A small amount of flow agent can help your fine cohesive powder flow smoothly through your process without arching or ratholing. But exactly how much flow agent do you need? Read this article to discover how using a shear cell tester can help you quickly and accurately determine the amount of flow agent you must add to your powder to reduce or eliminate flow problems.

Fine powders exhibit interparticle adhesion, which often makes them cohesive. This characteristic can cause several flow problems, including erratic flow, arching, ratholing, and equipment jams or blockages. A common way to reduce or eliminate these flow problems is to add a small amount of a flow agent (also called a flow aid or anticaking agent) to the cohesive powder. Typical flow agents include fumed silica, clay, talc, zeolite, magnesium chloride, and stearic acid. These materials coat the surface of the powder particles, reducing or eliminating interparticle adhesion.

Unfortunately, in many plants a flow agent is added to a fine powder by trial and error, requiring several additions of the flow agent until the powder mixture flows as desired. This process is not only time-consuming and costly, but subjective, as well, making it difficult to achieve repeatable results. Adding to the challenge, the acceptable amount of flow agent is typically limited to 2 percent by volume of the total powder mixture. This limit, based on standards set by governing bodies such as the FDA, underscores the need to characterize and precisely define the amount of flow agent your cohesive powder requires.

A faster, less expensive, and more accurate way to do this is to run a series of flow behavior tests on your powder using an automatic shear cell tester. This method may also eliminate any need to test your powder mixture in a pilot-scale process.

Running flow function tests with a shear cell tester

By using the automatic shear cell tester to run one type of flow characterization test — the flow function test — you can quickly and accurately determine how much flow agent is needed to improve your powder’s flow behavior.

About the shear cell tester. The automatic shear cell tester, as shown in Figure 1a, is a common shear cell apparatus available from various manufacturers for characterizing powder flow properties. Several flow characterization tests, including the flow function test, are built into the tester’s software. The software allows each test to be quickly set up and run by a lab technician without requiring extensive training. Only a small powder sample is required for testing, and the tester can provide comprehensive flow characterization results in 1 to 2 hours. In addition to executing the tests automatically, the software does all the calculations, simplifying the task of analyzing the flow data. Shear cell test methods are well-defined in ASTM test methods D6128, D6682, and D6773.1
Flow function test method. Performing a flow function test with the shear cell tester simulates your powder’s flow in a bin or other vessel through an orifice. The test allows you to measure how much strength (called the unconfined failure strength) the powder retains at a stress-free surface following consolidation to a given stress level (called the major principal consolidation stress). This consolidation stress level correlates with a specific fill level in a vessel. Running a series of flow function tests can help you characterize the amount of flow agent that must be added to your powder to achieve reliable flow from your process equipment.

For the initial flow function test before any flow agent is added to the powder, the technician loads a powder sample into the tester’s trough (an annular [ring-shaped] shear cell), shown in Figure 1b. After entering the sample’s weight into the software, the technician initiates the test. The software automatically runs the flow function test, consolidating the powder in the trough to defined strengths and shearing it horizontally with the tester’s vaned lid (Figure 1c), to measure the powder’s yield stress (that is, the stress level at which it yields and flows). The results are plotted in a curve as unconfined failure strength (yield stress) versus major principal consolidation stress, with one data point for each consolidation strength applied in the test.

Plotting the results. The flow function test results shown in Figure 2 illustrate five regions commonly accepted by the bulk solids industry for characterizing a powder sample’s flow behavior: nonflowing, very cohesive, cohesive, easy flowing, and free flowing. The red curve in this figure represents flow function test results for one powder sample, with each data point representing the sample’s flow function at that defined consolidation stress. As you can see, the curve shows that this powder sample is cohesive at 0.5 kilopascals of consolidation stress and easy flowing at higher consolidation stresses.

We know that adding a flow agent to the powder will allow it to flow more easily, without segregating, but we need to determine precisely how much flow agent will produce the desired flow behavior.

Determining the correct flow agent proportion

Once you have the initial flow function results for your powder, you can run additional flow function tests on powder samples containing an increasing amount of flow agent (up to the 2 percent limit), until the powder mixture achieves the desired flow behavior. By helping you accurately measure what proportion of flow agent your powder mixture requires, these flow function tests provide a benchmark that future powder mixtures can be checked against.

Consider this example: We perform an initial flow function test with a sample of powder A, a powder blend that contains no flow agent. The results, as illustrated by the blue curve in Figure 3, show that the material is very cohesive at various consolidation stresses. This cohesiveness results in an erratic flow pattern that causes the blended powder to segregate, producing an incorrect mixture. We know that adding a flow agent to the powder will allow it to flow more easily, without segregating, but we need to determine precisely how much flow agent will produce the desired flow behavior.
To do this, we add a small amount of flow agent to powder A and test it again (yellow curve in Figure 3), repeating this process with more flow agent (red curve) until enough flow agent has been added to allow the powder to flow easily.

To further define the correct amount of flow agent this powder requires, we can use a flow index value, which is a single-point measure of the powder’s flowability based on the flow function test results. For a given flow function, the flow index is a value usually ranging from 0 to 1.0 that represents the inverse of the slope of a straight line running from the data point at the highest consolidation stress to the origin (where the X and Y axes meet). The steeper the slope, the higher the flow index, and the more cohesive the powder. The flow index value’s relationship to the five
flow behavior regions is:
• 0 to 0.10: free flowing
• 0.10 to 0.25: easy flowing
• 0.25 to 0.50: cohesive
• 0.50 to 1.00: very cohesive
• 1.00 and over: nonflowing

Another option is to choose a flow index value at a specific consolidation strength to define the amount of flow agent we must add to the powder. So, for example, if a powder sample’s flow function curve shows a 0.19 flow index at 4 kilopascals of consolidation stress, this means that the powder is easy flowing at that consolidation stress. In future tests, this stress value can be used to indicate that the correct amount of flow agent has been added to the powder. We can also use this value to improve plant operating procedures by requiring that the vessel fill level for the powder be maintained at or above the flow index value equal to 4 kilopascals of consolidation stress.

Once the flow function tests have benchmarked the correct amount of flow agent for your powder, you can use the shear cell tester to check new powder mixtures against this benchmark before the mixtures go into your process.

**Improving your process**

Beyond helping you determine how much flow agent to add to your fine cohesive powder, using the shear cell tester can also help you control your process. The tester can perform fast quality assurance and quality control tests to ensure that your powder is flowing as expected in your process. This will catch any changes to powder flow properties caused by your process or environment before they can result in process downtime, lost production, or off-spec product.

**Reference**


**For further reading**

Find more information on shear cell testing and flow agents in articles listed under “Particle analysis” and “Solids flow” in *Powder and Bulk Engineering*’s article index (in the December 2012 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.

**Vinnie Hebert** is Powder Flow Tester product manager at Brookfield Engineering Laboratories, 11 Commerce Boulevard, Middleboro, MA 02346; 800-628-8139 or 508-946-6200, ext. 7171 (v_hebert@brookfieldengineering.com, www.brookfieldengineering.com). He also manages product education and training at the company. He holds a BS in electrical engineering from Roger Williams University in Bristol, R.I.