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The Johanson Indicizer™ System vs. the Jenike Shear Tester

New Technology Simplifies Solids Flow Properties Characterization

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1. Historical Perspective

The industry standard for measuring cohesive properties for many years has been the Jenike Shear Cell.

Since their first commercial use in 1959, the Jenike Shear Cell techniques have provided insights for arching and ratholing tendencies in bins and hoppers. When I started working with Dr. *Andrew* Jenike in 1958, my first assignment [1] was to work out a method of sample consolidation that would produce more consistent and reproducible results. These test techniques have remained basically unchanged in the past 33 years [2, 31. Consequently, I know well the strengths and weaknesses of the test procedures and their interpretations.

2. Shear Cell Deficiencies

One of the major problems with using the Jenike Shear Cell is that during shear, the shear force concentrates at the front of the shear cell. The shear force is non-uniformly applied to the sample. Similarly, the vertical force is also applied non-uniformly. At best, the results represent average stress conditions typically varying from a near zero stress to the maximum applied (about two times larger than the average).

One of our early innovations at the University of Utah was applying the shear stress through both the top disk and the top ring [2]. This helps distribute the shear stress but applies a torque to the top disk. This results in a vertical force concentration at the front of the test cell during shearing.

The stress non-uniformity in the Shear Cell (see Fig. 1) can be rationalized to some extent when the strength is directly proportioned to the applied pressure. However, for material like wet clay or wet sand, this rationalization fails badly.

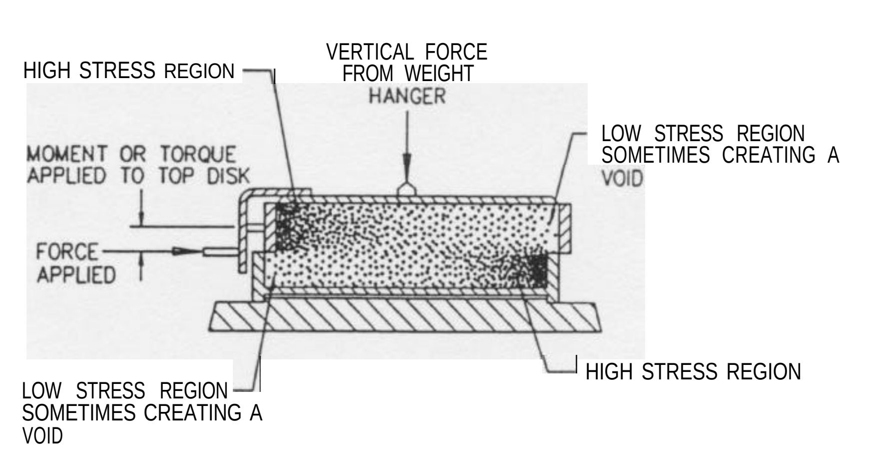
The non-uniform stresses in the Shear Cell also cause the major principal stress to be undefined. This undefined stress direction throughout the test sample is the major cause of variable "steady state" consolidation conditions and the frequent scatter in the measured "failure" shear stresses.

The Jenike Shear Cell indirectly measures the solids' unconfined yield strength and as a result, requires several test points to establish the yield locus and its accompanying Mohr stress circle representing the unconfined yield strength (see Fig. 2). The variations in consolidatlon stress state as well as physical differences from sample to sample cause scatter in the data points.

3. Interpreting Shear Test Results

With scattered data, an accurate interpretation of the yield locus is very difficult. For example, the test results in Fig. 2 with three points, all supposedly on the yield locus, can be interpreted at least three different ways as indicated. Each way can be justified. The direct curve is justified because this is the data run. The straight line through the upper two points is justified because field loci are almost always straight. This interpretation disqualifies the lower point because it lies to the left of the failure circle tangency point with the yield locus. The least square fit to the data simply recognizes that the data might be scattered. This could result in a factor of three difference in the "measured" strength value for this set of tests. The "interpreted" major principal pressure also varies significantly. The result is the severe scatter, shown in Fig. 3, of the unconfined yield strength versus the major principal compaction pressure T_1.

Fig. 1: Jenike Shear Cell showing non-uniform stress distribution



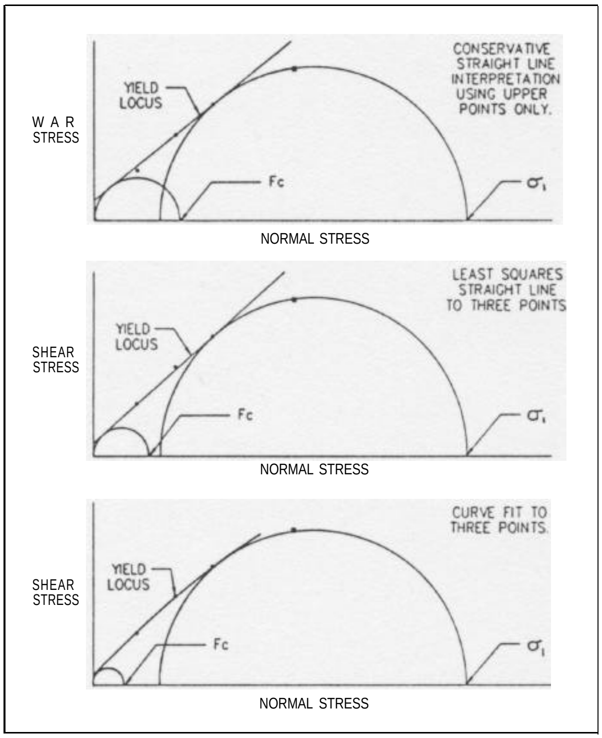


Fig. 2: Various interpretations of shear tests

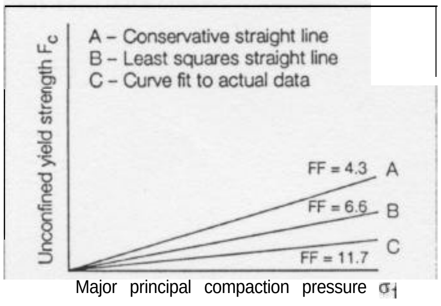


Fig. 3: Yield strength results from the three different interpretations

This large scatter in test results is even more pronounced when the sample consolidates over time. Differences in moisture loss between samples on the same yield locus can produce extremely confusing results and make a reasonable interpretation impossible. Some of my colleagues have used a single point time "test" with a yield locus parallel to the instantaneous for determining the results. The problem with this approach is, which one of. the three possible yield loci in Fig. 2 do you use?

4. A New Approach

When I separated from Jenike and Johanson in 1985, I resolved to find a better way of measuring the bulk solids flow properties. After years of research and hundreds of tests, we established the Johanson Indicizer (see Fig. 4) measurement techniques [6].

The heart of the measurement is the test cell shown in Fig 5. The sample is consolidated with a unique two-piece piston that measures the consolidation pressure directly on the inner piston while the inner and outer pistons move together. The outer piston receives all the drag effects on the cylinder walls and thereby eliminates any drag effects in the inner piston when the compaction pressure is measured.

This unique innovation (U.S. and foreign patents pending) consolidates the sample uniformly to a known major principal stress level. Once the consolidation is complete, the vertical load is removed. The lower piston drops to allow the sample to be unconfined. The outer, upper piston is then raised relative to the inner piston and shear failure induced by the downward movement of the inner piston. The unconfined yield strength is directly measured.

5. A New Direct Interpretation

This new technique quickly produces a strength versus consolidation point with a single test without multiple samples, without *Mohr* circles and without interpretation of scattered data. Tests may be run in one tenth the time required for the old Jenike tests - the data interpretation is direct. We can preassign the consolidation pressure calculated for a given outlet size (including effects of impact loading), measure the strength and calculate the critical arching outlet dimension directly with one test. This is the Johanson Arching Index, AI [4]. This one test replaces at least six shear tests (three for each of two pressure levels) and two difficult and judgemental *Mohr* circle interpretations. The time saving is at least 10 to one and the accuracy increase can be a factor of four with some materials.

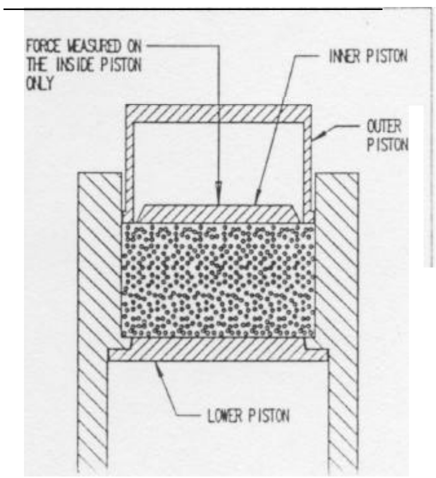
Similarly, the determination of the critical rathole dimension can be obtained with a single test run at pressures associated with the bin in question. This is the Johanson Rathole Index, RI [5].

6. A Valuable Research Tool

Direct comparison of one material to another or one process condition to another can be made by using our standard indices measurements. These three standards represent 5 ft diameter bins (our pharmaceutical standard), 10 ft diameter bins (our base standard) and 20 ft diameter bins (our ore/coal standard). However, we prefer to run the tests for the existing conditions at a specific plant or facility or in a specific process. In this way, the AI and RI are precise to the unique site conditions. Using these techniques, JR Johanson can easily evaluate the effects of temperature, moisture, moisture migration [6] or chemical reactions accompanying the process.

We have easily been able to achieve + 5% repeatedly on our retesting of a single sample. If repeated tests lie outside this range, we know that something other than test technique is causing the variation. For example, one of our technicians recently presented me with RI (Rat-

Fig. 5: Indicizer test cell



hole index) for a wet limestone (15% H_2O). We ran the tests for various times (up to one week) at rest.

The results were extremely scattered when plotted as a function of time. Since each point represented a single test sample, I had the technician measure the moisture content of each sample after it was failed. When the results were replotted as a function of moisture loss (from the original sample), the scatter disappeared and a linear relation between strength gain and moisture loss emerged [7]. This research understanding would have been impossible with the Jenike Shear Cell.

7. A Direct Comparison

Table 1 compares the Johanson Indicizer and the Jenike Shear Cell tester. In addition to those advantages already mentioned, the Johanson Indicizer has a much greater range of possible consolidation pressures both on the low and high range. It can measure minute values of strength needed to evaluate pharmaceuticals for capsule filling and for measuring strength of compacts subject to 40,000 psi.

When the cohesive properties of samples containing larger particles must be measured, the Johanson Indicizer' can do it with less than half the sample and at higher consolidation heads than the Jenike Shear Cell. Measuring solids strength at various shear strain rates is easily done by the Johanson Indicizer. Elastic wind-up strength is performed only by the Johanson Indicizer [8].

Table 1: Comparison between the Johanson Indicizer and the Jenike Shear Cell tester

Function	Jenike Shear Cell	Johanson Indicizer
Ease of operation	Requires skilled technician with knowledge of Mohr circle interpretation and how the yield locus curve fits the data. Test results will vary significantly from one technican to another.	Fully automated tester removes all technician variation. The computer guides the technician to a consistently accurate test. No special skills are necessary.
Technician time and skills to determine arching dimension in a hopper	Requires a skilled technician and at least six tests to determine arching dimension. It also requires time-consuming interpretation using theoretical skills. Total time is about one hour.	Takes about five minutes to determine the arching dimension.
Accuracy	Depends on the material being tested and the technician. The critical arching dimension may vary by a factor of four for any given material just by differences in interpretation of test results.	Reproduces arching dimension for the same sample consistently at + 5% for a variety of materials. Because one test produces one result, the interpretation is always consistent.
Sample consolidation pressure	Applied non-uniformity. It is not known until three or more tests (hopefully at the same pressure) are complete.	Predetermined and uniform throughout the sample.
Failure shear plane	Uncertain position often produces questionable test validity.	Consistent control eliminates wasted and invalid tests.
Measurable strain rate sensitivity	Available but difficult to interpret because of wandering shear plane.	Available by simply adjusting failure load application rate.
Time tests	Available, but difficult to interpret.	Available with direct interpretation, one sample-one result advantage.
Large particle testing	Requires a sample volume about 450 times the particle size cubed.	Requires a sample volume about 200 times the particle size cubed.
Low pressure measurements	Limited to about a 15 inch head of solids minimum consolidation.	Limited to about a 2 inch head of solids, minimum.
High-pressure measurements	Limit of about 200 psi. maximum.	Limit of 40,000 psi, maximum.
Elastic windup strength measurements	Not available.	Available.

8. Hopper Flow Rates

Strength-associated arching and ratholing are not the only bulk solids flow properties that must be evaluated. The Johanson Indicizer System includes a unique Flow Rate Indicizer (Fig. 6) that measures both the compressibility and air permeability of a sample.

The on-board computer combines both these numbers to produce the maximum expected flow rate when the solids totally deaerate inside a hopper.

This FRI index in pounds/minute also correlates with various other material-sensitive process flow rates [9].

For standard indices, the required technician time is about one minute and the total test time about five minutes.

For specific indices testing, the test time may be as long as ten minutes.

9. Slide Angles

The Jenike Shear Cell tester is also used at times to measure directly the angle of slide or friction angles of bulk solids on hopper or chute surfaces.

This is accomplished by the Johanson Indicizer System using the Hopper Indicizer shown in Fig. 7. This tester directly measures the slide angle under various conditions and calculates the recommended conical hopper angles (HI) to achieve mass-flow and critical chute angles (Cl) to prevent buildup.

These tests are dependent on the hopper or chute liner material. Consequently, the tester provides the option of using various liner samples. The total time required for both these indices is about 10 to 15 minutes.

10. Conclusions

We finally have the answer for those who have been spending their valuable time carefully running, re-running and Interpreting Jenike Shear test results.

The new Johanson Indicizer System not only produces more accurate results, it does it much faster and wtth an instantaneous, direct interpretation. This allows the researcher, the solids flow expert, the design engineer, the purchasing agent or the equipment vendor to access solids flow properties with ease and confidence.

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