The Basic Principles of Sieve Analysis

Introduction

Many natural and manufactured materials occur in a disperse form, which means that they consist of differently shaped and sized particles. The particle size distribution, i.e. the number of particles of different sizes, is responsible for important physical and chemical properties such as:

- mechanical bulk behavior
- surface reaction
- taste
- miscibility
- filtration properties
- conductivity

This list could be continued at great length. The examples clearly show how important it is to have a knowledge of the particle distribution, particularly within the context of quality assurance in the production of bulk goods. If the particle distribution changes during the manufacturing process then the quality of the finished product will also change. Only a continuous monitoring of the particle size distribution can guarantee a constant product quality.

Particle size determination methods

There are different methods for determining the particle distribution. The choice of a particular method depends primarily on the dispersion status, i.e. on the degree of fineness of the sample.
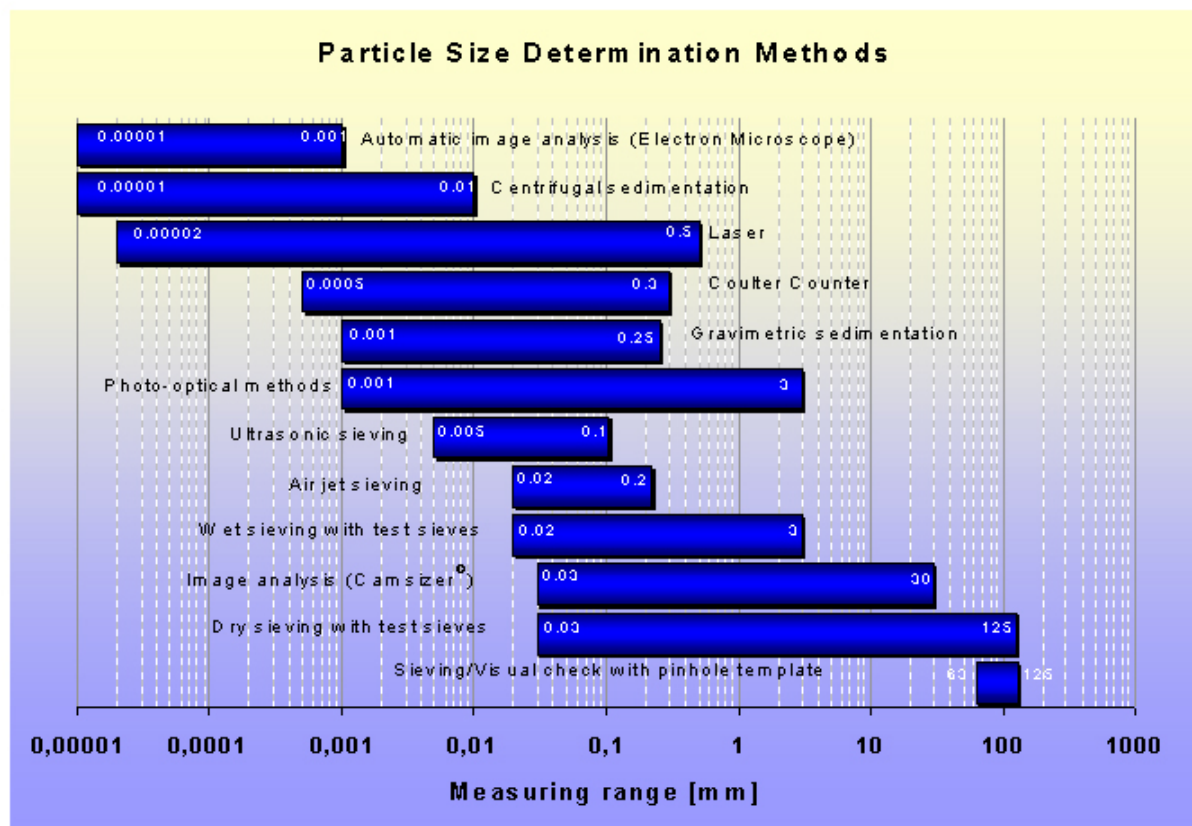

Fig. 1: Particle size determination methods

The oldest and best-known method is particle size determination by sieve analysis. The particle size distribution is defined via the mass or volume. Sieve analysis is used to divide the granular material into size fractions and then to determine the weight of these fractions. In this way a relatively broad particle size spectrum can be analyzed quickly and reliably.

What happens in a sieve analysis?

During sieving the sample is subjected to horizontal or vertical movement in accordance with the chosen method. This causes a relative movement between the particles and the sieve; depending on their size the individual particles either pass through the sieve mesh or are retained on the sieve surface. The likelihood of a particle passing through the sieve mesh is determined by the ratio of the particle size to the sieve openings, the orientation of the particle and the number of encounters between the particle and the mesh openings.

As explained later, the likelihood of passage and therefore the associated quality of the sieved sample also depends on the sieve movement parameters and the sieving time.

The different sieving methods

Depending on the material and the demands placed on the sieving result, various sieving methods are used for determining particle size and distribution. A basic differentiation is made between the following methods:
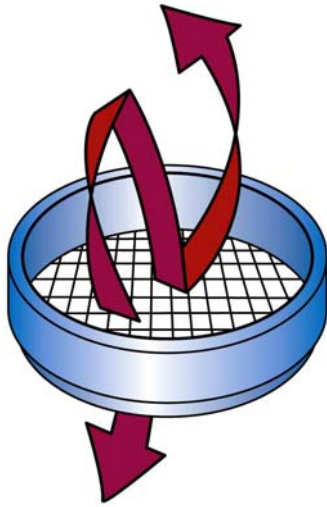
1. Manual and mechanical sieving

Today, manual sieving is only used where no electricity supply is available, e.g. for rapid on-site random checking for oversize and undersize. It is only used for orientation purposes.

In contrast, sieve analyses in the laboratory and for quality assurance are carried out with sieve shakers. Modern sieve shakers are characterized by the fact that their mechanical parameters, such as sieving time and amplitude or speed, are carried out with exact reproducibility. In the laboratory a differentiation is made between horizontal sieve shakers and throw-action sieve shakers.

Fig.2: Retsch Sieve Shakers AS 200 and AS 300 control

1.1 Throw-action sieving

Throw-action sieve shakers are also known as vibratory sieve shakers. An electromagnetic drive sets a spring-mass system in motion and transfers the oscillations to the sieve stack. The sample is subjected to a 3-dimensional movement and is distributed uniformly across the whole area of the sieve. The amplitude can normally be set continuously in the range from 0-2 mm or 0-3 mm.

Modern instruments, like the AS 200 control and AS 300 control from Retsch, additionally enable the required amplitude to be entered digitally. During the sieving process, a built-in measuring system and control unit performs a continuous comparison between the set and actual amplitude values. This provides the optimal preconditions for reproducible sieving parameters. Digital accuracy for the sieving time and the interval function is a matter of course.

Fig.3 : In throw-action sieving the sample is subjected to a 3-dimensional movement.

1.2 Horizontal sieving

In a horizontal sieve shaker (e.g. Retsch AS 400 control) the sieves move in horizontal circles in one plane. Horizontal sieve shakers are preferably used for needle-shaped, flat, long or fibrous samples, as their horizontal orientation means that only a few disorientated particles enter the mesh and the sieve is not blocked so quickly. The AS 400 control permits the use of test sieves with a diameter up to 400 mm. The large sieving area makes it possible to sieve large amounts of sample, for example as encountered in the particle size analysis of construction materials and aggregates.
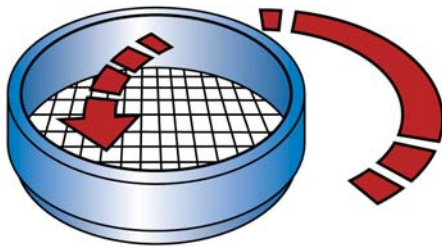

Fig. 4: In horizontal sieving the sample moves in horizontal circles.

In addition, in the fine particle size range and for obtaining single fractions, ultrasonic and air-jet sieving are used for special applications.

2. Single sieve and sieve set sieving

The use of a single sieve, frequently also known as sieve cut, is only used to determine the percentage of undersize and oversize particles. Particle size distribution in the normal sense is not carried out. In a single sieving process, only a single sieve with a defined mesh is subjected to the sieving movement together with a collector pan. It is normally used only for orientation purposes.

Sieve set sieving is the process in which a set of several sieves is used together with a collector pan. The tests sieves are arranged in a stack with the largest mesh openings at the top of the stack. The sample is placed on the top sieve.

3. Dry and wet sieving

Most sieving processes are carried out on dry materials. However, there are many applications in which wet sieving cannot be avoided, e.g. when the material to be tested is already present as suspension or when a very fine sample that tends to agglomerate has to be sieved.

As in dry sieving, a sieve stack is assembled on a sieve shaker. The sieving process is additionally supported by water from a spray nozzle located above the uppermost sieve. The sample is placed on the uppermost sieve in the form of a suspension. Rinsing is carried out until the sieving liquid leaving the sieve stack outlet is no longer turbid with solid particles. In wet sieving, the sieving liquid must not alter the physical or chemical properties of the sample.

How can an optimal sieve analysis be carried out?

Various preconditions must be fulfilled for a reproducible and meaningful sieve analysis and the settings must also be properly adapted to suit the particular problem. The most important criteria are briefly described below.

Representative part-sample

The most important requirement for a reproducible sieve analysis is to obtain a representative partial sample from the whole of the bulk material to be tested.

'Representative' means that the properties of the part-sample, in this case the particle distribution, must be identical to the properties of the whole bulk material to be sampled. If this requirement is not fulfilled, then the results of the sieve analysis can only be applied to the particular part-sample.

The amount of sample depends primarily on the maximum particle size, the number of sieves in the sieve stack and their openings. The sieves must not be overloaded. For a sieve with a diameter of 200 mm and 2 mm mesh the amount of sample should not exceed a volume of 200 ml (e.g. 300 g sand). For a mesh of 0.5 mm, the limit is 80 ml, for a 0.125 mm sieve 40 ml. Further information can be found in DIN 66 165.

Calibrated and certified test sieves

Standardized sieves in accordance with ISO 3310 or ASTM E11 are normally used for a sieve analysis. These standards describe the technical requirements for the sieves and methods for checking them.

The choice of test sieve (diameter and mesh) depends mainly on the amount of sample and its particle size distribution. The number of sieves and the steps between the nominal mesh openings should be selected so that as much as possible of the whole range of sizes contained in the sample is separated into fractions. Information about this can also be found in the main and secondary series of ISO 3310 and ISO 565.

Although the majority of the sieves used have a diameter of 200 mm or 203 mm/8", sieves with a diameter of 100 to 400 mm are also used.

At the customer's request the manufacturer can provide an acceptance report or a test sieve calibration certificate. The latter is particularly important if the test sieve is to be calibrated within the context of test agent monitoring.

Optimal sieving time and amplitude or speed

The settings for the sieving time and the optimal amplitude or speed depend on the material to be sieved. National and international standards, internal regulations and standards normally provide detailed information about product-specific sieve analyses and their associated sieving parameters. The instruction manual for the sieve shaker should also provide guidelines for this.

If this basic information does not exist then the sieving time and amplitude or speed must be determined experimentally. This is done by first selecting a relatively short sieving time (e.g. 5 min) and carrying out sieving at various amplitudes or speeds to determine at which values the largest amount of sample passes through the sieves (optimal sieving quality). An initial approximate value for the amplitude can be obtained by observing the sample movements. These should not be too weak (the sample will not be adequately loosened up) and not too strong (the particles "float" and have no chance of passing through the mesh).

In the next step sieving is carried out with different sieving times at the amplitude or speed determined above. When the weight of the material passing through the sieve in one minute changes by less than 0.1% of the sample amount (DIN 66 165) the optimal sieving time has been achieved.
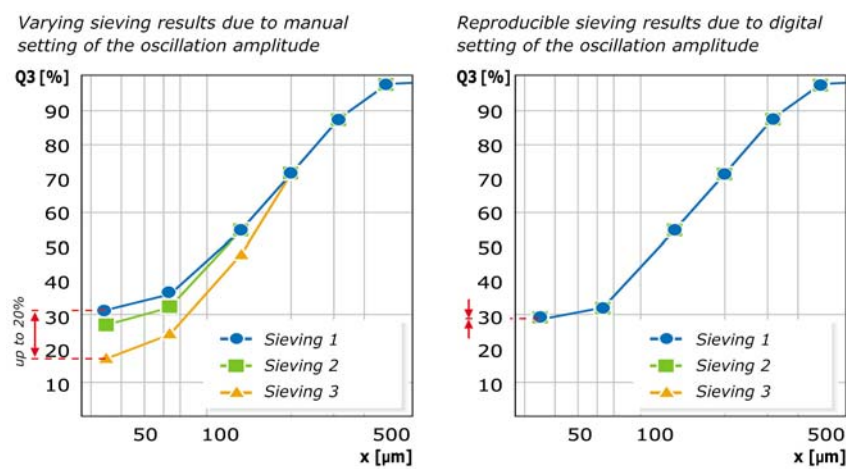

Fig. 5: Manual and digital setting of the amplitude and the effect on the sieving results

Sieving aids

Sieving aids are used for very fine samples that tend to adhere together. They are used to make the sample sievable. A differentiation is made between mechanical sieving aids (e.g. rubber cubes, brushes, balls, chains) for eliminating molecular adhesive forces, and additives (e.g. talcum, Aerosil®) for greasy, sticky and oil-containing products. Antistatic sprays reduce electrostatic charges, surfactants reduce the surface tension in wet sieving.

Fig.6 : Chain ring and rubber cubes are typical sieving aids

Error-free evaluation

Evaluation takes place when the sieving process has finished. The sample residues in each test sieve are determined by weighing and are then assigned as a percentage of the sum of the individual fractions. The difference between the original sample weight and the sum of the individual fractions is the sieving loss. If this is greater than 1% then, according to DIN 66 165, the sieving process must be repeated.

The results of the evaluation can be shown graphically and in tabular form. As can be seen from Figure 5, the fractions (p_3) are normally shown as a histogram (bar graph) and the cumulative frequency curve (Q_3) from the percentage mass fractions is plotted against the nominal sieve mesh (x). In this example 19% of the sieved material has a particle size between 0.063 mm and 0.125 mm. From the cumulative frequency curve, for example, it can be seen that 67% of the material is smaller than 0.250 mm.
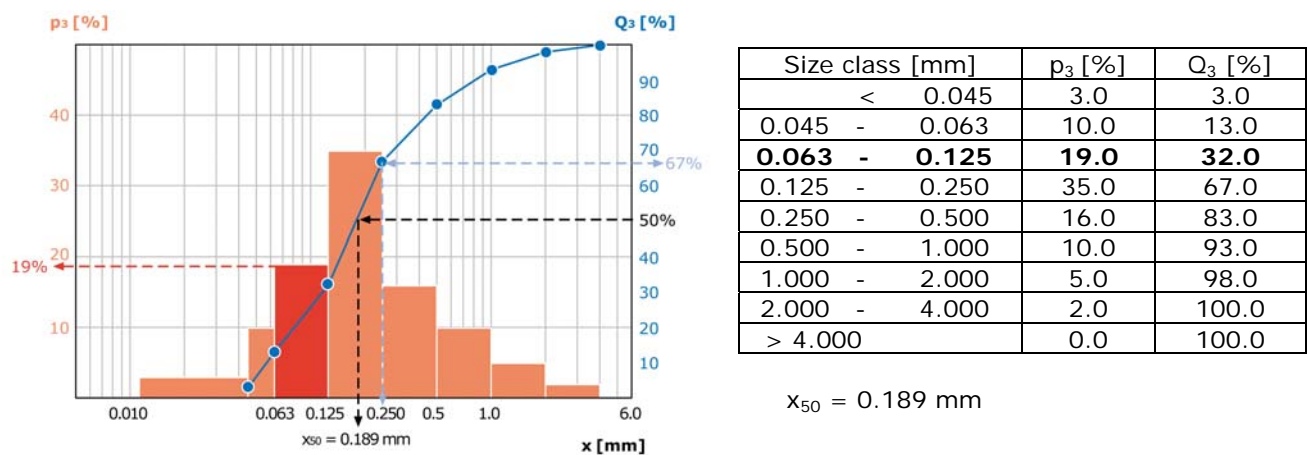

Size class [mm]		p_3 [%]	Q_3 [%]
<	0.045	3.0	3.0
0.045 -	0.063	10.0	13.0
0.063 -	**0.125**	**19.0**	**32.0**
0.125 -	0.250	35.0	67.0
0.250 -	0.500	16.0	83.0
0.500 -	1.000	10.0	93.0
1.000 -	2.000	5.0	98.0
2.000 -	4.000	2.0	100.0
> 4.000		0.0	100.0

$x_{50} = 0.189$ mm

Fig. 7:
Fractions p_3 (left-hand y-axis) and cumulative frequency curve Q_3 (right-hand y-axis)

Frequently used characteristic features can be calculated from the result, for example the x_{50} value, which defines the median particle diameter of the sieved particle fraction; in the example shown above it indicates that 50% of the sample is larger or smaller than x=0.189 mm.

PC-supported programs for evaluating sieve analyses work very quickly and reliably, eliminate calculation and graphics errors and meet the requirements of modern quality management systems (DIN EN ISO 9000ff). In contrast, manual evaluation is very time-consuming and also the risk of operator and random errors is large.

Professional evaluations are offered, for example, by the EasySieve® software from Retsch. It communicates with the sieve shaker and the balance and gives the user simple instructions for each particular working step. The calculated sieve analysis result is available directly after the end of the sieving process. The result is presented in a well-laid-out, standardized measurement protocol.

Final remarks

Analytical sieving is used in the R&D sector, for quality control of raw materials, intermediate and finished products as well as for production monitoring. Despite new developments in the field of optical particle measuring instruments it remains a proven, reliable and inexpensive method for determining the particle size. However, the result of a sieve analysis is only meaningful and reproducible when the preconditions described above are fulfilled. Modern sieve shakers with digital settings, such as the AS-control series from Retsch, supported by a powerful evaluation software, allow for exact sieving results that are reproducible throughout the whole world.

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Annex

Short glossary of sieve analysis

Test sieving
Test sieving is a sieve analysis for determining whether the distribution of the particle sizes in a sample fulfills certain requirements.

Sieve passage
The sieve passage is the fine material that passes through the sieve during a sieve analysis.

Sieve residue
The sieve residue is the coarse material that remains on the sieve after a sieve analysis.

Sieving loss
The sieving loss is the difference in weight between the original sample and the sum of the recovered fractions. According to DIN 66 165 part 1 it should not exceed 1% of the original sample weight.

Relative open sieve area
The relative open sieve area is the sum of all the open mesh areas of the sieve relative to the total area of the sieve.

Available open sieve area
The available open sieve area is the sum of the open mesh areas of the sieve that have not been blocked.

Cut sharpness
The cut sharpness characterizes the quality of the sieving into individual fractions.

Equivalent diameter
In sieving the equivalent diameter of a particle is the diameter of a sphere with the same mass or volume.

Undersize
Mass fraction below a defined cut point.

Oversize
Mass fraction above a defined cut point