In previous “Mixing mechanics” columns, I’ve discussed aspects of mixing related to the dispersion (or distribution) of ingredients throughout a bulk solid blend and how to achieve a homogeneous blend relative to a certain sample size. I’ve focused on the blend’s degree of compositional variability as a function of its location in the mixer and assumed that the particles themselves remained unchanged during mixing. In doing so, I’ve paid little attention to a class of mixing phenomena called **micromixing**, in which the mechanical energy applied during mixing changes the characteristics of individual particles in the blend.

Micromixing can refer to a range of mixing phenomena, including:
- Particle attrition or breakage
- Softening of low-melting-point ingredients
- Changing of particles’ crystalline form or changing from crystalline to amorphous particles
- Coating of small particles of one ingredient onto large particles of another ingredient (called dry coating or ordered mixing)
- Particles acquiring electrostatic charge
- Moisture evaporation or transfer between ingredients
- Agglomeration during flow due to one of the preceding phenomena

Micromixing can change a blend’s overall properties and behavior, often causing unwanted effects that become evident during processing. Dry coating and electrostatic charge acquisition can significantly change a blend’s flowability, resulting in material sticking to metal surfaces and caking or the sudden occurrence of lumps with a different composition than the blend as a whole. Dry coating can cause the blend as a whole to become more or less hydrophobic depending on whether the small particles coating the material are hydrophobic or hydrophilic. This might cause the blend to behave differently during subsequent processes that utilize moisture, such as wet granulation, pharmaceutical tablet coating, or product dissolution. Dry coating can also affect a blend’s bulk density or compactability. For example, extensive dry coating by a low-melting-point ingredient, such as magnesium stearate (a common lubricant), can cause a blend to generate weak interparticle compacts that break or delaminate easily.

While these effects of micromixing are quite different from each other, they all share some characteristics. Each is strain-dependent, meaning that the effect is often proportional to the total amount of mechanical energy per unit mass applied to the material. Some of these effects require a minimum shear rate to occur because a certain level of mechanical stress is necessary to break, soften, or otherwise alter the particles. As a result, micromixing is also strongly scale-dependent, and the effects all tend to intensify in larger-scale equipment, where shear rates and strain levels are higher.

Micromixing is important from both a process development perspective and a product quality perspective. In many applications, micromixing is beneficial (or even necessary) to produce a final product with the desired characteristics. Multiple ingredients are often simultaneously milled, for example, to achieve intimate contact between ingredients, and many additives, such as lubricants, glidants, anti-statics, and powder surfactants, require controlled application of shear to achieve their effects.

More commonly, however, micromixing is unanticipated and can lead to an undesirable product outcome. Minor changes to environmental conditions, ingredient properties, equipment details, and other factors can cause unwanted micromixing in a previously successful blending operation. Despite its ability to affect a blend’s final characteristics and quality, micromixing hasn’t been extensively studied. In fact, most bulk solids processing equipment isn’t even equipped with sensors enabling the operator to determine the shear rate or mechanical energy being applied to the material.

If your blend is exhibiting signs of unwanted micromixing, ask yourself:
- Are you applying high levels of strain at high shear rates? Answering this question often simply requires a fresh-eyes examination of your process flow chart. It’s usually easy enough to recognize if any process components are beating up the powder.

The following processes typically apply enough mechanical energy or a high enough shear rate to cause significant micromixing:
- All dry mills, which by definition must apply a high enough shear rate to reduce the material’s particle size
- Convective blenders equipped with moving blades, where the material experiences a long processing time (such as ribbon blenders, sigma-blade blenders, and others)

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**Practical powder blending: Micromixing**

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• Tumblers with intensifier bars that rotate at high speed (such as V-blenders and double cones)
• High-shear granulators used in dry mode to blend powders
• Feed frames in tablet presses, where the particles are sheared under normal compression
• Very large rotating blenders (>100-cubic-foot capacity), where the processing time is long (>400 blender revolutions).

In each of these processes (and many others, as well) a large amount of mechanical energy per unit mass creates shear stress and friction between particles and between particles and equipment surfaces. The friction and shear stress converts this mechanical energy into chemical, electrical, and heat energy, which, depending on the blend’s composition and particle size distribution, may cause one or more of the micromixing effects discussed earlier. The material shown in Figure 1a, for example, has acquired electrostatic charge as a result of extensive shearing in the hopper of a gravimetric feeder and is sticking to the metal feeder spout.

To confirm whether your blend’s problem is being caused by micromixing, subject a small blend sample to increasing amounts of shear (in a small-scale V-blender equipped with an intensifier bar, for example). After each blending cycle, test the sample for relevant properties (such as bulk density, flow, wettability, compressibility, and particle size). If you detect significant and relevant changes as the shear increases, you likely have a shear-sensitive material in your blend that’s reacting adversely to your process. Such materials include low-melting-point powders such as magnesium stearate, unstable hydrates such as lactose, micro or nano-agglomerates such as fumed silica, and weak, friable granulations.

Solving an unwanted micromixing problem caused by shear typically involves either replacing a shear-sensitive ingredient with a new ingredient capable of handling your current process or redesigning your process steps to better control shear. Many processes unnecessarily apply high levels of strain at high shear rates, either because of legacy issues (such as using the equipment available at the time of installation rather than tailoring the equipment to the specific application) or because the process was scaled up without paying proper attention to the effects of shear.

In such a case, the operator needs to carefully diagnose the situation to implement an effective remedy, which may also involve micromixing. Figure 1b shows the same material as Figure 1a, but this time the material has been premixed under high shear with a glidant. The glidant has dry coated the other ingredients, improving the blend’s flow and electrostatic properties, resulting in a much more controllable process and a dramatic decrease in the amount of material sticking to the spout.

By controlling the micromixing process, you can impart blends with desired flow and antistatic properties, hydrophobility, and other characteristics. This requires a functional understanding of how shear affects a blend, so you can apply shear at a rate and amount that will reliably produce a final product with the desired properties.

Fernando J. Muzzio is director of the National Science Foundation’s Engineering Research Center on Structured Organic Particulate Systems (http://ercforsops.org/) and Distinguished Professor, chemical and biochemical engineering, Rutgers University, Piscataway, N.J. He can be reached at 848-445-3357 (ffmuzzio@yahoo.com). He earned his BS in chemical engineering at the University of Mar del Plata, Buenos Aires, and his PhD in chemical engineering at the University of Massachusetts, Amherst. He has published more than 200 peer-reviewed papers on mixing and blending, presented at numerous conferences, and earned several patents.