Aperture Testing of Sand Screens Using Calibration Microspheres

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Summary

This report describes the development of a new method for the direct measurement of aperture sizes in sand screens. Pivotal in the calibration process is a sonic sieving device that energises the microspheres to efficiently transport them through the filter mesh. From the percentage passing, a calibration graph supplied with the standard is used to determine the aperture size of the filter mesh. The analysis time is only 1 minute. Sampling variations both from a single roll and across several rolls were examined on 3 sand screen grades. The uncertainty of the method was less than 5%. This unique method provides a direct traceability to the International unit of length, both NIST and NPL

Key words: Filter testing, aperture size, pore size, calibration microspheres.

1. Introduction

Simple wire woven meshes such as test sieves are not difficult to calibrate because they are essentially 2-dimensional and light easily passes through the weave enabling direct measurement by microscopy. Complex 3-dimensional weaves however, are opaque and so cannot be analysed by the same method. An alternative to microscopy is the use of test dusts. However these have broad distributions and are not very accurate for determining a precise aperture size. Furthermore they are irregular in shape so calibration depends on having a uniform shape distribution as well as size distribution. A far more accurate method is to use narrow size distribution calibration microspheres which peak at the expected aperture size of the mesh to be analysed (figure 1).

By accurately measuring the particle size distribution both by microscopy and a precision sieving method, it is possible to construct a calibration graph for the microspheres where the percentage of the beads passing an unknown mesh can be used to calculate the mean aperture size (figure 2).

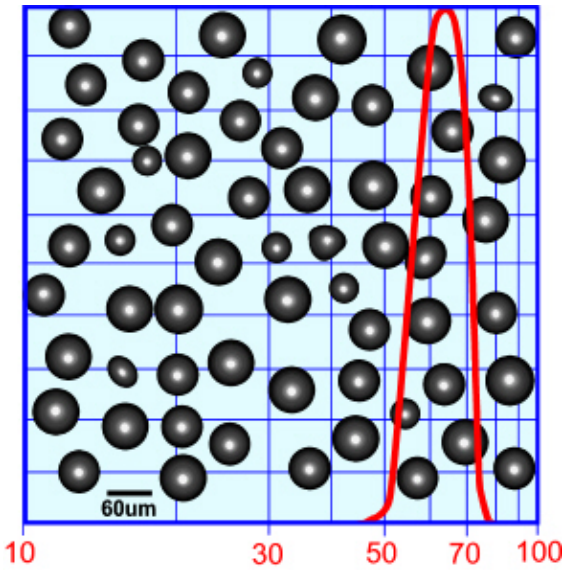

figure 1: 53 – 75µm calibration microspheres

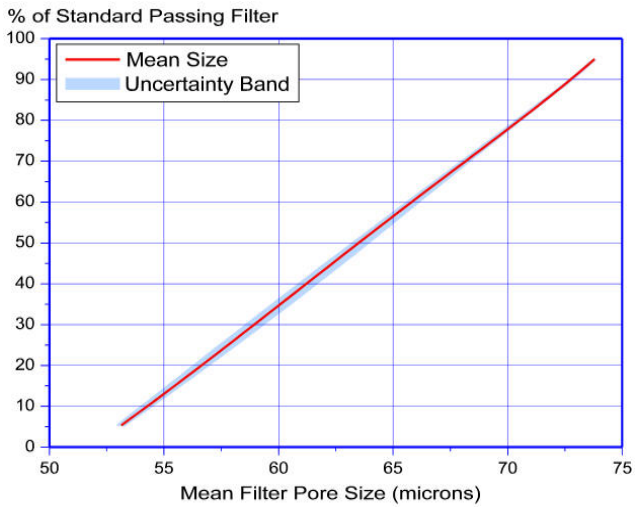

figure 2: 53 – 75µm microsphere calibration graph

2. Results

2.1 The Calibration Procedure

Whitehouse Scientific produces a range of 20 filter calibration microspheres for calibrating meshes from 16 to 600µm (see table 1) whose diameters are traceable to the International unit of length (NIST and NPL).

Table 1: Band Widths of Filter Standards (µm)

16-26	19-34	26-39	31-47	36-59
45-63	53-75	63-87	75-103	79-103
79-124	107-148	127-175	152-209	180-248
214-296	252-347	304-418	361-498	384-591

The first important requirement in calibrating a sand screen is to use an efficient method of transporting the beads through, what is effectively, a 3-dimensional mesh. Simple shaking by hand or even mechanical shaking is not an option because of the possibility of the tiny beads being lodged in 'blind alleys' in the mesh.

figure 3: The sonic filter tester (Gilsonic)

The Gilsonic Autosiever (figure 3) is a unique system that uses intense sonic energy to produce an oscillating column of air which flows through the body of the mesh. A tapping action helps to clear trapped particles within the mesh. This process energises the individual microspheres at rates of 3600 cycles per minute rather than mechanically shaking the mesh as in a conventional screening process – see figure 4.

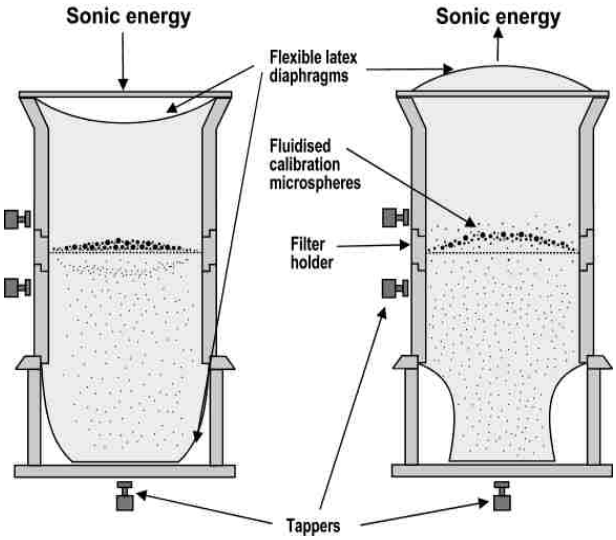

figure 4: Sonic sifting action

An on-board computer programmes the entire test sequence thus eliminating any operator bias – see computer control panel in figure 5.

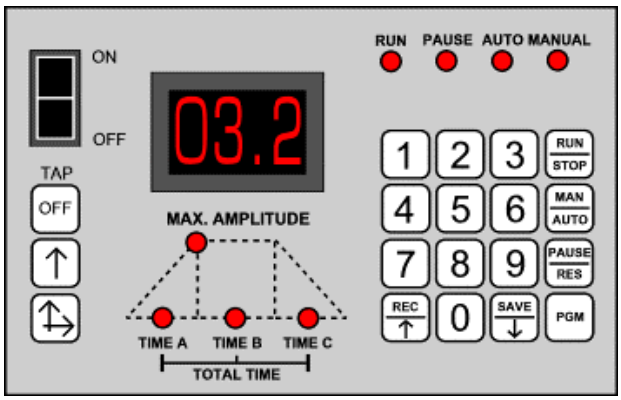

figure 5: Gilsonic AutoSiever control panel

To measure the average aperture size of a mesh, a 90mm diameter circle is cleaned in an ultrasonic bath for 5 minutes before being sealed onto a clear plastic ring to make a small sieve. The assembled sieve mesh is weighed to 1mg on an analytical balance.

About 0.5g of the calibrating microspheres are then weighed onto the mesh. The assembled mesh with the microsphere standard is then loaded onto the filter tester and a test run performed to determine the minimum amplitude of oscillation required to fluidise the microspheres evenly over the surface of the mesh. Ramp up and ramp down values refer to

the time taken to reach the maximum set amplitude and then to reduce to zero again.

A typical test sequence is as follows: Ramp up (A): 0.1minute, maximum. amplitude: 40, run time (B): 1 minute, ramp down (C): 0.1minute.

On completion of a test, the mesh and frame are removed and re-weighed to determine the percentage of microspheres passing. The mean aperture size can then be found from the calibration graph supplied with the test certificate, see figure 2.

2.2 Mesh variations in relation to the sampling position on the roll

The calibration or certification of the filter standards using highly accurate electroformed test sieves has been shown to be exceptionally repeatable with variations below 1% across the entire width of the size distribution (note: the uncertainty band in figure 2). On the more complex weaves, it is very important to establish the expected variations so that a measurement uncertainty can be ascribed to the aperture size. It is also important to assess the consistency of the weave in both warp and weft direction.

In the first repeatability experiment, three 90mm discs were cut close together from a stainless steel wire mesh of nominal aperture size 120µm and tested using a 107-148µm calibration standard. The average aperture sizes obtained were 121µm, 120µm and 119µm which were exceptionally close and within the 1% error bar of the standard.

The microspheres passing the mesh were then analysed by microscopy and image analysis (Whitehouse Shapesizer). The results in figure 6 show that microspheres up to 130µm actually passed the mesh so, although the average aperture size was about 120µm, there are some apertures up to 130µm in the mesh. In practice, the maximum aperture size measurement considerably increases the analysis time but it could be a useful addition to the average aperture size.

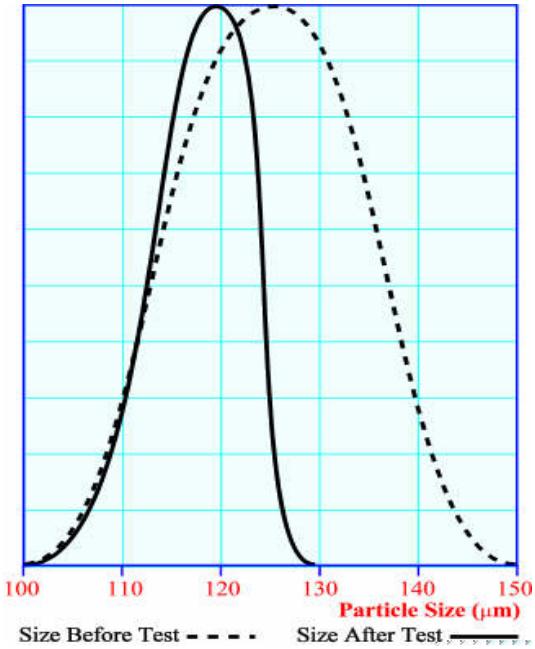

Figure 6: Particle size difference in microspheres after passing test mesh

The next experiment investigated the effect of the sampling position on the variability of the results on a 270µm mesh. A 214-296µm calibration microsphere standard was used in this experiment.

Two adjacent samples were cut from the edge of a 3 metre long section of mesh. The results in figure 7 show such close agreement that they are almost certain to be coincidental (more tests are required to establish the exact uncertainty of the method - see later). Samples were also taken down the length of the roll.

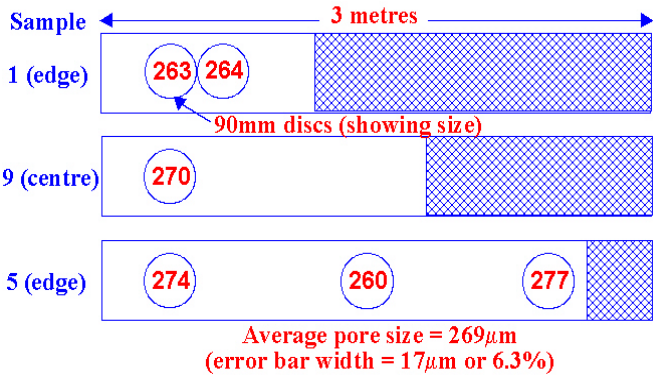

Figure 7: Effect of sample position on aperture size

The next series of experiments were performed on a tighter weave which had a nominal aperture size of 150 microns using the 127-175µm

calibration microspheres. Pairs of discs were taken across the webs of three different specimens.

The results in table 2 show that, when samples are taken which are physically close on the roll, the maximum difference in aperture size observed was approximately 5%. Thus, the repeatability of this method is usually less than 5%.

Table 2: Replicate testing across different meshes

Code	Position (left edge)	% Dif.	Position (middle)	% Dif.	Position (right edge)	% Dif.
A	148 & 149	0.7	146 & 150	2.7	146 & 142	2.8
B	141 & 144	2.1	139 & 138	0.7	147 & 145	1.4
C	152 & 151	0.7	137 & 144	5.1	143 & 142	0.7
Maximum difference observed = 5%						

2.3 Uncertainty calculations from random sampling

Having established that the size variations were approximately 5%, the next phase of the work was to examine the overall uncertainty from roll to roll by taking much larger samples.

25 random samples from 3 nominal sizes of 270µm, 230µm and 150µm were analysed. Figure 8. The results show excellent consistency in the measuring method and hence quality of the weaving process.

The results, summarised in table 3, show the overall mean values and the measurement uncertainty of the process.

Table 3: Uncertainty Calculations of the Sonic Filter Testing (25 samples)

Nominal Size µm	Measured Range µm	Uncertainty (2 x SD)	Final Size µm
270	263 – 283	12.4µm	272 +/-12.4 (4.6%)
230	225 – 240	6.8µm	231 +/-6.8 (2.9%)
150	143 – 154	6.0µm	147 +/-6.0 (4.1%)

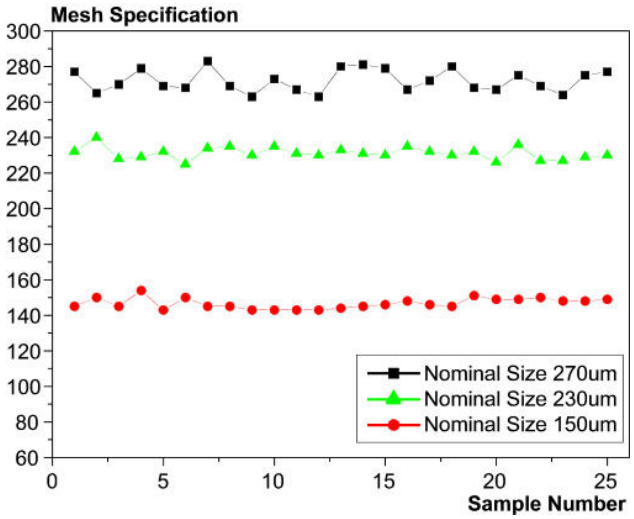

Figure 8: Size variations of sand screen meshes using the sonic testing method

3. Conclusion

The measurement of Sand Screen meshes using calibration microspheres has been shown to be a very accurate and repeatable method of analysis. The uncertainty of the measuring technique was less than 5%. This new method of measuring aperture sizes in complex weaves, unlike bubble point testing, is the only direct and absolute method to date that also gives high resolution. It is also easy to understand in that it relates to real particles passing through the meshes. Furthermore, it is the only method that is directly traceable to the International unit of length.