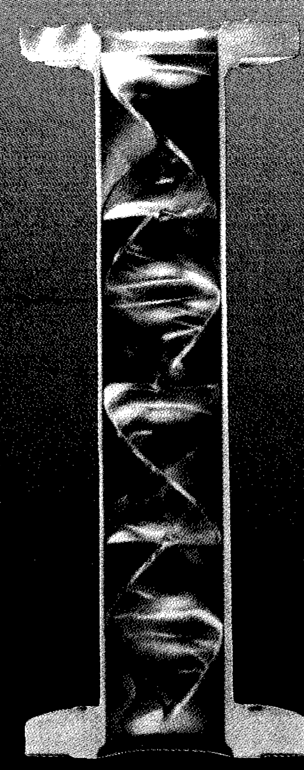
Another way to prevent your final mixture from segregating is to discharge the mixture from your dynamic mixer to a passive (also called *static*) mixer. A typical passive mixer is shown in Figure 4. In operation, the mixture enters through the top inlet, and as it flows downward through the mixer toward the outlet, baffles inside the vessel slow down and randomize the particles' positions. Choose a passive mixer suited to your cleaning requirements; some passive mixers have complex baffle structures that are difficult to clean between batches.

Q *Is my mixture an explosion hazard?*

A The bulk solids industry keeps developing finer and finer powders, and this increases the potential for explosions created by powders suspended in air. If you handle a new, finely dispersed powder, especially a metal or pharmaceutical powder, have it analyzed by an explosion safety lab. The lab can determine its explosion hazard potential and determine what safety precautions you need to take to safely handle the powder in your plant.[6] **PBE**

Figure 4

Passive mixer



References

1. B.H. Kaye, C.G. Clark, and J. Bohan, "Monitoring mixer performance using the size distribution information on samples taken from a mixing process," *Proceedings of Fine Powder Processing '99,* Pennsylvania State University, University Park, Pa., September 1999.

2. This sampler is not currently commercially available; contact the author for more information.

3. Aerodynamic Particle Sizer aerosol spectrometer, TSI Inc., St. Paul, Minn.

4. B.H. Kaye, M. Fairburn, and K.A. Hood, "Efficient sampling protocols," *Proceedings of the Powder & Bulk Solids Conference 2000,* Rosemont, Ill., May 2000.

5. B.H. Kaye, *Powder Mixing,* Chapman and Hall, London, 1997.

6. Find specific testing information in the article "Testing to assess your powder's fire and explosion hazards" by Dr. Vahid Ebadat in *Powder and Bulk Engineering,* January 1994, pages 19-26.

For further reading

Find more information on mixing in articles listed under "Mixing and blending" in *Powder and Bulk Engineering*'s comprehensive "Index to articles" (in the December 2001 issue and at www.powderbulk.com).

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