Retsch Technology
Solutions in Particle Sizing

the sample

Verder Scientific Customer Magazine| Issue 42

part of VERDER scientific

DYNAMIC IMAGE ANALYSIS

Particle characterization of powders, granules and suspensions in a size range from 1 µm to 30 mm

Dear readers, customers and business partners,

Every particle analysis technique has its typical application areas, but each type also has advantages and disadvantages when compared with other methods. In this special issue of the VERDER SCIENTIFIC customer magazine "the sample" on particle characterization we present RETSCH TECHNOLOGY's product range for Dynamic Image Analysis (DIA) and give an overview of the most important measuring techniques.

RETSCH TECHNOLOGY is the only worldwide supplier of DIA, laser diffraction and sieve analysis equipment with an extensive understanding of the advantages and disadvantages of each method.

We are also pleased to present the new CAMSIZER generation in this issue: CAMSIZER P4 provides faster cameras with higher resolution, a brighter light source and new software features. These improvements increase the measurement accuracy and extend the measuring range as the higher resolution provides a more precise size and shape analysis, particularly of small particles.

Also, the strengths and weaknesses of the different measuring techniques are compared to give you a valuable aid in deciding which method is best suited for your individual requirements.

If you are looking for the best solutions in particle characterization, contact us!

Your

Dr. Jürgen Pankratz
Director VERDER SCIENTIFIC

Particle Ch

with Dynamic Image Analysis

Dynamic Image Analysis (DIA) is a modern high-performance method for the characterization of particle size and particle shape of powders, granules and suspensions. RETSCH TECHNOLOGY's optical analyzers CAMSIZER P4 and CAMSIZER XT are based on this technology, covering a measuring range from 1 µm to 30 mm. Dynamic Image Analysis is used in many industries for quality control as well as in research & development. It increasingly replaces more established methods such as laser diffraction or sieve analysis.

HIGH RESOLUTION SIZE AND SHAPE ANALYSIS FROM 1 MM – 30 MM

Imaging techniques have a number of advantages over traditional methods such as sieve analysis or laser diffraction. **Measurements are carried out on every single particle image resulting in the detailed determination of a variety of size and shape parameters.** Thanks to the ability to analyze, for example, length, width, roundness or angularity of particles DIA provides much more information than alternative methods.

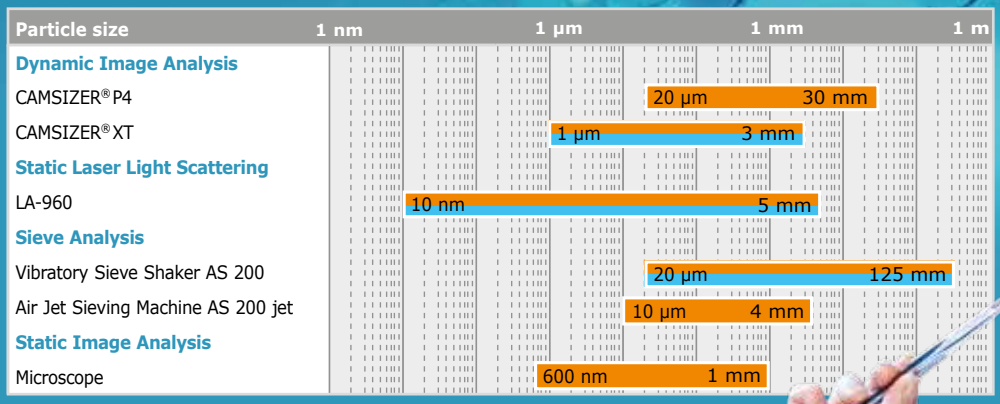
Analyzers based on DIA are generally equipped with an optical system consisting of cameras, objective lenses and light sources as well as a sample feeding system. The particles are captured by the cameras as "shadow projections" while moving between light source and camera. An essential prerequisite is a finely tuned optical system with strong light sources and short exposure times, and high-performance software – the cameras of the CAMSIZER analyzers take more than 270 images per second which are evaluated in real time. The average measurement time is 2 to 5 minutes, which corresponds to several million single particles.

SAMPLE VOLUME

A representative sample volume is required to obtain meaningful analytical results. It depends on the particle size and the distribution width – with increasing size and width, the sample volume also increases. For fine powders with particle sizes of a few microns, a few milligrams of sample are sufficient to provide reliable results due to the large number of particles. For gravel, broken ores or coal, however, several kilograms are required. Sampling and sample division are essential for accuracy and should, therefore, be carried out with the same thoroughness as the actual analysis. The use of sample dividers (such as RETSCH's PT 100 rotating sample divider) is strongly recommended, par-

aracterization

MEASUREMENT RANGES OF VARIOUS METHODS

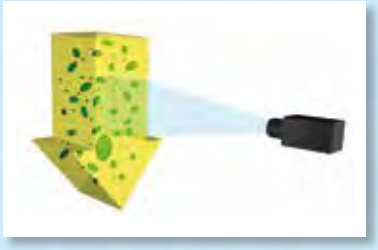


ticularly for samples with a wide particle size distribution. The reliability and repeatability of the results increase with the quantity of sample material. Compared to other particle measurement techniques, such as laser diffraction or static image analysis (microscopy), DIA usually analyzes a relatively large amount of sample which is a clear advantage.

Comparison static and dynamic image analysis

STATIC (ISO 13322-1)

- **Particles do not move during measurement**
- **High resolution > 0.5 µm**
- **Analysis of a few hundred particles (not statistically sound)**
- **Limited measuring range < 1 mm**
- **Time-consuming**
- **Particles are detected in stable orientation (2 dimensions)**



DYNAMIC (ISO 13322-2)

- **Particles are captured in motion relative to camera**
- **Resolution > 1µm**
- **Analysis of a few million particles (representative mixture)**
- **Wide measuring range up to 30 mm**
- **Fast**
- **Particles measured in random orientations (3 dimensions)**

DYNAMIC IMAGE ANALYSIS

From particle image to size distribution

DIA analyzes the shadow projections of particles. Both the CAMSIZER P4 and CAMSIZER XT transform grayscale images through a multistep algorithm into binary images to determine the exact outlines. All size and shape parameters are measured on this basis. The values of the single measurements are assigned to 10,000 size classes during the measurement, providing an extremely high resolution.

SIZE AND SHAPE PARAMETERS OF DIA

Imaging methods offer the crucial advantage of using various size definitions, allowing for direct length and shape measurement. Depending on the application, a variety of size parameters may be of interest. If, for example, elongated particles such as cellulose fibers, catalyst rods, plastic extrudates or rice grains are analyzed, the length of the particles is the relevant parameter. If, however, the sample needs to be compared to a sieve analysis, the focus is on particle width as the particles' orientation allows them to pass the sieve apertures with their smallest projection area. In DIA particle size distributions are based on different size definitions. The parameter $x_{c\ min}$ defines the particle width, $x_{Fe\ max}$ describes the length. Consequently, the $x_{Fe\ max}$ result is bigger than $x_{c\ min}$. The size definition x_{area} is based on the calculation of a circle with equivalent surface from each particle (see fig. 1, green curve).

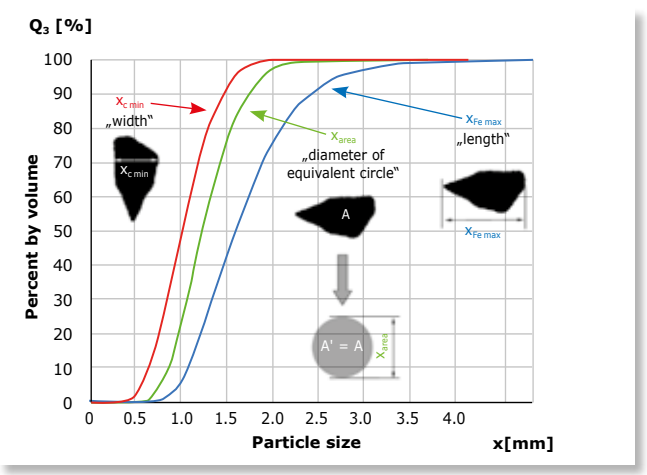


Fig. 1: Different size definitions of DIA

MEASURING RANGE

The lower and upper limits of the measurement range of image analysis systems are determined by various factors (see ISO 13322-1 and -2). The lower limit is defined by the resolution of the camera. The decisive criterion is the smallest particle size which the optics can still reproduce on a single pixel (= picture element) on the camera chip. The reproduction scale is ascertained with the help of calibration objects with exactly defined dimensions. The smallest measurable particle shadows at least half a pixel on the camera chip and this size is usually defined as the detection limit or lower limit of the measuring range.

The upper limit of the measuring range of DIA analyzers is determined by the field of view of the cameras.

Particle projections on the edge of the field of view have to be rejected because the correct particle size cannot be determined (fig. 3). This results in larger particles being underrepresented as they are more likely to be located near the edge. The software of the CAMSIZER systems features an algorithm in accordance with ISO 13322-1 which compensates for this effect, which ensures that the percentage of large particles is correctly represented.

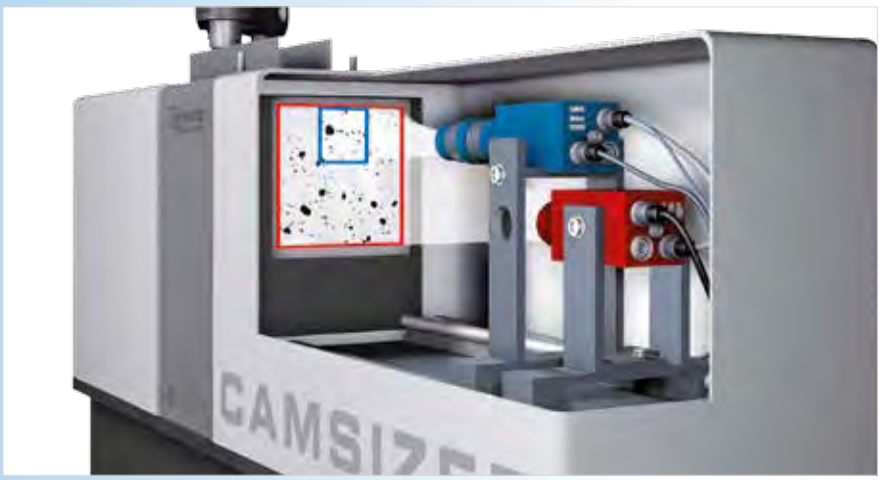


Fig. 2: Dual Camera Technology CAMSIZER P4

Fig. 3: The upper limit of the measuring range of a camera is determined by the likelihood of a large particle being completely visible in the field of view.

This corrective function is reliable up to a particle size of 1/3 of the camera's field of view. Larger particles can hardly ever be measured in a meaningful way and only if a large sample quantity is available.

DIA systems are usually limited to a dynamic size range - approx. factor 50 between smallest and largest particle. However, as most particle distributions and product portfolios cover a much wider range, either the coarser or finer fraction is not adequately represented. To correctly measure particle size distributions by imaging it would theoretically be necessary to carry out various measurements with different camera resolutions and combine these arithmetically. For the CAMSIZER family this problem is solved by the **patented dual camera technology** (fig. 2): two cameras with different image scales simultaneously detect the particles. A zoom camera with a smaller field of view and a basic camera with a larger field of view at a lower resolution are linked by the software to allow for **evaluation of wide particle size distributions in one measurement**. Therefore, it is possible to cover a size range of three decades and produce reliable measurement statistics.

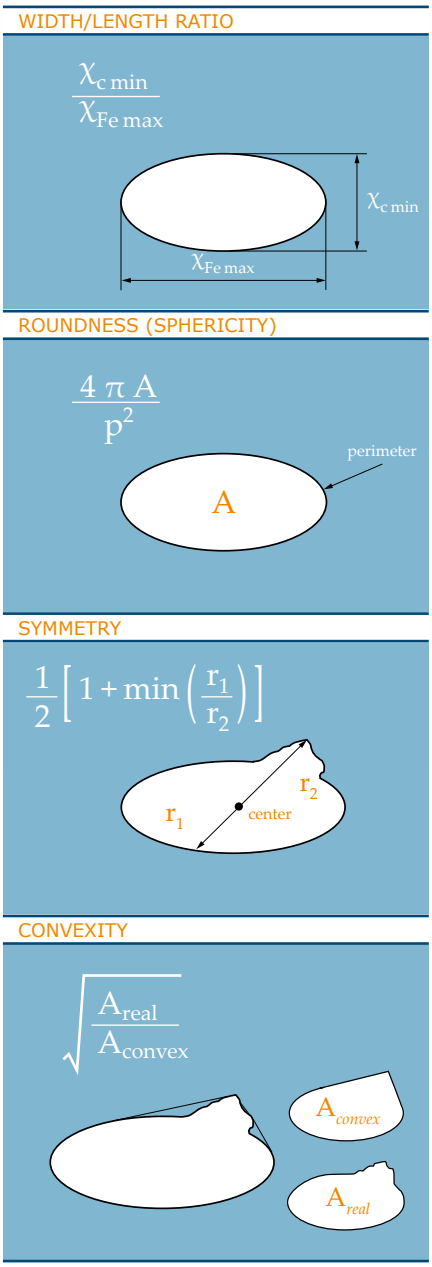


Fig. 4: In addition to different size definitions, a variety of shape parameters can be determined to evaluate the product quality. The figure shows the most relevant shape parameters.

CAMSIZER® P4

dual camera technology

The new generation in Dynamic Image Analysis

CAMSIZER P4 is the latest generation of the well-proven CAMSIZER system which – with more than 1,000 installations worldwide - is one of the most successful instruments for particle characterization with Dynamic Image Analysis. CAMSIZER P4 offers comprehensive characterization of particle size and particle shape of dry, pourable bulk goods in a size range from 20 µm to 30 mm. Thanks to the patented Dual Camera Technology no adjustments of measuring range or hardware are required. The extremely bright LED stroboscope light source, short exposure time, and a frame rate of 60 images per second allow for particle images with the highest resolution, which ensures consistent quality control. And the typical measuring time is only 2 to 3 minutes! The high-performance CAMSIZER software rapidly and precisely determines a huge variety of size and shape parameters and makes CAMSIZER P4 an indispensable tool for applications in research & development and quality control. Routine operations can be optimized by using an Autosampler or by integrating the analyzer into the process line.

In addition to the proven CAMSIZER functions, the fourth generation features the particle library CAMSIZER X-Plorer to store and evaluate individual images, 3D scatterplots and new shape parameters (angularity).

TYPICAL APPLICATIONS

- Abrasives
- Catalysts
- Chemicals
- Coal/coke
- Coffee
- Construction materials
- Fertilizer
- Food
- Glass/ceramic
- Metal powder/ silicon
- Pesticides
- Pharmaceutical products
- Proppants
- Refractory products
- Proppants
- Salt/sugar
- Sand
- Washing powder
- Wood chips

CAMSIZER P4 is the fourth generation of the CAMSIZER product family. Essential improvements compared to the previous model include:

- Brighter light source
- Better contrast
- Higher camera resolution
- More depth of sharpness
- Extended measuring range
- Improved shape analysis
- Particle library CAMSIZER X-Plorer
- 3D scatterplots

New Possibilities

NEW: PARTICLE LIBRARY CAMSIZER X-PLORER

In addition to the evaluation of size and shape parameters in real time, the new data structure of the CAMSIZER software permits the storage of large volumes of image data directly in the particle library.

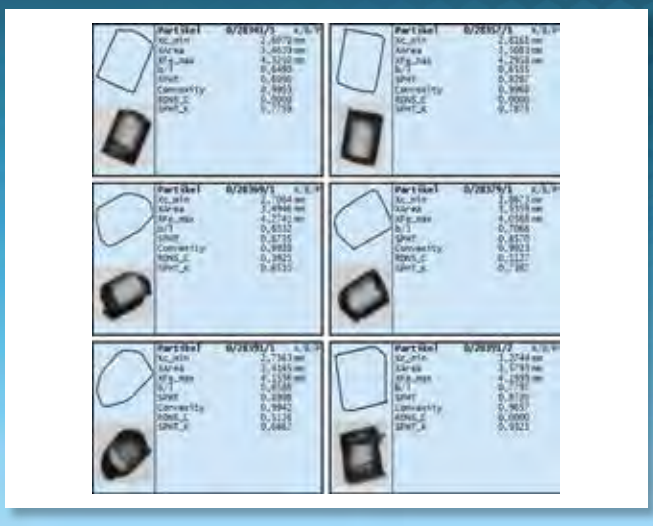


Fig. 1: Excerpt from CAMSIZER Xplorer: plastic extrudates

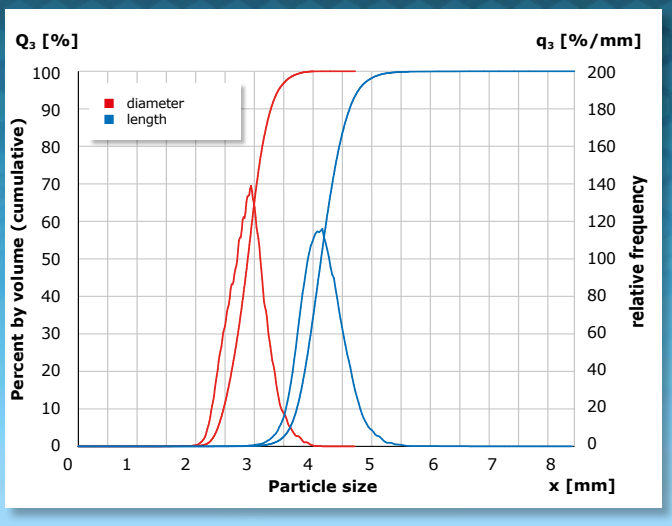


Fig. 2: Separate measurement of diameter and length with CAMSIZER P4

Due to the to rapid interfaces and a high data processing rate CAMSIZER P4 processes hundreds of thousands of particles per measurement. The size and shape parameters of each particle can be individually displayed. By selecting the appropriate filters particular types of particles can be directly selected and analyzed separately, for example the width and length of plastic granulate particles (fig. 2). Thanks to the bright, homogenous light source and high depth of focus, even transparent particles are reliably detectable and measurable.

EVALUATION IN REAL TIME

A crucial advantage of CAMSIZER P4 is the evaluation of results in real time. A graphic preview is available during the measurementand the measuring process can be visually controlled by watching live images. The software evaluates all particle images directly during measurementwhile individual images can be stored in the particle library.

NEW: 3D CLOUD

In addition to the well-known two-dimensional graphic display of particle size and particle shape, the CAMSIZER X-Plorer software also allows three-dimensional displays (scatter grams, 3D clouds), which show three parameters in one graphic. Each point of the diagram (fig. 3) represents one particle in the data base. Therefore, it is possible to differentiate samples which don't show any difference in a two-dimensional display. Individual components of mixtures are identified more rapidly and easily allowing for separate evaluation of different particle populations at a later date. The example shows a mixture of reflective glass beads (round, transparent) with an anti-skid material of corundum (non-round, non-transparent).

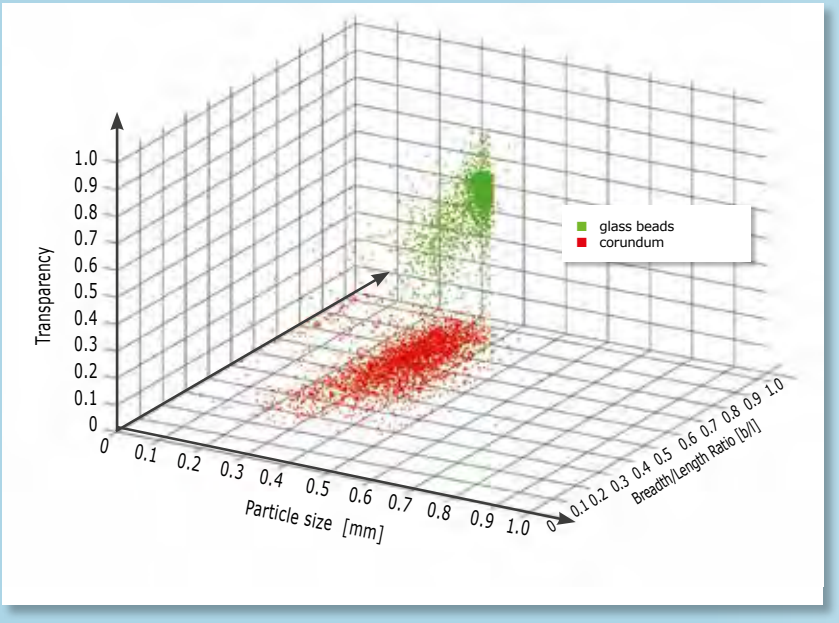


Fig. 3: Graphic display of 3 parameters – particle size, transparency and breadth/length ratio – of a mixture of glass beads and anti-skid material

NEW: EXTENDED SHAPE ANALYSIS

Thanks to the great depth of sharpness and excellent resolution, the CAMSIZER P4 is ideally suited to analyze complex particle shapes. A new software feature determines the corner roundness/angularity of particle images by calculating the mean radius of all corners and dividing it by the radius of the largest incircle (fig. 4).

This shape parameter is particularly suitable for characterizing materials for which roundness is an important characteristic, such as, abrasives or special sands. Traditional shape analysis according to Krumbein and Sloss involves evaluation of sand grains under the microscope and visual assessment with the help of a table (fig. 5). The new CAMSIZER P4 algorithm provides identical results to the time-consuming manual analysis method which have been verified in hundreds of tests. Moreover, these results have better repeatability and are independent of individual visual impressions.

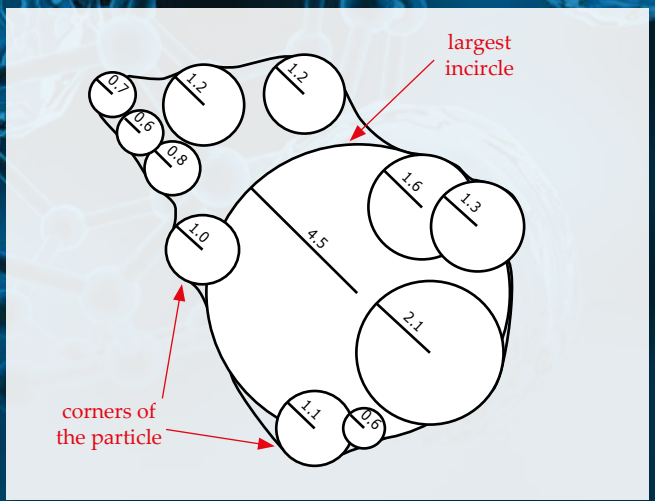


Fig. 4: The "corner roundness" is the mean radius of all corners divided by the radius of the largest incircle

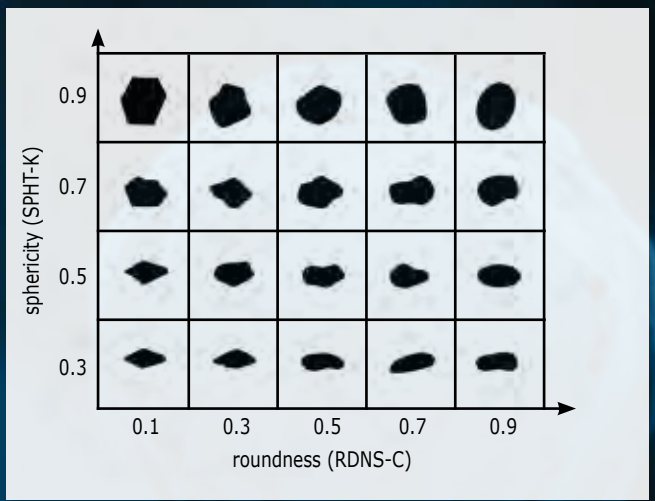
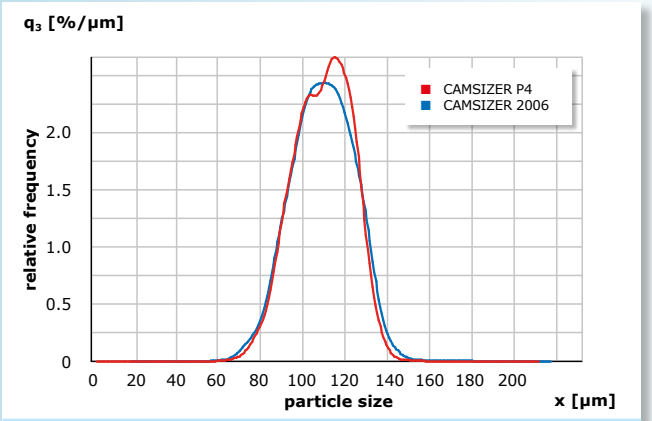


Fig. 5: Table for visual evaluation of roundness and sphericity according to Krumbein and Sloss

HIGHER RESOLUTION – MORE ACCURATE ANALYSIS

A sample of fine glass beads (d_{50} = 110 mm) was measured with CAMSIZER P4 (red) and with the second generation CAMSIZER 2006 (blue). The sample shows a slight bi-modality which CAMSIZER P4 is able to detect thanks to its higher resolution and improved depth of sharpness.

The d_{10}, d_{50}, d_{90} values, however, are very similar for both CAMSIZER models. With respect to the particle shape of the glass beads (here: roundness, sphericity) CAMSIZER P4 is able to measure the higher roundness values.



	CAMSIZER P4	CAMSIZER 2006
d_{10}	91.4 µm	90.3 µm
d_{50}	110.5 µm	109.9 µm
d_{90}	126.6 µm	128.6 µm

Fig. 6: Analysis of glass beads with CAMSIZER P4 and CAMSIZER 2006. The improved resolution of CAMSIZER P4 is clearly visible

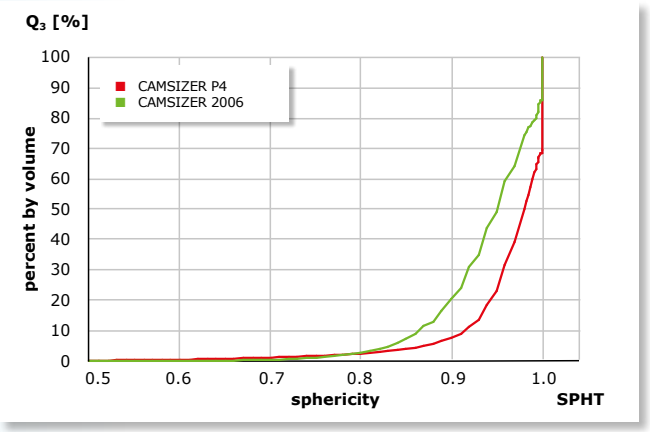
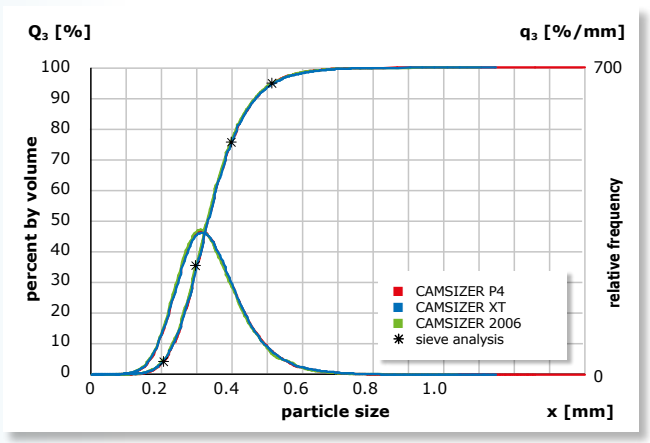


Fig. 7: Measuring the sphericity of glass beads with CAMSIZER P4 and a previous model. Thanks to the improved optics the new generation provides precise shape analysis even of very small particles

THREE MODELS – ONE MEASUREMENT RESULT

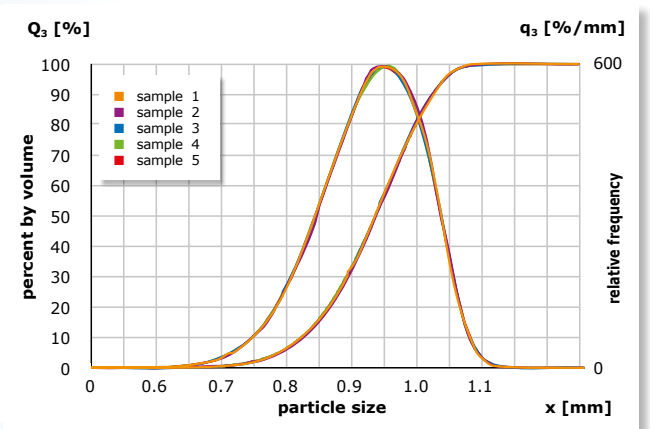
CAMSIZER P4 and CAMSIZER XT use the same measuring principle, but are different with regard to resolution, dispersion and sample feeding. Figure 8 shows the result of a sand sample with a wide size distribution between 10 and 800 µm. The sample can be measured with both CAMSIZER P4 and CAMSIZER XT. The graphic compares the results of CAMSIZER P4 with those of CAMSIZER XT and an older version of the CAMSIZER. The results are comparable and also match those obtained by sieve analysis.

Fig. 8: Analysis of a sand sample with CAMSIZER P4, CAMSIZER XT, CAMSIZER 2006 and sieve analysis. The measurement of simple samples with a wide size distribution doesn't reflect the different resolutions



MAXIMUM REPRODUCIBILITY

The excellent repeatability of the measurement results confirms the reliability of Dynamic Image Analysis. The example shows the measurement of 5 samples of EPS (expanded polystyrene) with CAMSIZER P4. The curves are identical and the d_{10}, d_{50} und d_{90} values clearly document the reproducibility of the measurements.



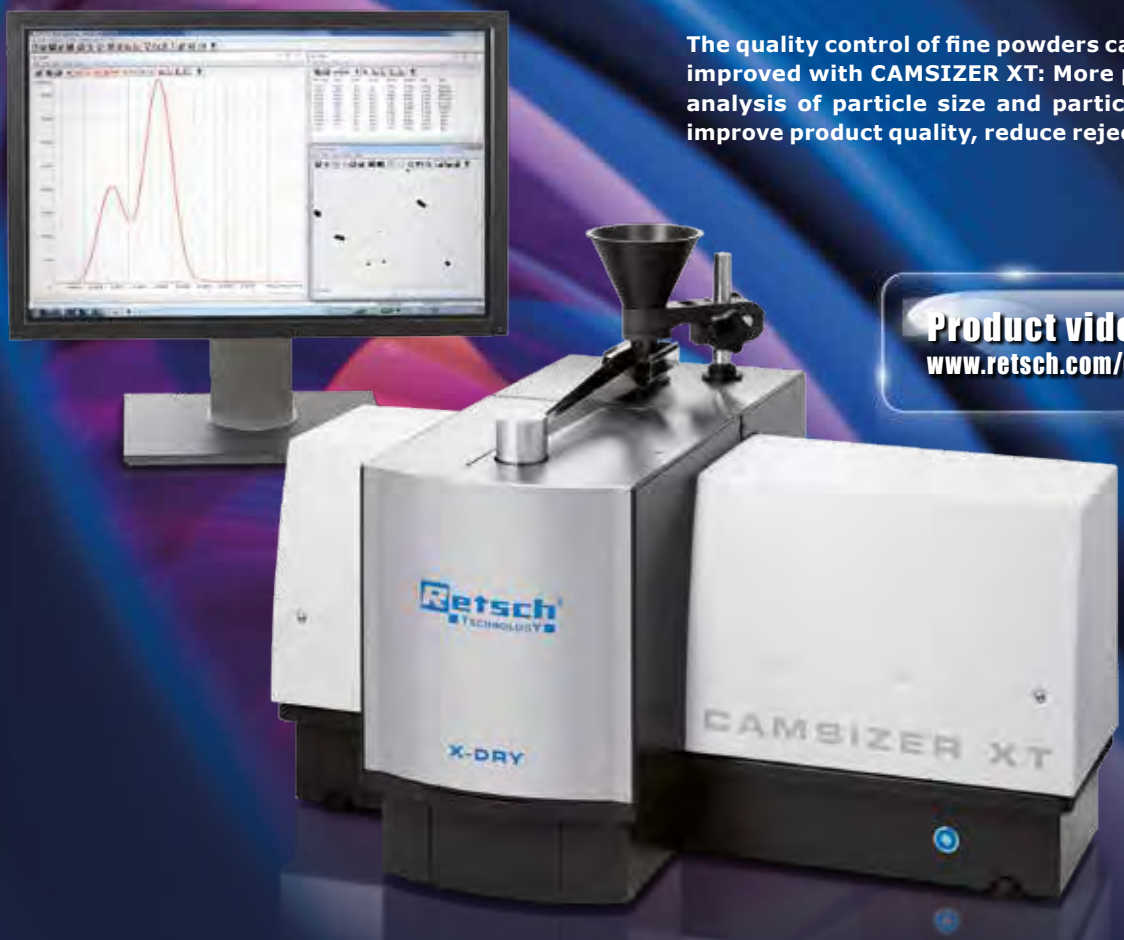
	measurem. 1	measurem. 2	measurem. 3	measurem. 4	measurem. 5
d_{10}	872.5 µm	872.7 µm	873.4 µm	872.0 µm	872.0 µm
d_{50}	985.9 µm	985.9 µm	986.5 µm	985.9 µm	985.2 µm
d_{90}	1073.8 µm	1073.8 µm	1073.9 µm	1073.6 µm	1073.7 µm

Fig. 9: Measurement of 5 EPS samples with CAMSIZER P4 with excellent repeatability of the results

CAMSIZER® XT

dual camera technology

For the characterization of fine powders



The quality control of fine powders can be substantially improved with CAMSIZER XT: More precise and faster analysis of particle size and particle shape helps to improve product quality, reduce rejects and save costs.

Product video at
www.retsch.com/camsizerxt

CAMSIZER XT is specially designed for the analysis of fine powders and granules which tend to agglomerate. Compared to CAMSIZER P4, the CAMSIZER XT model features optics with higher resolution as well as additional sample feeding options.

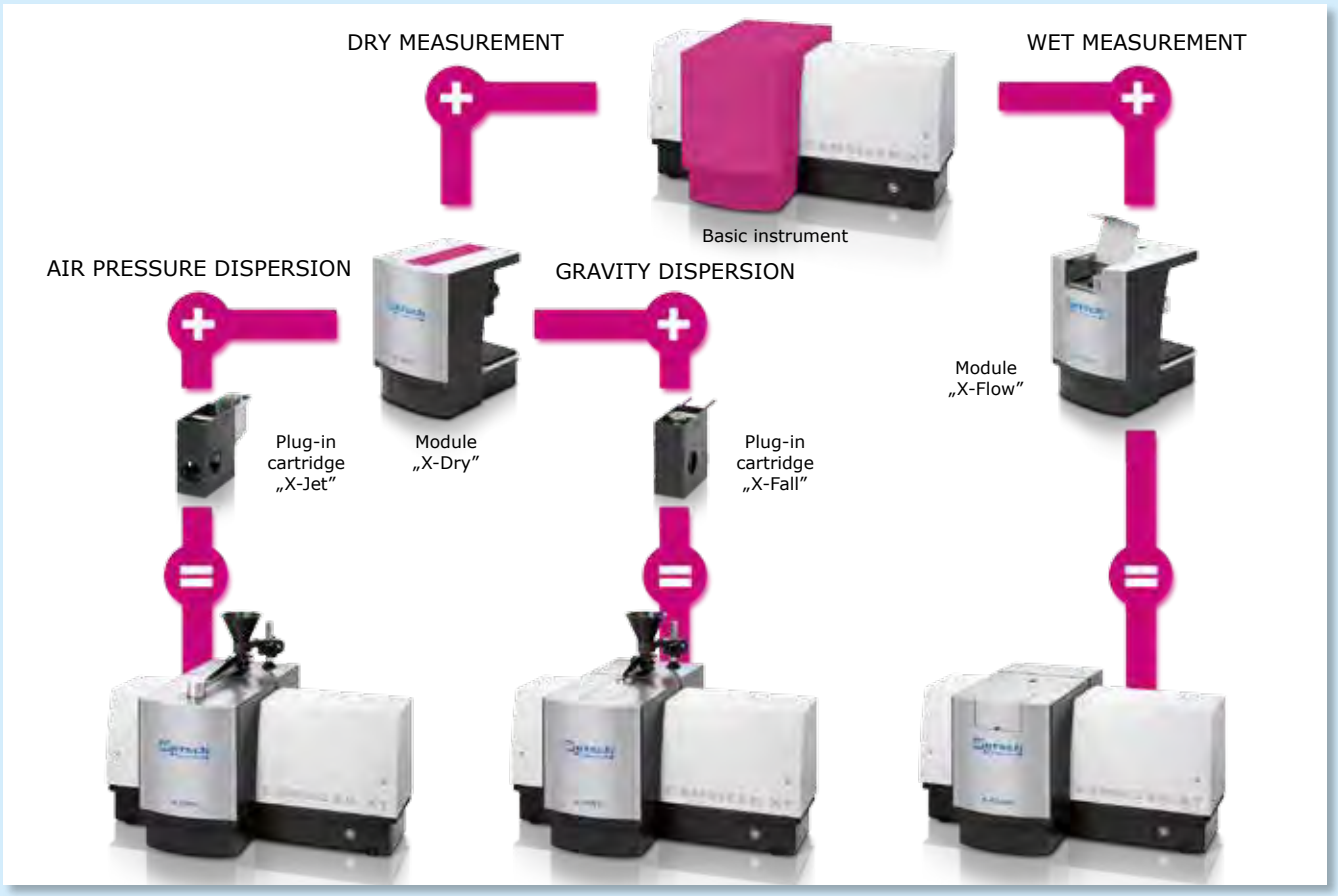
Due to strong interacting forces between the particles, very fine particles tend to agglomerate which makes it difficult to detect the geometric dimensions of each individual particle. Therefore, the particles should be adequately dispersed when fed to the measurement area. CAMSIZER XT offers different sample feeding modules to ensure thorough particle dispersion. Agglomerates are broken up into primary particles by adequate mechanical force prior to analysis. The challenge, particularly for sensitive materials, is to find a way to break up agglomerates without destroying the individual particles

CAMSIZER XT features different dispersion options. Dry samples are dispersed by gravity or air pressure where the powder is accelerated in a dispersion nozzle by compressed air and the resulting shearing forces dissolve the agglomerates. Variable nozzle geometry and the possibility to continuously adjust the dispersion pressure between 10 kPa and 460 kPa allow adaptation to the requirements of the sample material.

Pourable, non-agglomerating samples are simply measured in a free-fall without additional dispersion. CAMSIZER XT also analyzes particles in liquids (suspensions, emulsions) where agglomerates can be dispersed by ultrasound, if required. The modular design of the analyzer allows for easy and convenient changing between the different dispersion options.

Modular design for optimum measurement conditions

CAMSIZER XT's "X-Change" system offers three alternative dispersion methods, allowing the selection of the optimum method for each sample type.



AIR PRESSURE DISPERSION WITH „X-JET"

Measuring range
from 1 µm to 1.5 mm

The dispersion (i.e., the separation of the particles when passing through the measurement area) is a crucial precondition for the proper measurement of the individual particles. Thanks to the flexible pressure adjustment of the "X-Jet" plug-in cartridge materials can be measured under optimum conditions. With the dynamic image analysis method used by CAMSIZER XT, it is possible to detect broken particles and agglomerates by analyzing the particle shape and then adjusting the pressure as required. The sample is collected in a vacuum cleaner after the measurement. If the sample material needs to be recovered for further analysis, an optional cyclone is available. The air pressure dispersion accelerates the particles to up to 50 m/sec. Thanks to extremely short exposure times, it is possible to measure particles < 5 microns. The new optional dispersion nozzles also allow for dispersion of particles substantially larger than 1.5 mm.

GRAVITY DISPERSION WITH „X-FALL"

Measuring range
from 10 µm to 3 mm

Pourable, non-agglomerated samples can be analyzed by using the "X-Fall" plug-in cartridge. In this mode, the particles fall from the chute and through the field of view of the two cameras accelerated only by gravity. Thanks to the low speed of the particles, the large field of view and the high frame rate, the detection efficiency is very high, even for larger particles. Often only a few coarser particles e. g. 3 mm) in the sample are sufficient for reliable, reproducible detection. After the measurement the sample material falls into a collector box and is available for further analyses without loss or contamination. An extension of the measuring range to 8 mm is optionally available.

WET DISPERSION WITH „X-FLOW"

Measuring range
from 1 µm to 600 µm

The wet module "X-Flow" analyzes samples in a range from 1 to 600 microns in suspensions or emulsions. An advantage of this module is the small required sample volume. A low particle concentration in the dispersion medium of, as an example, 20 mg/l is already sufficient to detect enough particles for a reproducible result in only 1 minute. The measurement range of the "X-Flow" module starts at 1 micron. With this module the CAMSIZER XT also analyzes particles much larger than 1 mm and with low density without difficulty, as the particles are kept suspended in the dispersion medium. This is also possible because the cuvette of the standard measurement cell is 4 mm wide. Agglomerates can be further separated by an integrated ultrasonic probe.

Application Range

ABRASIVES: RELIABLE DETECTION OF OVERSIZED GRAINS

Abrasives are divided into macro grains and micro grains with the division being made at a mean particle size of approximately 60 µm. Abrasives consisting of very hard minerals such ascorundum, quartz, garnet, silicon carbide, boron nitride, or diamond can be produced industrially or obtained from natural resources. A narrow particle size distribution without oversized grains is important to ensure uniform abrasion of the surfaces without leaving scratches. Particle shape is also a quality criterion. Depending on the use and type of abrasive, a spiked or blocked shape is generally preferred.

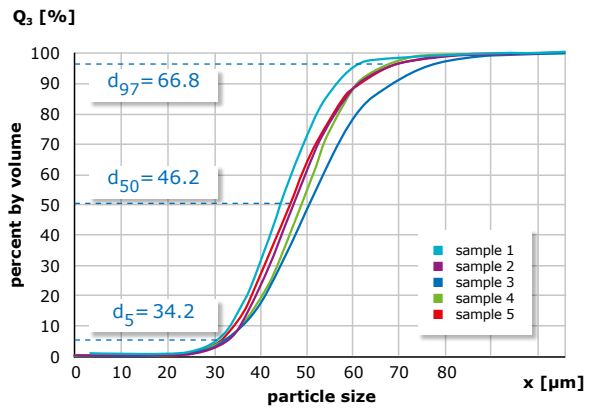


Fig. 1: Particle size distributions of abrasive samples from 5 different manufacturers

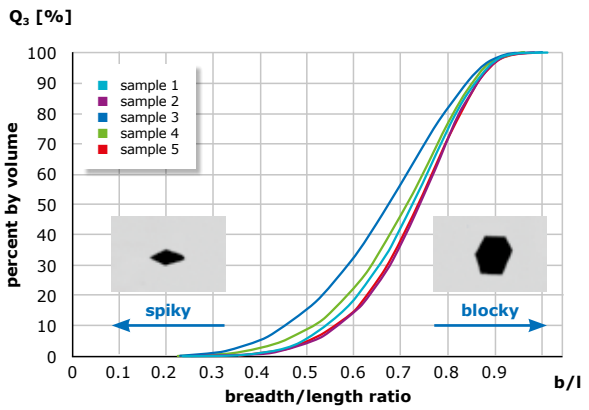
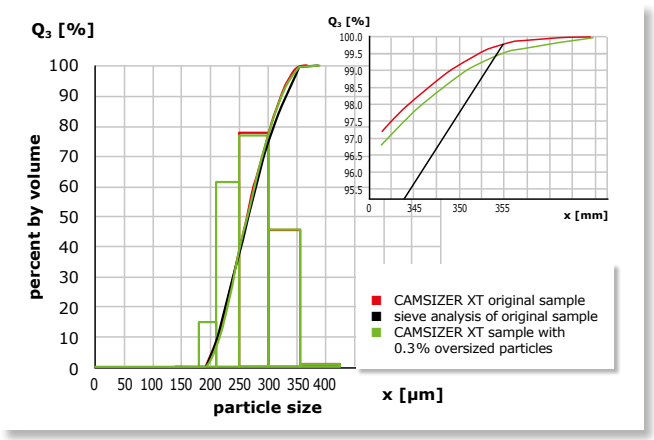


Fig. 2: Breadth/length ratio of abrasive samples

Graphic 1 shows the size distribution of 5 abrasive samples (P320 Macrogrit) from 5 different manufacturers. The specification of these grits according to FEPA should be: d_{50} = 46.2 ± 1.5 µm ; d_{97} max. 66.8 µm ; d_5 min 34.2 µm. The results of the CAMSIZER XT measurement with air pressure dispersion at 50 kPa show that sample 1 and 2 are clearly out of specification.

The 5 samples also have very different particle shapes. Figure 2 shows the breadth/length ratio as a Q_3 distribution. The further left the curve runs, the more elongated and spiky is the particle shape.



For the quality control of abrasives the reliable detection of oversized grains is essential. Figure 3 illustrates the measurement of a sample with a P60 grit (d_{50} approx. 260 µm). The red curve represents the analysis result of the CAMSIZER XT, the black line resp. the black dot in the zoomed-in graphic that of sieve analysis. The green curve shows the measurement result after 0.3% oversized grain were added to the original sample. Even this small amount of a few grains of sample is reliably detected by CAMSIZER XT.

Fig. 3: CAMSIZER XT reliably detects small amounts of oversized grain (green curve) and optionally provides identical results to sieve analysis.

MILK POWDER: EFFECTIVE DISPERSION WITH AIR PRESSURE

Substances such as baby formula or drink powders are granulated during the production process. The desired particle size is achieved by agglomerating the primary particles during the time the components are homogenized. Thanks to effective air pressure dispersion heavily agglomerated substances, such as milk powder, can be reliably analyzed. In this example the smallest primary particle size is only 10 microns. Figure 4 shows measurements of milk powder with different dispersion pressures. With increasing pressure the agglomerates break more easily and the resulting particle sizes are smaller which is confirmed when looking at particle images which are automatically taken. Therefore, it is possible to not only determine the size of the primary particles, but also to characterize different stages of agglomeration which reflect the stability of the instant powder for storage, transport and final processing.

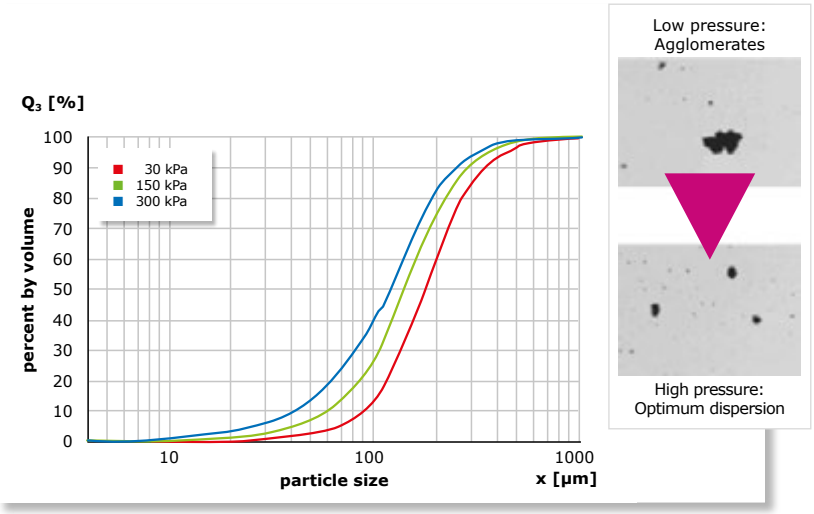


Fig. 4: CAMSIZER XT measurements of milk powder with varying dispersion pressures. The particle sizes become smaller with increasing pressure

STARCH: SHAPE IS WHAT COUNTS

Starch powder is a filling material used, for example, in paper manufacturing or pharmaceutical production. The example shows very similar size distributions of two different starch powders, the d_{50} value (median) is even identical. However, the particle shape in this case, the breadth/length ratio, is very different. The fibrous sample (blue) shows low b/l values, whereas the comparative sample (red) contains compact, isometric grains with substantially higher b/l values.

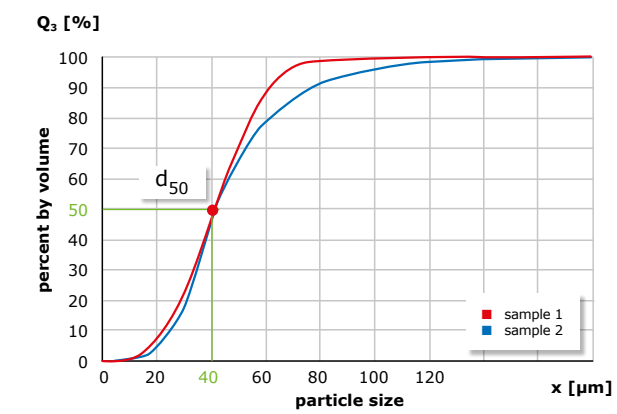


Fig. 5a: Size distribution of two different starch powders

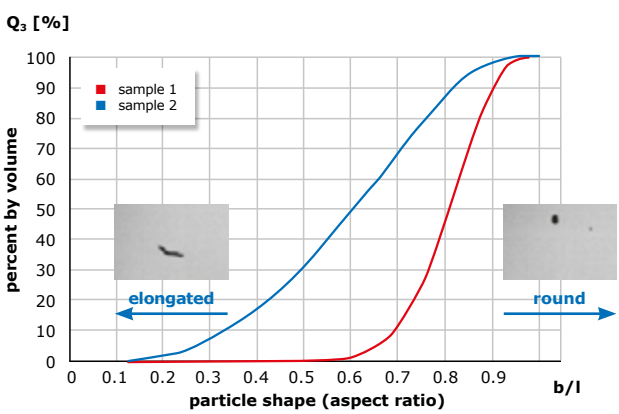


Fig. 5b: The breadth/length ratio of the two samples is very different

Comparison of particle analysis methods

Dynamic Image Analysis (DIA) | Laser Diffraction | Sieve Analysis

Dynamic Image Analysis (DIA)
CAMSIZER® XT

Laser Diffraction
LA-960

Sieve Shaker
AS 200 control

The most common methods to determine the particle size are dynamic image analysis (DIA), static laser light scattering (SLS, also called laser diffraction) and sieve analysis. Each method covers a characteristic size range within which measurement is possible (see table on page 3). In the three methods presented here, all measure particles in a range from 10 µm to 3 mm. However, the results for measuring the same sample can vary considerably. As DIA is the only method which permits analysis of various different particle size parameters and at the same time of particle shape it is possible to compare the results with other methods.

DYNAMIC IMAGE ANALYSIS VERSUS SIEVE ANALYSIS

The crucial difference between DIA and sieve analysis lies in the fact that image analysis measures the particles in random orientation. During sieving the particles move on the sieve mesh until they fall through the apertures in a particular orientation with their smallest projection surface. Therefore, when comparing DIA results with sieve analysis, the parameter "particle breadth" should be considered, as this is also determined by sieve analysis. Results for spherical or ellipsoid particles (e. g. rice grains) are more or less identical; regarding lenticular particles as an exemplary model for flat particles, the differences between sieve analysis and DIA become obvious. Depending on the random position of the particle when the picture is taken by the camera, larger (= wider) or smaller (=narrower) diameters are measured (fig. 1). Sieve analysis results, however, always indicate a 30% smaller diameter of the lenticular particles. This leads to systematic differences between the results of sieve analysis and DIA, depending on the particle shape. As both CAMSIZER XT and CAMSIZER P4 also measure the particle shape, these differences can be easily compensated by a software functionality, thus obtaining results which are compatible to those of sieve analysis.

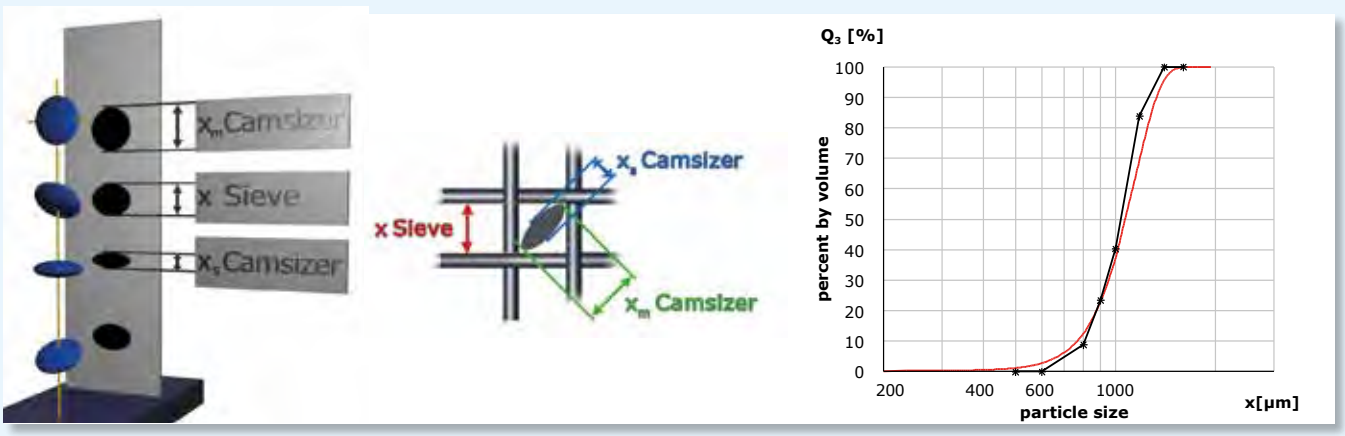


Fig. 1: Model of a measurement of lenticular particles with sieve analysis and DIA. The lense falls diagonally through the smallest possible sieve aperture. DIA "sees" the lense larger or smaller, depending on its orientation. This results in different particle size distributions: the red curve shows the DIA result, the black dots represent sieve analysis results. With the sieve correlation function of the CAMSIZER software it is possible to obtain identical results to sieve analysis. This allows specifications based on sieve analysis to be maintained after a system change.

DYNAMIC IMAGE ANALYSIS VERSUS STATIC LASER LIGHT DIFFRACTION

With static laser light analysis, also called laser diffraction, particle sizes are measured indirectly by detecting intensity distributions of laser light scattered by particles at different angles. These are the basis for calculating the particle size distribution. **Laser diffraction methods are based on the assumption that all particles are spherical, which makes it impossible to differentiate between width and length of a particle**. This frequently **results in wider particle size distributions** than obtained with other analysis methods.

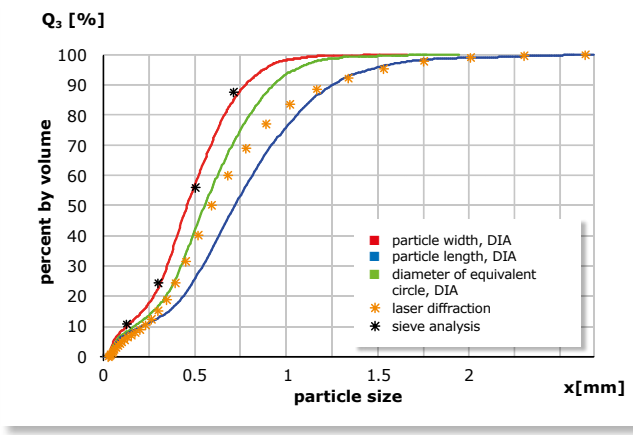


Fig. 2: Analysis of a coffee sample with different methods

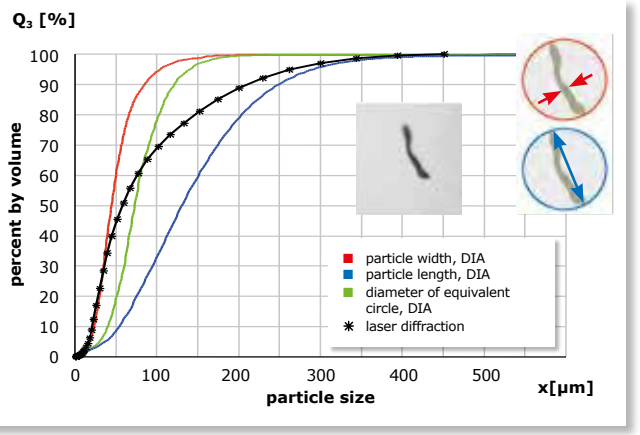


Fig. 3: Analysis of cellulose fibres with CAMSIZER XT (DIA) and laser diffraction

Figure 2 illustrates the comparability between SLS, DIA and sieve analysis using the example of ground coffee. Sieve analysis provides the finest results and the measurement of particle breadth with CAMSIZER® XT comes very close to this result. There is no comparability between sieve analysis and laser diffraction; the result obtained with SLS corresponds roughly to the x_{area} parameter (diameter of equivalent circle). The various particle dimensions which are measured are all attributed to spherically shaped particles. Therefore, SLS always provides wider size distributions than image analysis.

This becomes even more apparent in figure 3, which shows a measurement comparison of cellulose fibers. Whereas DIA distinguishes between the thickness and length of the fibers, SLS is not able to do so. The measurement curve of laser diffraction
first runs parallel to the width measurement of DIA (red) and then approaches the "fibre length" (blue). DIA is able to determine width and length separately.

COMPARISON OF MEASUREMENT TECHNIQUES

This table shows the strengths of the most common particle analysis methods. Dynamic Image Analysis is superior to the other techniques in many areas.

Performance Features	Dynamic Image Analysis e.g. CAMSIZER®	Static Image Analysis e.g. mikroscope	Laser Diffraction e.g. Horiba LA-960	Sieve Analysis
Reproducibility and repeatability	++	○	++	+
High resolution for narrow distributions	++	++	+	○
Measurement of wide distributions	++	○	+	+
Particle shape analysis	++	++		
Reliable detection of oversized grains	++	○	○	++
Measurement speed & time	+	○	++	○
Analysis of multimodal distributions/mixtures	++	+	+	○
Information on composition (e.g. via spectroscopy, Raman etc.)		++		
Investment	**high**	**high**	**high**	**low**
Operating costs (labor input)	**low**	**high**	**low**	**high**

++ highly suitable + suitable ○ suitable to a limited extent impossible

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