Shear cell testing: Predicting powder consolidation in packages

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Understanding how your dry bulk powder settles and consolidates over time can help you prevent customer dissatisfaction with packages that seem insufficiently filled with powder or that contain lumpy or hardened powder that won’t easily empty from the package. This article explains how you can use an automatic shear cell tester to obtain this information.

Weighing your filled packages before they’re shipped to your customers ensures that each package delivers the guaranteed quantity of powder. But the powder in each package consolidates during shipping and handling, so a package’s fill volume as it leaves your plant is often greater than its actual volume once it arrives at the customer’s loading dock. Will this make your customer feel cheated? And will the consolidated powder now contain lumps or become hardened, creating discharge headaches for the customer?

Powders naturally consolidate over time because of their own weight: As powder is filled into a small bag, bulk bag, or other package, air becomes trapped in voids between the particles, creating the powder’s “loose-fill density.” But as the particles’ weight causes them to rearrange themselves in the package, they squeeze out the air and the voids gradually disappear. This achieves a closer packing condition, in turn increasing the powder density and shrinking the powder volume.

Being able to predict how much the powder volume can shrink by the time your customers receive their packages lets you assure them they’re getting fair value. Although a simple tap density test that measures the powder’s settling action can provide this information, this test can’t help you predict how much strength the powder can gain over time when it’s compressed under other packages during storage. A powder that gains strength can form lumps or chunks that make the package hard to empty or, under extreme conditions, even harden into a brick-like mass that’s impossible to discharge — information your customer needs to know. A good way to predict both how much the powder will settle and how much strength the consolidated powder will have is to test the powder using a shear cell tester. The results can help you fully inform customers about what settling and consolidation effects to expect with their packaged powder.

Measuring density changes during consolidation

An annular shear cell tester, as shown in Figure 1a, is a common shear cell apparatus that can be used to predict powder density changes during consolidation. The powder is loaded into the tester’s annular (ring-shaped) shear cell, which consists of a trough (as shown in Figure 1b) covered with a lid, and the shear cell is placed on the tester’s turntable. The lid is pressed down to apply a defined force to the powder sample to achieve a specific consolidation stress within it. As the lid compacts the powder, the sam-

Figure 1

Shear cell tester

a. Tester

b. Trough

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You can run a shear cell test called the flow function to measure time consolidation on a powder sample. This test simulates what happens when a powder is discharged from a package in gravity flow after a certain storage period and automatically measures the frictional resistance between particles as they try to slide by each other in normal flow behavior. Of course, as the frictional resistance increases, powder flow can become limited or even stop. In the test, the powder sample is loaded into the shear cell’s trough and covered with the lid; after an appropriate time interval, the trough and lid are rotated together horizontally and, when the powder’s failure strength is overcome, the trough continues to rotate while the lid holds its position. This determines the force (the major principal consolidation stress) required to cause the particles to flow against each other (the powder’s unconfined failure strength).

The flow function test is repeated at time intervals representing the time the powder will be stored in its package before being discharged for use. So if the package will be stored overnight, over a weekend, or for a longer time, the flow function test is run again after that interval. The software automatically runs the flow function test, and the resulting data provides a graphical picture of how the powder’s flowability can change with time consolidation.

Results from three flow function tests of a food seasoning powder are shown in Figure 3. The first test was run immediately after the powder was produced, the second after it had rested for 1 hour, and the third after it had rested for 8 hours. As the results show, the powder is classified as cohesive right after production and as nonflowing after resting 8 hours.
hours. Clearly this powder will present problems for the customer, who will probably be concerned about whether the powder will also harden as it becomes nonflowing. Flow function test results can also show that a powder is more cohesive at lower consolidation stresses. This can mean that as the package empties, the powder will be less likely to discharge smoothly from it — another important piece of information your customer should know.

By giving an early warning that your customer will face discharge problems, flow function results can help the customer take steps to deal with them. For instance, the customer may choose to switch package types or avoid stacking packages to prevent powder in bottom packages from hardening. Or the customer may decide to use fluidization or another conditioning method to help discharge consolidated powder from packages. In some cases, the customer may decide to reformulate the powder or add a flow agent that can reduce the powder’s tendency to gain strength and harden.

**Real customer service**

Shear cell testers are available from various manufacturers and are as affordable for quality control labs as they are for R&D environments. Operating this automated instrument requires only minimal training. Using shear cell tests to measure your powder’s density changes and consolidation over time allows you to provide real customer service: predicting how a powder will behave when your customer discharges it into a process.

**For further reading**

Find more information on powder flow tests in articles listed under “Solids flow” in *Powder and Bulk Engineering*’s comprehensive article index (in the December 2010 issue and at *PBE*’s website, www.powderbulk.com) and in books available on the website at the *PBE* Bookstore. You can also purchase copies of past *PBE* articles at www.powderbulk.com.

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