The Evolution Powder Tester versus traditional yield strength tests

The Evolution Powder Tester is designed to measure the unconfined yield strength of powders and granular materials quickly, accurately, and repeatably. The heart of the design is the analysis cell.

Traditionally, analysis cells for unconfined yield strength tests have been composed of split cylinders with top and bottom disks. The cylinder commonly has a height greater than two times its diameter. The cylinder is first screwed together or bound with ring clamps with the bottom disk secured in place. The cylinder is then filled with sample powder and the top disk is placed on top of the powder. The sample is them compressed to a predefined pressure. After compression, the cylinder is removed from the sample by unscrewing the clamps or screws holding the two cylinder halves together and they are removed leaving a freestanding sample. Pressure is then applied to the top of the sample until the sample yields. The maximum value in the pressure at the point of yield is the unconfined yield strength. Variations on this approach include full cylinders with latex sleeves allowing the sample to be pushed through the cylinder.

With the Evolution Powder Tester, the sample is compressed in a delrin cup with a moving bottom which allows the sample to be lifted from the sample cup after compression. Several size cups are offered but the height of the sample cup is always half of the diameter. These dimensions were arrived at by researching the problems with traditional unconfined yield strength tests and by comparing the strength results measured with the Evolution to those measured by powder shear tester. After this research and testing, it became clear that having cell heights equal to half their diameter produced strength results similar to shear testers in roughly a two minute measurement. This is evidenced by the Evolution measuring the literature values for the only powder flow standard available, BCR Limestone.

Problems with traditional approach

Sample removal – The test sample must be removed from the cylinder without damaging the sample. This is difficult due to the height of the sample as well as the friction between the cell walls and the sample powder. When a latex sleeve is used, this must also be removed carefully to not damage the sample.

Wall friction – When a sample is compressed in a cylinder, the pressure on the top of the sample powder is higher than the pressure on the bottom due to the friction between the cell walls and the sample powder. The taller the cell, the more the frictional effect. This friction results in yield strengths that are below the true yield strength of the material because the sample is not subjected to the full compressive pressure. Attempts have been made to reduce this friction by using lubricated latex sleeves[1] to encase the sample powder but this is impractical in industrial situations and it is not clear how low the friction actually is in the test cell. Results for these tests are lower than shear test values. Current literature suggests this is due completely to wall friction effects2 and not to lack of uniform consolidation as previously suggested3.

Inconsistent filling – When the height of the test cylinder is twice the diameter, the cylinder is difficult to fill evenly. In most cases the cell is filled by applying a small layer of powder and then compressing the sample to the test pressure. This is repeated until the cylinder is filled. This takes time and care and is not practical in industrial situations. In addition, it is not clear how layering the sample powder affects the strength of the compressed material. Also, air can become entrapped in the sample cells creating inconsistencies in sample density, more so for samples with low permeability.

Weak samples break due to powder mass – When powders do not have much strength they cannot sustain a freestanding cylindrical form with a height that is two times the diameter. This limits the strength test range for a traditional unconfined yield strength tests.

Powder mass contributes to compresion force and measured break force – For a confined or unconfined mass of powder, the pressure on the lower part of the sample increases with sample height due to the mass of the sample column. Therefore, this mass must be corrected for when calculating the actual compressive force on a cylinder of powder. This correction is non-trivial, however, due to the fact that the force changes with height. This is also true when the strength of the unconfined sample is measured. The exact pressure on the failure point depends on the height in the sample. This means the failure height must be measured to calculate the correct pressure value for tall samples. This is difficult after the sample has failed and broken apart and samples do not fail along a horizontal line.

Traditional Problems Solved by Evolution

Sample removal : The Evolution automatically lifts the sample from the cell from the bottom. This ensures the sample is not damaged on removal.

Wall friction: The height of Evolution sample cups are always half of the diameter. Because the height is lower, the effect of wall friction is lower. In addition, the sample cups are made of delrin which is a low friction material.

Inconsistent filling : Because the Evolution sample cups are relatively wide for their height, they are easy to fill evenly. The cups do not require sample powder to be added in layers but at one time. This improves accuracy and repeatability. Also, entrapped air is easily released due to the low height of the sample.

Weak samples break due to powder mass - After compression, unconfined samples prepared by the Evolution have a low height compared to their width. This means less pressure is generated by the powder mass itself on the the sample column. The Evolution can therefore measure very free flowing samples.

Powder mass contributes to compression force and measured break force – With the Evolution test cell dimensions, the possible error in the calculation of the actual compressive and break force on the sample is reduced by a factor of four.

Why traditional tests use cells twice the height of their diameters

The theory regarding unconfined yield strength tests is that the sample height must be twice the diameter so the failure plane of the sample does not go through the top or bottom of the sample cylinder but goes across the middle of the cylinder[3]. In this way the lid on top of the sample and base of the sample do not affect the strength measurement. This seems reasonable but no data has be presented to show the affect of the the failure plane going through the top or bottom of the sample. With the huge errors and difficulties presented by using tall cells, it seems how much error is generated by using less height would be widely measured and reported. This is not the case. In addition, when testing unconfined yield strength by direct compression, most samples actual fail at the bottom of the sample column and not in the middle of the sample regardless of the height of the sample.

In our research, we tested samples with many geometries and found that our strength tests with the Evolution matched shear tester results most closely with a sample cup height of half the diameter of the cup. With heights above this value, strengths where lower than shear tester results due to the problems spelled out above. Below this value, strengths became higher that shear test values because samples began to extrude between the top and bottom of the cells rather than fail. We also attempted to measure the effect of the friction between the lid and bottom of the sample cup on the measurements by using a lubricated latex sleeve on the top and bottom of the sample during the analysis. These results showed no difference from the tests with the standard lid.

Finally, the only universally accepted standard for powder flow measurements is BCR Limestone which was tested using the Jenike linear cell. This cell is comprised of a horizontally split cylinder in which the powder is sheared. The height of the split cylinder is roughly one half the diameter. In these cells the failure plane is forced to be in the center of the sample where the cylinder is split. Jenike clearly favored reducing wall friction over top and bottom effects.

The Evolution has been designed as a fast, easy to use, and repeatable tester to measure powder flowability in industrial situations. By balancing the problems with traditional unconfined yield strength tests with the needs of industrial users, the Evolution provides users with an easy to use and easy to understand method for comparing their powders and granular materials.

1) Effects of Cyclic Loadinand Variousu Test Conditionsonsons in an Uniaxial Tester ,Trude.Nysaeter, Gisle. Enstad, Part. Part. Syst. Charact. *24* (2007) 271–275

2) Comparison between a Uniaxial Compaction Tester and a Shear Tester for the Characterization of Powder Flowability,Luca Parrella, Diego Barletta, Renee Boerefijn and Massimo Poletto1
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3) Investigations on the caking behavior of bulk solids - macroscale experiments, Michael Rock, Jorg Schwedes, Powder Technology 157, June 2005, pages 121-127, Elsevier B.V.,Maryland Heights, MO, USA

Evolution Powder Tester Overview

The Evolution Powder Tester (EPT) is an economical and easy to use powder flow tester that measures the unconfined yield strength of a material (a critical flow property) at pressures up to 500kPa. The unconfined yield strength can be measured at one pressure or at many different pressures in order to create a flow function. The flow function presents the material's gain in strength as more pressure is applied to it. The Evolution Powder Tester is the perfect powder tester for measuring the flowability and compressibility of materials in low to high stress situations such as silos and storage containers. The system also measures how materials react to the storage conditions over time.

The Evolution Powder Tester (EPT) offers many advantages over traditional shear and other uni-axial testers. The EPT is a standalone instrument designed just for powder testing and is not an accessory to a general purpose instrument. This allows the design to be cost effective, easy to operate and suitable to any laboratory or manufacturing environment. In addition, it takes approximately 3 minutes for a user to test one sample. This is significantly less testing time than other shear or uni-axial testers.

With the EPT, time consolidation tests can be performed with sample cells and weights that allow a material to be subjected to various pressures over long periods of time. The EPT time cells are designed so that they can be easily placed in ovens or humidity chambers to study their effects on materials in storage situations. Studying the effects of humidity and pressure over long periods of time are difficult with traditional shear testers and uni-axial testers. The analysis cells for many these instruments are very expensive and do not include the means of applying pressure for significant periods of time.

The Evolution Powder Analyzer uses uni-axial compression to assess the flowability of powders. The operator begins the flowability test by filling the analysis cell with either 25 cc or 75cc of sample. The cell is then placed in the Evolution and the material is compressed to a predefined pressure. This pressure is referred to as the major consolidation stress. This stress can also be applied using weights over a long period of time to measure the effects of time, humidity, and temperature.

After compression, the Evolution removes the sample from the cell and applies force to the material until it breaks. The pressure required to break the sample is the unconfined yield strength. The unconfined yield strength represents the force required to make the material flow. A flow factor can be calculated by dividing the major consolidation strength by the unconfined yield strength. The greater the value of the flow factor the better the material will flow at any given pressure. A plot of the unconfined yield strength versus the major consolidation stress is referred to as a flow function and represents the material's flowability under a wide range of pressures.