MIXING MECHANICS

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Mixing cohesive powders

Many mixed products contain cohesive ingredients. These ingredients are in the mixture because they provide some benefit to the finished product. Yet, trying to get a cohesive ingredient properly mixed into the final blend presents significant challenges.

Cohesive powders contain "self-loving" particles: They tend to stick together in clumps and don't disperse readily with other particles. Breaking up these cohesive clumps and getting the particles to mix intimately with other particles requires high mixing energy and shear.

Figure 1 shows the difference between a completely segregated blend (Figure 1a) and a randomized blend (Figure 1b) of free-flowing ingredients. Figures 2 through 4 illustrate different types of blends containing both cohesive and free-flowing ingredients. Figure 2 illustrates the difference between a blend with one cohesive ingredient (Figure 2a) and a blend with all cohesive ingredients (Figure 2b).

Figure 3a shows a poorly mixed blend where one cohesive ingredient's particles are still clumped together because of their self-loving bonds. Figure 3b shows a blend where the cohesive particles have been properly separated, then allowed to form bonds with the other particles in the blend.

Finally, if the cohesive powder has much smaller particles than the other ingredients in the blend, you might end up with something more like Figure 4, which shows how small cohesive particles can attach to larger particles to form coated particles. Blends that look like Figure 3b or Figure 4 are excellent mixtures because their structures will make them much less likely to segregate. In fact, the cohesive particles hold the blend together.

Next, I'll discuss types of cohesive bonds, suggest a few ways to break them down, and give a couple of practical examples describing how to do this during mixing.

Types of cohesive bonds

Cohesive powders are defined by an attractive bond — including Van der Waals forces and electrostatic charging — or a stronger adhesive bond between the individual particles.

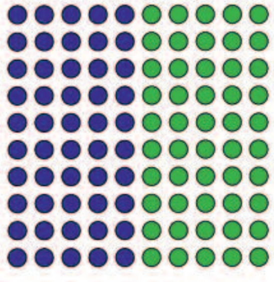
Van der Waals forces are typically the weakest attractive forces, but with small particles can be quite strong. These forces are caused by fluctuating polarizations among nearby molecules on particle surfaces. Van der Waals forces increase by the square of the distance between the centers of two particles, which means that very tiny particles can become very cohesive. This is why granular sugar can be very free-flowing, but finely ground confectioner's sugar can be very cohesive.

Electrostatic charging can be a mildly strong attractive force that creates cohesive structures. Many plastic powders and some pharmaceutical polymer powders that must be processed in a very dry environment can have significant cohesive electrostatic attraction. Electrostatic attraction occurs when electrons are exchanged between two surfaces that contact or rub each other. This rubbing can be between particles or be-

Figure 1

Blends of free-flowing ingredients

a. Completely segregated



b. Randomized

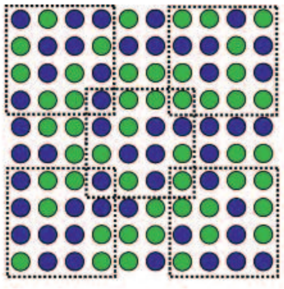
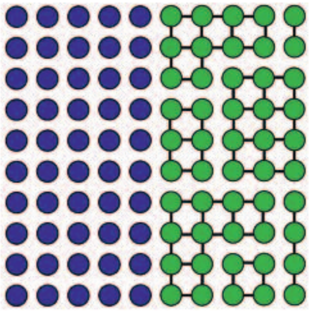


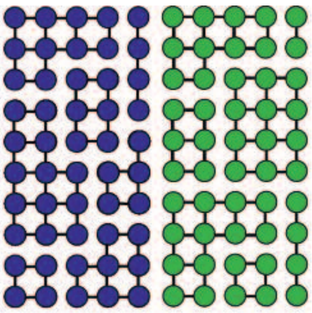
Figure 2

Poor blends containing cohesive ingredients

a. With one cohesive ingredient



b. With all cohesive ingredients



tween a particle and a surface, such as a chute or screen. This electrostatic charging is very hard to measure because it can be localized *on* a particle.

It's also very hard to measure electrostatic charging *within* a particle. A particle could be electrically neutral, but have localized charging on the surface. The positive-to-negative attraction makes the cohesive bonding between particles strong.

Electrostatic forces can sometimes be neutralized through a grounding system or through appropriate application of a corona discharge. Since water is a conductor, humidity can also be used to relax electrostatic bonding. In one instance, I saw paper fibers attract strongly at 25 percent relative humidity, but when the relative humidity was raised to 35 percent, the fibers didn't have any cohesive attraction at all.

Adhesional bonds are the strongest and are typically chemical in nature. For example, some crystalline particles, such as salt, have a lattice structure at the molecular level. Under compressive pressure, such as storage in a bin, the surface molecules may recrystallize with their neighbors at the particle-to-particle contact points, forming very strong adhesional bonds. Humidity in the air can also provide enough moisture to create an adhesional bond: Two particles in contact start to adsorb moisture on their surfaces, causing the surfaces to melt or soften and join. Then the moisture diffuses into the particle centers, leaving behind a "dry bridge" bond. For example, this is what causes caking in a dry detergent that contains sodium carbonate.

Breaking down cohesive bonds

To break down the cohesive bonds between particles and get them mixed well into a blend, you need a mixer that can impart shear. You also need to match the amount of shear the mixer imparts to the cohesive strength between particles. Pure tumbling mixers have virtually no shearing capability, so they don't mix cohesive particles well. Convective mixers with screws, paddles, or ribbons will impart some shear, so they can mix mildly cohesive particles. For example, flour can be mixed with white sugar in a simple kitchen mixer because the flour is only mildly cohesive. But if brown sugar that's been exposed to moisture is added to the flour–white-sugar blend, then the kitchen mixer will fail at intimately mixing in the brown sugar. The moisture-induced dry bridges in the brown sugar will be too strong for the simple mixer, and the cohesive clumps will always be visible. Higher shear is needed.

High-shear mixers typically impart shear through high-speed impaction. Higher shear is imparted in combination mixers that combine one type of mixing, like tumbling, with high-shear impaction devices. Examples are a tumbling V-blender with a high-speed impaction bar and a plow mixer with a high-shear chopper blade in the mixing zone. Even higher shear can be attained in extruders and roll mills.

Examples of cohesive-bond busting

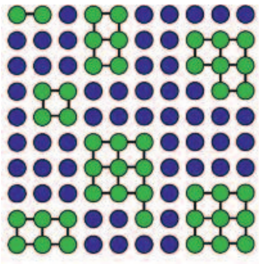
A good example of mixing with impaction shearing is dry-blending color pigments into a white powder bed to change the powder color. The pigment particles tend to be a submicron size and are extremely cohesive. If placed into a standard mixer with the white powder, the pigments will form clumps and never extend into the batch. When high-speed choppers are added to the mixer, the choppers start to break down the pigments and shear them onto the larger white particles, evenly distributing them as a coating. I've seen one case where a desired color was achieved after mixing the color particles for 5 minutes. When the mixer ran longer, the product color became too vivid. The additional mixing time continued to break down the submicron bonds and extended more color particles into the white powder, causing the final product to be off the color spec.

High-pressure roller compaction with a granulator is another form of high-shear mixing. This method is often used in the

Figure 3

Poor and excellent blends containing cohesive ingredients

a. Poorly mixed with cohesive clumps



b. Well mixed with cohesive and noncohesive particles effectively blended

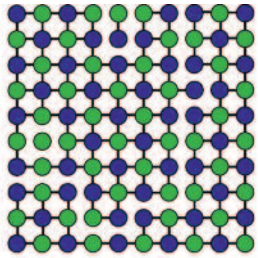
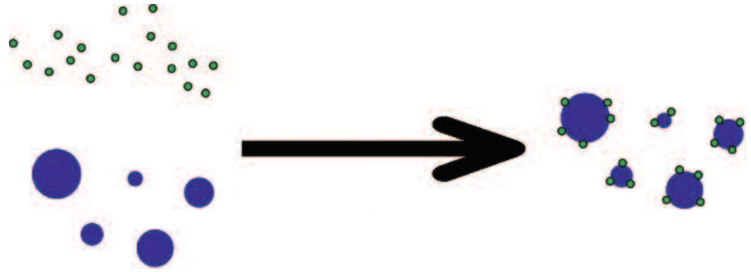


Figure 4

Small cohesive particles coating larger noncohesive particles



pharmaceutical industry where the active ingredient is usually very fine and highly cohesive and forms only a small percentage of the overall blend. The active ingredient is blended with other ingredients in a typical batch mixer, then delivered to the roller compactor. The roller compactor's high pressure tears apart (shears) the cohesive powder bonds in the early portion of the compactor's nip region (where the rollers meet), then squeezes the particles together as they keep moving between the rollers and form a continuous homogeneous sheet. The sheet falls into a granulator, which reduces it to produce granular particles that are individually homogeneous with the entire blend.

A final note

Using cohesive powders can be a great a way to add more structure to a powder blend and prevent the blend from segregating as easily. The key to successfully blending cohesive powders is to break the cohesive bonds between the particles and get them to attach to the other particles in the blend. **PBE**

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