Grain Sieve Calibration - a method development

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1. Introduction

Traditionally, slotted sieves have been measured by Vernier callipers. However, the method has a large associated uncertainty band, which can result in disputes, particularly in the trading of grain. Although there are sieve calibration microspheres available for square holed sieves, the calibration graphs used do not apply to slotted sieves, because the calibrating microspheres are not 100% spherical. This review examines the accuracy of slotted sieves using a microscopic technique accurate to 0.01mm and then uses the sieves to recalibrate a narrow particle size distribution microsphere standard in terms of the first dimension or flatness. Once a new calibration graph has been produced, the standards can be used to calibrate an unknown slotted sieve.

2. Defining size

With the exception of spheres, every particle has three dimensions: height, width and length, described here as the 1st, 2nd and 3rd dimension respectively. A square holed sieve measures the 2nd dimension while a slotted sieve measures the 1st dimension, figure 1. The more non-spherical the particle, the greater the difference between the two methods of sieve analysis.

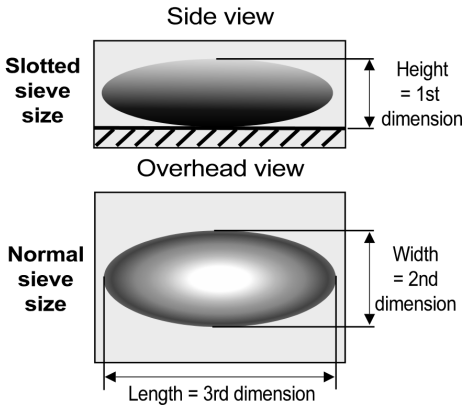

Figure 1. Slotted sieves measure a smaller dimension than square holed sieves

3. Calibrating a slotted sieve

Slotted sieves usually have 6 rows of slots mechanically punched through a stainless steel plate. The frames may be 200mm diameter or square. The work in this research examines circular sieves, figure 2. There are two potential sources of error: variations within an individual slot and variation from slot to slot.

A microscope and image analysis system was used to calibrate the slotted plates prior to assembly into frames. The measurements were traceable to international standards (NIST and NPL) and were accurate to 0.008mm for slots from 2.0 to 2.8mm nominal size.

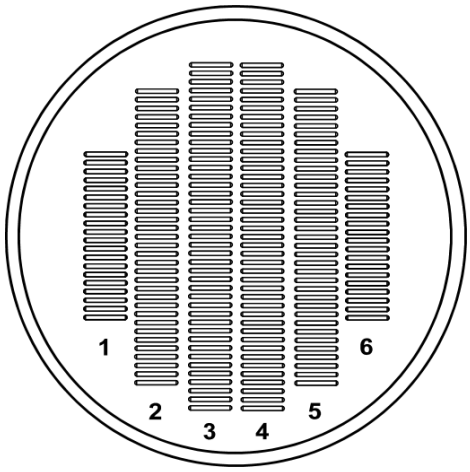

Figure 2. A 200mm diameter slotted sieve – rows numbered for analysis

3.1 Individual slot calibration

For each sieve used in the calibration of the microspheres, 4 slots were randomly selected across the diameter and measurements taken every 2mm down the 20mm length. The results for the nominal 2.5mm sieve in figure 3 show quite a large discrepancy within the slots, the worst case being slot 4 where the size varies from 2.34 to 2.45mm.

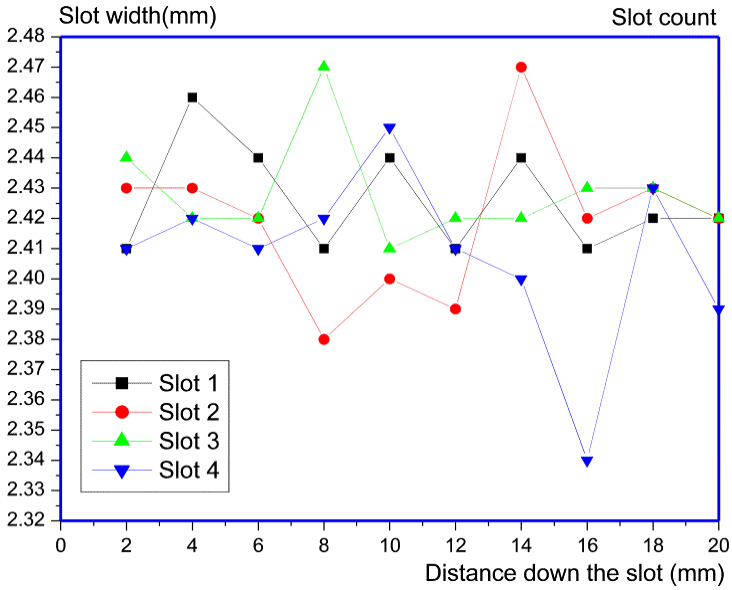

Figure 3. Width variation within individual slots

3.1 Analysis of 50 slots over the surface

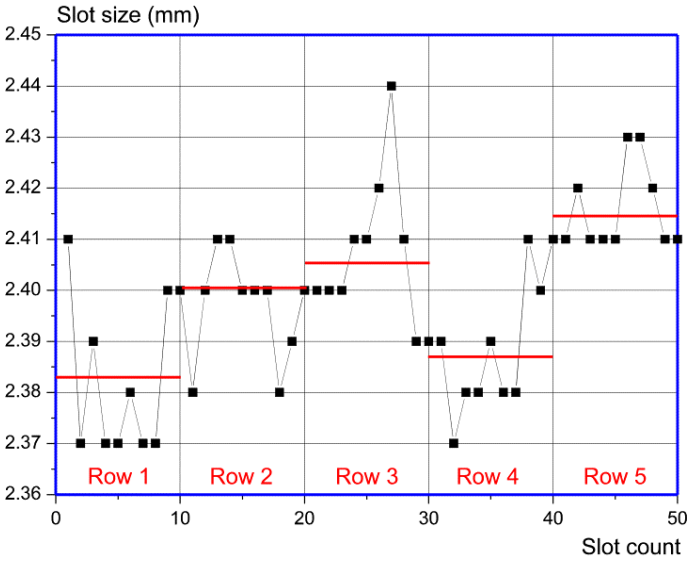

Figure 4. Analysis of 50 slot widths from 5 rows of a nominal 2.5mm slotted sieve

A single width measurement was taken at approximately the centre position from 5 out of the 6 rows of slots. The mean values (shown in red on the graph) vary from 2.38 to 2.41mm. This made the sieve considerably out of specification. To ensure that the calibration was correct a highly accurate ground glass ball of diameter 2.50mm was tested with a Mitutoya dial gauge accurate to 0.001mm. The result when analysed on the microscope was identical, confirming that there had been no error in the calibration against the NIST graticule.

Using this method, 4 slotted sieves were calibrated in preparation for measuring the size of a narrow particle size distribution glass microsphere standard. The results are shown in table 1.

Table 1. Size analysis review of 4 slotted sieves

Nominal sieve size (mm)	Row 1	Row 2	Row 3	Row 4	Row 5	Averages
2.80	2.78+/-0.02	2.79+/-0.02	2.78+/-0.01	2.78+/-0.02	2.77+/-0.03	**2.78+/-0.02**
2.50	2.38+/-0.03	2.40+/-0.03	2.40+/-0.03	2.39+/-0.02	2.41+/-0.02	**2.40+/-0.03**
2.20	2.14+/-0.03	2.13+/-0.02	2.13+/-0.03	2.16+/-0.03	2.16+/-0.02	**2.15+/-0.03**
2.00	1.99+/-0.03	1.97+/-0.02	1.97+/-0.02	1.97+/-0.03	1.97+/-0.03	**1.97+/-0.03**

4. Preparation of the microsphere standard

A narrow size distribution range of glass microsphere was prepared by sieving between 2.80mm and 2.00mm woven wire sieves of diameter 450mm. The master batch was then subdivided on a spinning riffler to produce individual bottles containing approximately 20g.

5. Microsphere calibration

The sieve plates from table 1 were then mounted into frames and a stack assembled so that all the slots were pointing away from the operator. A single bottle of microspheres was poured onto the top sieve and shaken for 1 minute as described in figure 5. The frame was not tapped nor the beads forced through in any way. The percentage of the beads on each sieve was then calculated.

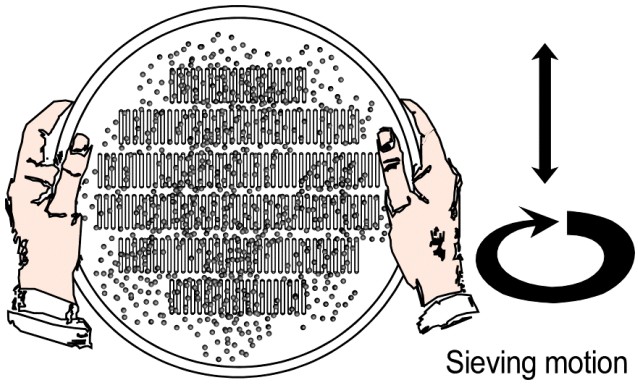

Figure 5. Sieving action to roll the beads over the slots

5.1. Repeatability on the same sample

Analysis of the same bottle was performed 5 times to see if there was any difference resulting from the presentation of different beads to different slots. The results in table 2 show remarkable repeatability with a maximum uncertainty of only 1.2%.

Table 2. Repeated analysis of the same sample

Sieve size(mm)	Test 1	Test 2	Test 3	Test 4	Test 5	Average (%)
2.78	97.9	98.3	98.3	98.5	98.4	**98.3+/-0.4**
2.40	66.5	65.8	65.8	66.8	66.2	**66.2+/-0.9**
2.15	27.0	26.2	25.9	26.1	25.4	**26.1+/-1.2**
1.97	4.2	4.0	4.0	4.3	3.5	**4.0+/-0.6**
Pan	0	0	0	0	0	0
Recovered (%)	100	100	100	100	99.6	

5.2. Repeatability on 5 different samples

When 5 different bottles of the calibrating microspheres were analysed, the uncertainty of analysis only rose to 3.6%, table 3.

Table 3. Repeatability of 5 analyses on different samples

Sieve size(mm)	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Average (%)
2.78	98.6	99.5	98.6	97.9	97.7	**98.5+/-1.4**
2.40	71.3	69.8	70.0	66.5	69.1	**69.6+/-3.6**
2.15	29.6	28.3	26.9	27.0	26.9	**27.7+/-2.4**
1.97	4.4	4.5	4.0	4.2	4.6	**4.3+/-0.5**
Pan	0	0	0	0	0	
Recovered (%)	100	100	100	100	100	

6. Construction of the microsphere calibration graph

The data from table 3 was used to construct a calibration graph, which can then be used to calibrate an unknown slotted sieve, figure 6.

The central green area is the recommended zone for maximum accuracy. It can be seen that the method can precisely distinguish slots that differ by only 0.05mm.

The relationship between the percentage passing and the slot size can also be expressed as a formula for use in spreadsheet calculations.

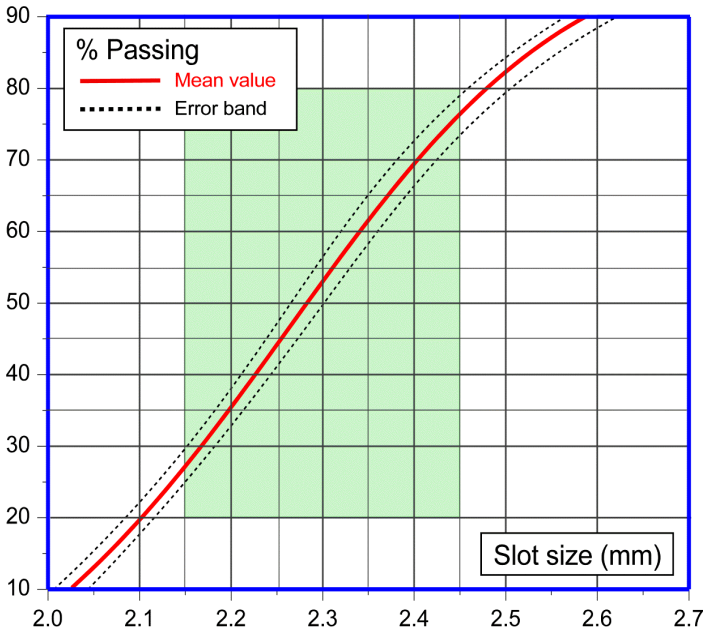

Figure 6. A calibration graph for a slotted sieve

7. Calibrating a slotted sieve

To calibrate a slotted sieve, simply choose a calibration bead in the correct particle size range and pour the complete contents of the bottle onto the sieve. Shake for 1 minute as illustrated in figure 5 without tapping the frame or forcing the beads through in any way. From the percentage of beads passing the mean slot size can be read off from the calibration graph on the certificate supplied with each bottle of standard (see attached).

8. Conclusion and recommendations

This new method of approaching the calibration of slotted sieves has shown great potential in that it can measure slot sizes to 0.05mm in about 1 minute. The method is very repeatable and the results can be traced back to American or European International units of length (NIST and NPL).

A surprising observation from the work was that some of the sieves used to calibrate the microspheres were well out of specification. Furthermore, the uniformity of the individual slots and the variation in slot sizes within a sieve was questionable. This meant that the master set of calibrated sieves had a significant uncertainty about the mean size. For example the nominal 2.5mm sieve was in fact 2.40+/0.03mm.

There are two possibilities of decreasing the uncertainty of the measurement below the present 0.05mm. Firstly, using calibration slots that have a higher tolerance, ideally below 0.01mm, and secondly by using an even narrower particle size distribution glass bead where large differences in percentages passing only result in small changes in the interpolated slot size. Both these options are currently being evaluated.