Is Sieve Calibration the holy grail?

by Art Gatenby

Prologue

Sieve calibration is the final step in determining whether processing yields suitable end results. In other words:

- Is your concrete going to be strong enough?
- Will you chocolates taste right?
- Will your washing powder flow and dissolve as advertised?
- Is there dangerous residue in your pill stock?
- Will the “frack sand” keep the fractures open?
- Is my salt of the correct grade?

If these are not correct, serious consequences could result (e.g. spoiled product, returned batches, rework or scrap).

These are the particle-size issues for which we test, frequently using woven wire mesh sieving techniques. For a long time, I've made sporadic attempts to understand how to ensure that tests really represent particle distribution. Many phenomena can affect these determinations. I have decided to undertake clarifying this murky process.

There are inherent irregularities in most woven materials. Regarding the woven wire mesh used in sieves, standards organizations (such as ASTM) attempt to determine the acceptable range of these irregularities and then set acceptable variation limits.

Mesh problems also arise from the testing process, as well as cleaning and various other forms of abuse. How do we determine if these processes affect sieve performance?

By means of illustration, I offer a particle’s perspective, a particle which I've named Pequeño. He encounters a sieve, undergoes a test, is cleaned out of an undersized hole and attacks several calibration operations.

Chapter One: Certification

I am Pequeño, a particle with a passion to get through any sieve and not be amongst the particles retained.

My story begins as I observe Brad, a professional sieve certifier, at work squinting through a microscope at a series of nearly square openings bounded by sections of wire that span the entire sieve. In one direction, the wires go straight across the sieve (weft). In the other direction, the wires alternately go over and under the straight wires (warp).

I'm from a large family of very small (about 150 micron) siblings. Brad is working on a number 100, 8-inch diameter sieve with 150-micron nominal apertures, holes or openings (they can be called any of these). It has about 500,000 of these openings. It should be easy for me to migrate to the next sieve.

Brad is inspecting and measuring 200 of these holes (about 0.04% of the total). He is measuring the wire in each as well as one side along the weft and one side along the warp. When finished, he will apply ASTM-specified formulae and determine if the sieve meets the specifications.

Within the acceptable specifications for these 200 openings, the average opening could be as large as 156.6 microns. There should be no problem of my getting through openings that size. However, this average could be as low as 143.4 microns. This could finish me, but the other specified dimension is the 193 micron maximum allowable size of an individual opening.

If I look around enough, I should even be able to get through an opening that Brad records as the minimum. Remember, Brad is only measuring 1-in-2500 openings.

If his task was to certify that the sieve met the highest standard -- the Calibration Sieve Category -- he would apply a reasonably tight standard deviation to his measurements. This would reduce my chances of getting through on the small average, which would only make it more of a challenge to find an opening through which I can pass.

In fact, I even have a shot at getting through a sieve with the next smallest designation (number 120 with 125 micron nominally-sized holes). The allowable maximum of any individual hole measured can be 168 micron -- an easy transit for me.

I like the theoretical odds of feeding my passion of getting through my size and smaller sized sieve openings (I hate to be in the retained category). In fact, I might even invite some of my larger siblings to join me.

In my next visit, I'll take you with me on some real production tests that use the sieve that Brad measured and professionally certified.

Until then,
Pequeño

Chapter Two: Inside a Sieve Test

In this scenario, Pequeño, along with some of his family and friends -- all small particles about 150 microns in size -- are on their way to a sieve test. Harry is a Quality Control Manager. He loads a stack of sieves onto a sieve shaker. From the top, the sieves are:

- #80 – 180 micron
- #100 – 150 micron
- #120 – 125 micron
- #140 – 106 micron

He dumps Pequeño and large quantities particles of varying size into the top sieve. Pequeño's first impression is that getting through the first #80 sieve is no problem. Then, the sieve shaker starts, causing violent motion -- up, down and circular.

Almost immediately, Pequeño and his little companions get to the #150 sieve -- his size. If the sieve is perfect, he might not make it to the 125 micron sieve. However, Pequeño finds that it is not perfect; rather, it is merely certified to be within standard ASTM tolerances. He quickly finds over-sized holes, which lead the way to the 125 micron sieve, which is supposed to be smaller than Pequeño and most of his family.

As the shaker continues its vigorous movement, he looks for the certified largest allowable opening on the #125 sieve. That is 168 microns, through which he and and some of his family members should find easy passage. If they don't shut off the shaker, he'll find one of these and pass through to the 125 micron sieve along with some of his cadre.

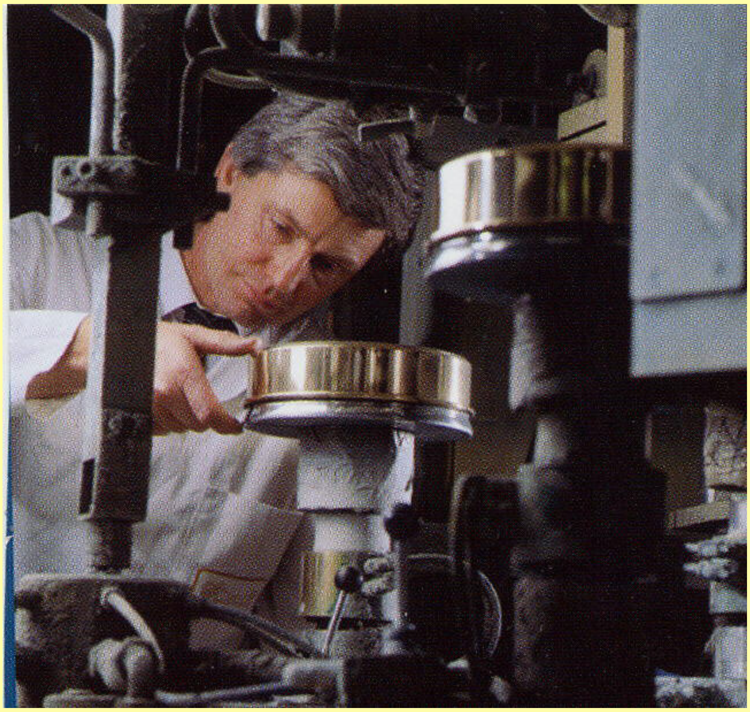
As it turns out, the #140 (106 micron) sieve gives Pequeño trouble; only a few of his ever-shrinking cohort squeeze through the maximum 141 micron opening.

Harry is depending on Brad's (the professional Sieve Certifier from Part I) previous work to retain all particles like Pequeño on the #120 to 125 micron sieve, and would thus never expect to find Pequeño sitting on the 106 micron sieve.

Brad's job was to make sure that sieves meet the Calibration Sieve Category (the highest standard) and thus apply a sufficiently rigorous standard to his measurements. However, this certification still leaves a high probability of 168 micron holes on the #120 sieve.

Harry's job is to run the sieve tests to see if his product meets predetermined particle size distributions. This specification did not call for Pequeño to pass beyond #120 (125 micron) sieve.

It turns out that the ASTM standard that Brad certified left a lot of wiggle room for Pequeño's passage to a sieve specified as smaller than his natural size. This leaves Harry with some tough QC questions.



Chapter Three: Certification is Not Certain

We now rejoin the story after the violent shaking has stopped. Harry, the tester, removed the sieves from the stack and emptied the contents onto a balance to obtain a retained-weight distribution for each one. When they came to the 106-micron sieve, Pequeño and couple of his siblings did not drop onto the balance, because they were stuck -- wedged into some of the openings.

When the analysis was completed, Harry used a brush to remove any residual material in the 106-micron sieve. Almost everything was cleaned out, but Pequeño was among the particles that were still wedged into openings. Harry saw them on a visual check and gently pushed them out through the openings.

This unfortunately caused the mesh to spread, creating 150 micron openings in this 106 micron sieve -- much greater than the largest allowable opening of 141 that Brad, the Professional Sieve Certifier from the first chapter, certified.

For Harry's next test, Pequeño and his 150-micron siblings are used in a stack that includes the following sieves:

- #80 - 180 Micron
- #100 - 100 Microns
- #120 - 125 Microns
- #140 - 106 microns

It is likely that many of them will find their way through the 106-micron sieve and fall on to the next-smallest-size sieve screen. This additional transit is a result of the cleaning process. Most would assume, given that it is certified, that the 125 micron sieve would catch all of the 150 micron particles. Not so. Worse still, a number of these particles will now pass through the 106 micron certified sieve, which has nominal openings 30% smaller than Pequeño.

Harry, the QC Manager from Episode II, has always relied on the certification process to insure that his sieves would perform to high standards. He never evaluated the process from the view of a small particle with the mindset: "I want to get through every opening and do not care how much error I create."

Only after repeated tests indicated anomalies in the results would Harry suspect a problem with sieve performance. After he experienced Pequeño and his siblings' onslaught, Harry began to consider better methods of predicting and checking real-world sieve performance than certification.

Chapter Four: Calibration Microspheres

Here in chapter four, the final chapter of Pequeño's saga, we return to Harry, the QC Manager who has been experiencing problems with his sieving results. Inconsistencies, disputes with production, and customer complaints are plaguing him. He has been depending on his sieve certifications to insure that his test standards adequately assure correct and consistent results. (He had no idea that Pequeño and family were doing their mischief).

Harry checked with other colleagues in the sieve testing game and got advice ranging from performing his own microscopic sieve inspections to setting up master stacks to compare individual sieve performance.

Appropriate visual inspection requires an optical comparator (expensive, and tedious to operate) or sending the sieves out to be recertified (which removes the sieves out of service for several days). Even then, Harry was not sure that this would detect or identify his problem. (Pequeño felt that this would be good for his cause of getting through smaller than 150µ mesh, though!)

Harry was leaning toward a master stack that would allow him to check each sieve's actual performance against a standard he developed. Pequeño was concerned that his life may become more complicated.

As Harry investigated the best way to develop the master stack, he discovered calibrated microspheres designed to define mesh size over the entire sieve.

These calibrating spheres would let him easily check the actual operating characteristic of an individual sieve. This check results in a mean aperture number that clearly defines how a sieve operates.

As Harry analyzed further, he concluded that he could select his master stack sieves using calibration microspheres and check his production sieves against the master results.

As he continued to ponder how this would work, Harry realized that he would not need a master stack. He could set up a program to establish the mean opening of new sieves, check them again when he seemed to have inconsistent sieving results and thus pinpoint problem sieves.

When Harry launched this calibration program, Pequeño and his family had limited opportunity to get past the #100 sieves. Further, Harry now knows if Pequeño is riding high.

So, the answer to the title question is this:

Yes, sieve calibration really is the holy grail!

Epilogue

Yes, there really is a holy grail for ensuring consistent particle size analysis.

If you've been following along, you know this fact was proven by Pequeño and his family of 150 micron particles who tried to bust our friend Harry's quality control by attempting to slip through the mesh in Harry's test sieves and defeat sieve certification.

Now that we have indeed confirmed that, yes, sieve calibration really is the holy grail that sieve testers have been looking for, let's get to work and dive a little deeper. Let's examine some methods of sieve calibration.

Walk Like an Egyptian

Sieving has been around since the days of the Egyptians, who used a sieving system to measure and distribute grain. And although the reeds they used as mesh got the job done, I'm sure they'd appreciate how far technology has taken the sieve calibration process. I mean, we consider it the holy grail for sieve performance!

And today, growing pressure for ISO 9000 certification has put a heightened interest in methods of ensuring quality sieves. There are several proven methods of sieve calibration, but let's examine what really works and what doesn't.

Master Sieve Stack

One method is using a master stack of sieves that includes each sieve size used in your process.

1. Two samples of your material would be selected.
2. One sample would be shaken through the master stack, and the results calculated.
3. The, the second sample would be shaken through your working sieves (similar to the master stack), and these results would also be calculated.

By comparing results, you could check for variances between the master sack and working sieves, then replace any working sieves that are out of whack.

Sounds simple enough, right? Well, it is -- but it's not a magic bullet. It can sometimes be hard to get an exact match if any of the master sieves need replacing.

Master Samples
Another sieve calibration process it to create master samples of all the material that are subject to a sieve test. Working sieves are put on a sieve shaker and loaded with the selected sample of the master sample.

The shaker does its job -- and then how much of the material is retained in each of the sieves is looked at and measured. The results are studied for acceptable tolerances. Then, sieves are replaced that produced results outside these tolerances.

Sounds OK, but master samples are hard to maintain.

Neither of these two approaches really hits the mark and gives you an accurate reading of just which sieve is troublesome. What to do, what to do? Oh, wait. There is better way!

Sphere This.
Just as our friends Harry and Brad learned in the previous Pequeño saga, there is a solution to optimal sieve calibration. It's called Calibration with Microspheres.

Not only is it easy to do, but using these microspheres gives a truly objective measure of a sieve's performance and condition.

Calibration microspheres are created in exact sizes for the sieves that need to be calibrated. These beads can be used to accurately determine mean aperture for each sieve to be tested.

Let’s break down how it works:

1. Select a sieve to be calibrated, mount it on a receiver pan, and tare the combination.
2. Pour a vial of the appropriate microspheres into the sieve, weight it and record the weight.
3. Shake the sieve and receiver combo for a couple of minutes.
4. Empty the receiver.
5. Weight the sieve and empty receiver.
6. Using the difference in the weights calculate percent retained.
7. Find the percent retained on the chart and plot the mean aperture.

This approach works best, and it gives all working sieves a mean aperture number in microns, which can be a true predictor of performance.

The End

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