Particle size and shape distribution of stable dust analysed with laser diffraction and imaging technique

M. Romann[1] and T. Hinz[2]

Abstract

Effects of particles on individuals and the dispersion of airborne particles are strongly dependent on their size, density, surface and shape. Risk assessment requires knowledge about mass or number concentration or fluxes concerned. For this purpose different kinds of measuring techniques are used, which react in particular way to the parameters mentioned above. Depending on the task an appropriate technique will be selected. It's well known that dusts from livestock facilities vary widely depending on the source. Sophisticated structures and large ranges of size distribution must be detected. For sizing laser diffraction technique was used to characterize samples of dust which were collected in stables of different species of farm animals. These results are now supplemented with Sympatecs imaging system for shape analysis.

Keywords: livestock, PM, size, shape, laser diffraction, high speed imaging

Introduction

Effects of particles on individuals and the dispersion of airborne particles are strongly dependent on their size, density, surface and shape (Schmitt-Pauksztat G. 2006). Depending on these parameters particles penetrate more or less deep into the breathing of individuals. Aerodynamic diameter is used to cover complex influences including shape and structures. This becomes complicated for particle dispersion caused by emissions in animal production. Therefore the well established laser diffraction technique for analyzing particle size distribution is not sufficient. In the following more detailed parameters for the characterization of the dust particles are described.

Materials and Methods

Particle analysis was carried out in the labs of Sympatec with samples which were taken in research facilities of the FAL and in a commercial piggery near Braunschweig. The different dust types are taken in stables of cattle, piglets, pigs, horses, sheeps and turkey.

The collection location was a central point inside of each stable with the exception of turkey where the sample was taken from the emission flow. This type of stable dust was chosen for the first investigations.

According to the conditions of measurements at working places (VDI 1980) probes were sucked with a velocity of 1.25 m/s in a height of approximately 1.5 m above ground. Figure 1 shows the setup of the sampler. Samples in the exhaust of the force ventilated turkey kept the conditions of isokinetic probe (DIN EN 12384-1, ISO 7708).

Independent of the air intake the equipments consist of a high volume sampler with an axis-type cyclone to separate the coarse fraction and a glass fibre filter to collect the penetrating fine dust particles, figure 2.

[1] Sympatec GmbH, Clausthal-Zellerfeld, Germany

[2] Federal Agricultural Research Centre, Institute for Technology and Biosystems Engineering, Braunschweig, Germany

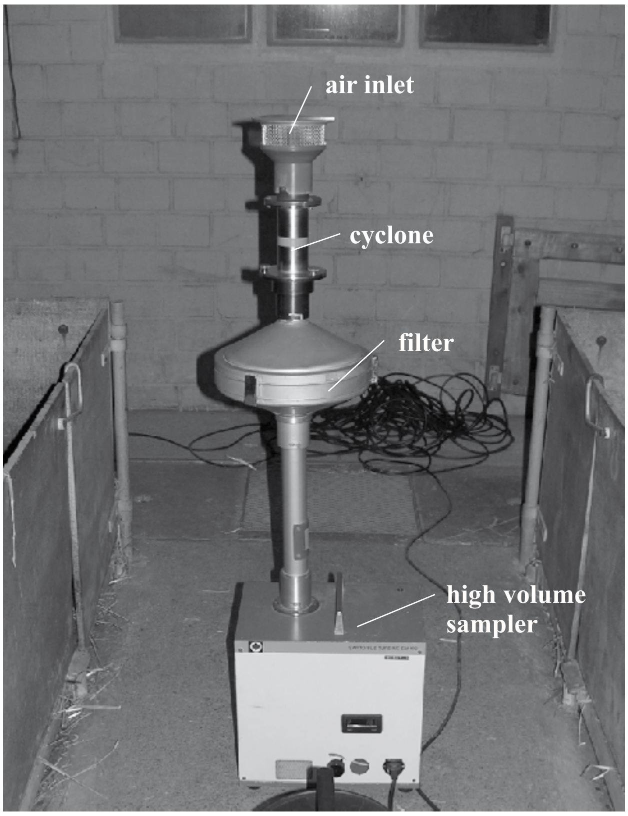

Figure 1:
Sampling dust inside a stable

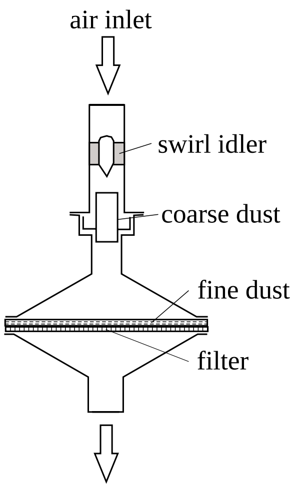

Figure 2:
Scheme of the equipment

The separation efficiency of the cyclone was fitted to the previously used Convention of Johannisburg, with a cut off diameter of 5 µm. Particles larger than 7.07 µm should be separated totally. Figure 3 shows the theoretical curve and the actual calibration while sampling with a flow rate of 50 m³/h.

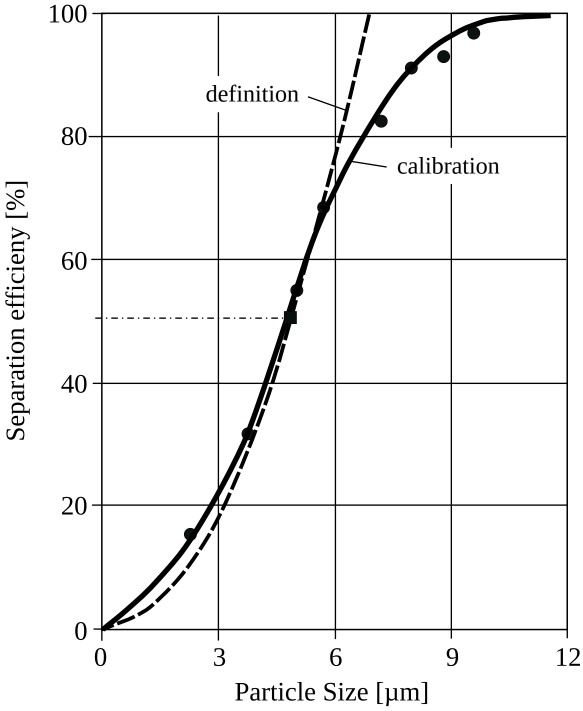

Figure 3:
Separation efficiency of the used cyclone

High volume sampling ensures proper amounts of dust in the cyclone beaker and on the filter in an acceptable time of running. Mass detection followed by weighing. After weighing the samples of the coarse fraction were transferred to the lab for further analysis.

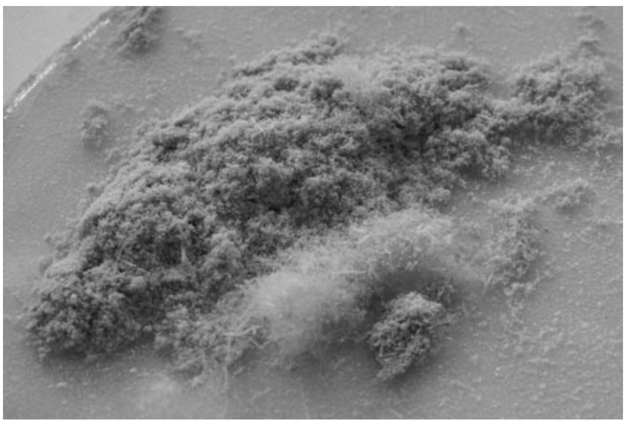

Figure 4:
Sample of stable dust

This sample can be divided into two different types of particles: a dusty appearing collection of "normal" particles and balls of fibrously particles that can be taken out by tweezers. A dry sample splitting is impossible.

The best way to handle the sample of stable dust carefully is to prepare a suspension of the entirely sample in dry isopropylic alcohol. Stirrer speed should be slow and it should change the rotation direction from time to time in order to avoid the collecting of fibres or the creation of fiber balls again.

The suspension can now be split and diluted for the measurements first with a HELOS laser diffraction together with the dispersing unit SUCELL and then with a QICPIC imaging system combined with the dispersing system LIXELL.

Results and discussion

Table 1 gives the concentration of the coarse and fine fractions split by the cyclone separator and its ratio coarse to fine. The suspension made up for the particle size distribution analysis and for the shape analysis contains only the coarse fraction.

Table 1:
Concentration of coarse and fine dust fraction, percentage coarse

Species	Fraction concentration coarse [mg/m³]	fine [mg/m³]	Percentage coarse	Position
Cattle I	0.116	0.00567	96	inside
Cattle II	0.180	0.029	87	inside
Piglet	1.144	0.159	88	inside
Pigs	0.860	0.057	93	inside
Horse	0.150	0.0268	85	inside
Sheep	0.072	0.017	89	inside
Turkey	2.560	0.296	90	exhaust

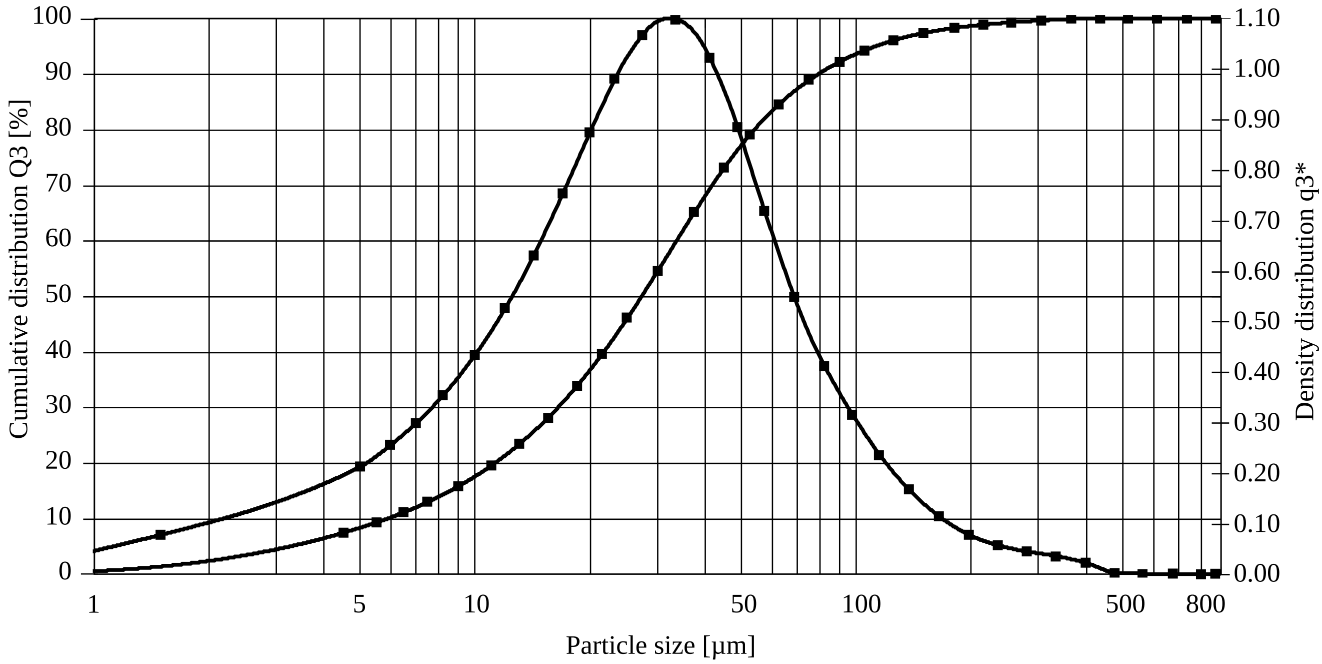

Figure 5:
HELOS - Cumulative and density distribution of the turkey stable dust.

The result of the laser diffraction analysis shows a distribution of laser diffraction comparable spheres. The measurement itself is done in less then one minute and is based of some million particles. Therefore the reproducibility and reliability of the result are very high. The standard deviation of three different measurements is below 0.5 %.

But even the best result does not show any information about particle shape.

More detailed information about the particles is given by the imaging system QICPIC. Its singularly combination of a high speed camera up to 500 images per second, shortest exposure times below 1 ns with special telecentric optics makes it possible to evaluate a high number of sharp particle images (Witt W. et al. 2006 and 2007).

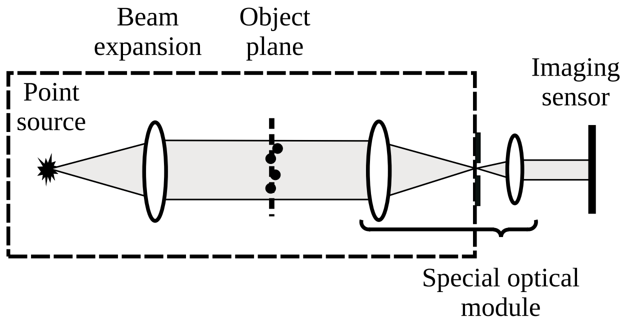

Figure 6:
Optical setup of QICPIC imaging system.

Before and during the measurement the sensor-control window of the WINDOX-software shows already particle images. This allows to check the measuring range and the concentration of particles in the suspension.
Considering the flow velocity in the cuvette and the volume of the suspension a frame rate of 50 images per second during a measuring time of 120 seconds has been suitable. In this case the measurement contains the images of 350,000 particles.

The software WINDOX calculates parameters like EQPC (diameter of the circle of equal projection area), the different Feret-diameters (distance between to parallel tangents), the minimum bounding area with its maximum and minimum value, length and diameter of fibres and the volume based fibre diameter. This list has to be supplemented with the shape parameters like sphericity, aspect-ratio, convexity, straightness and elongation of fibres and with the possibility to combine these parameters to USER-defined parameters.

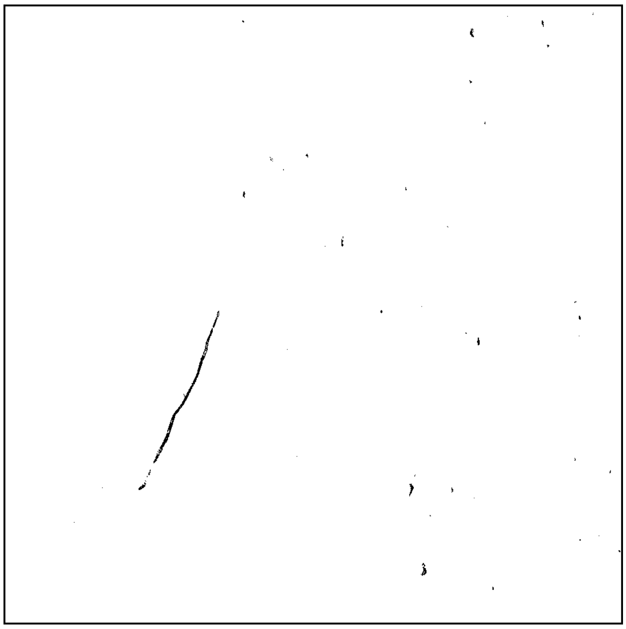

Figure 7:
QICPIC - Particles flowing through the cuvette during the measurement

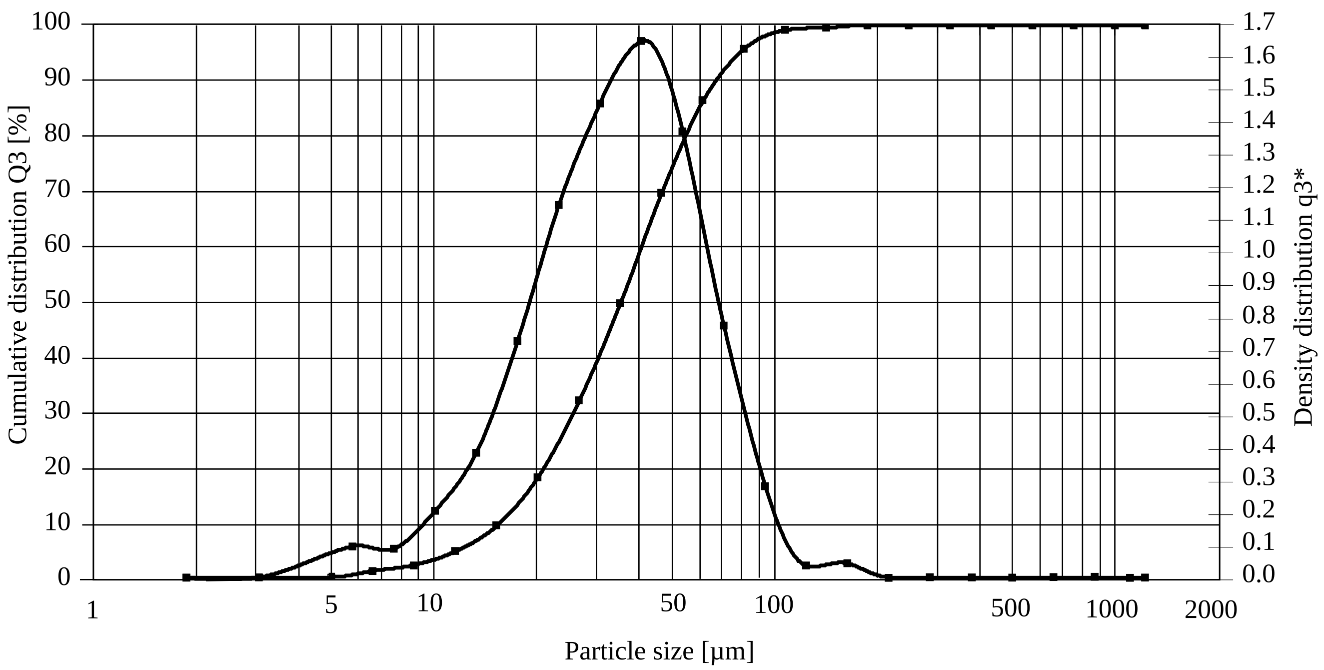

Figure 8:
QICPIC - Volume distribution of EQPC as first result. This diagram is slightly comparable to the volume distribution diagram of the laser diffraction result. (Figure 4)

With all these parameters and their combinations a widespread variety of different results can be created to characterize the very special properties of the sample:

- Particle size distribution of different particle diameters
- Distributions of user defined particle parameters
- Shape diagrams of different shape parameters vs. particle size
- Distribution diagrams of different shape parameters
- Shape diagrams of USER-defined particle parameters

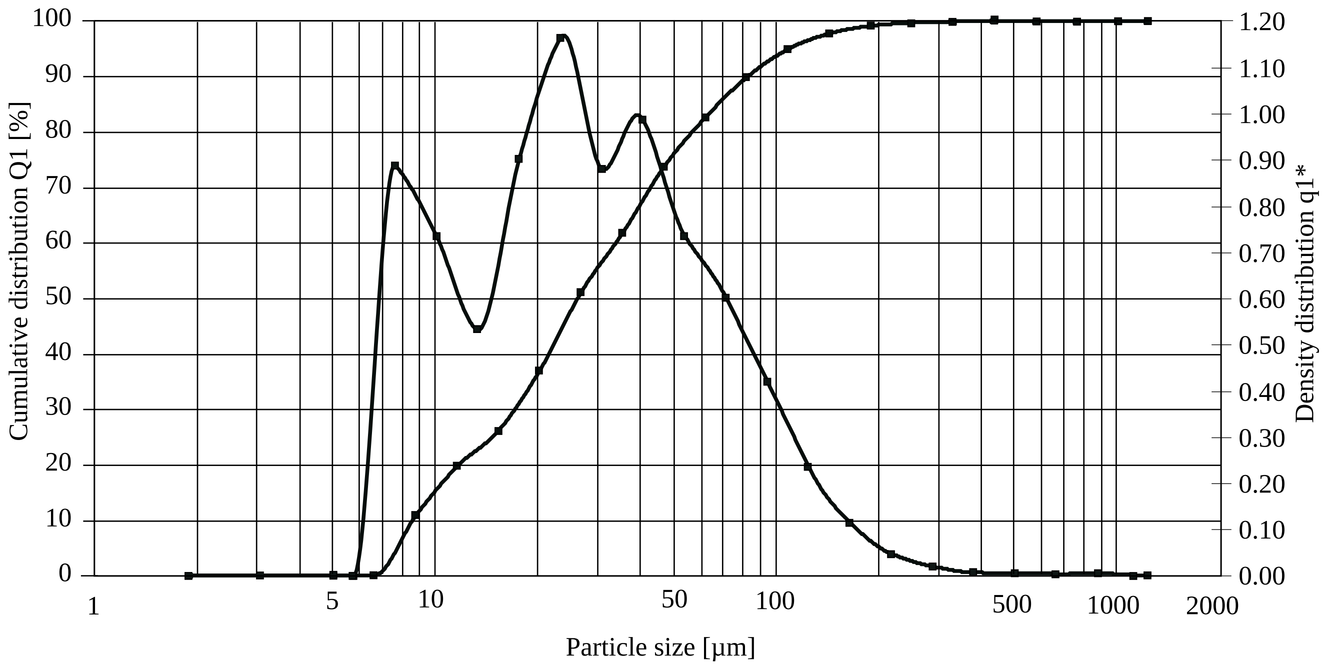

Figure 9:
QICPIC - Length distribution of Feret-Max as result for fibrously materials

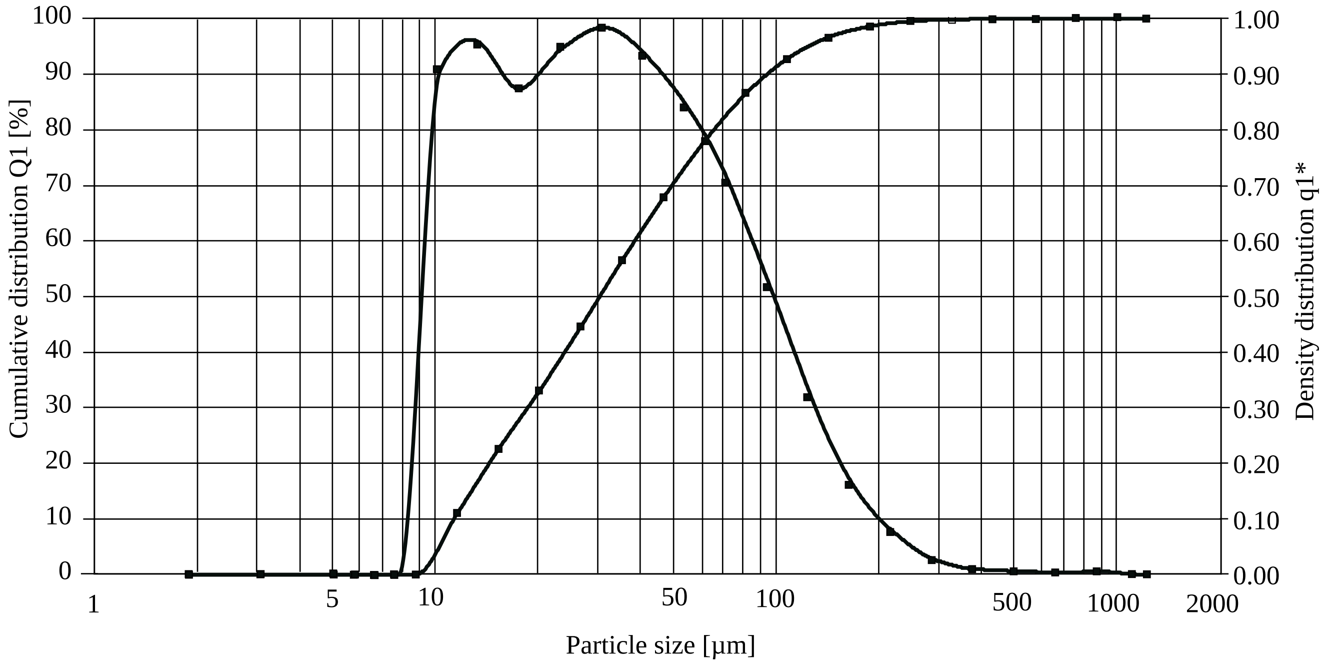

Figure 10:
QICPIC - Length distribution of LEFI (Length of Fibre)

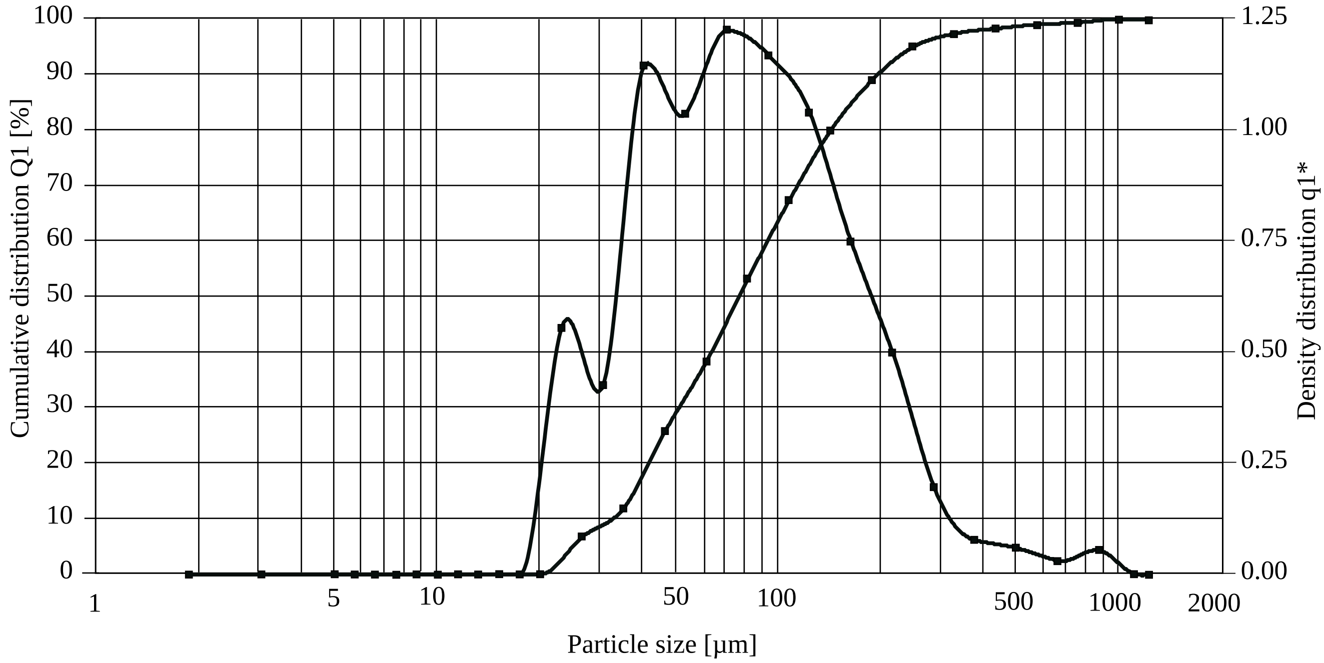

Figure 11:
QICPIC - Length distribution of LEFI > 20 µm and Aspect ratio < 0.25. This user filter suppresses the part of small, spherical particles

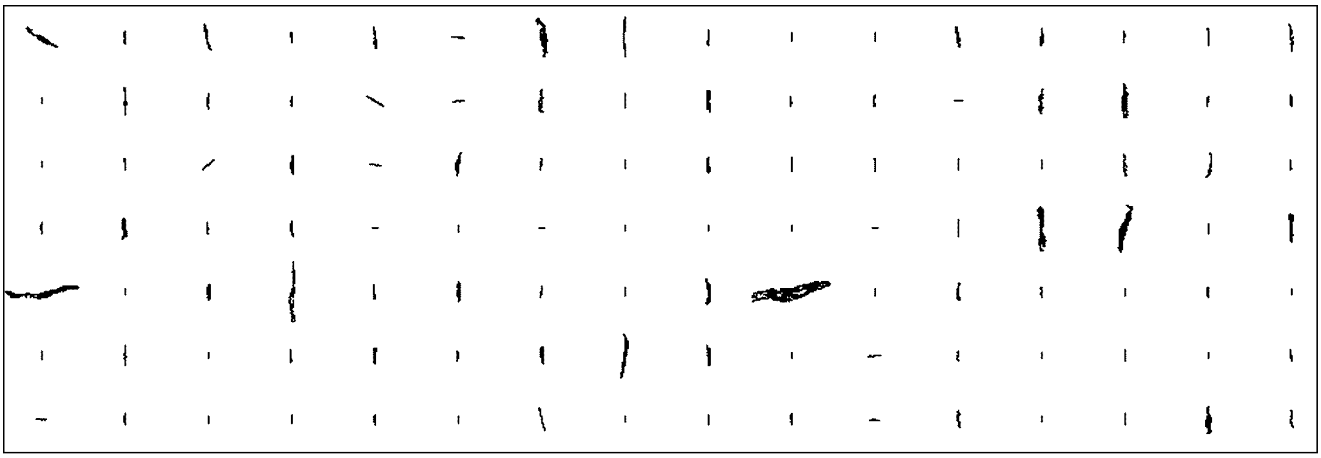

Figure 12:
QICPIC - Particle Gallery of the distribution shown in Figure 10

The last hint, that the sample of stable dust contains mostly needle-shaped particles is found in a shape-diagram:

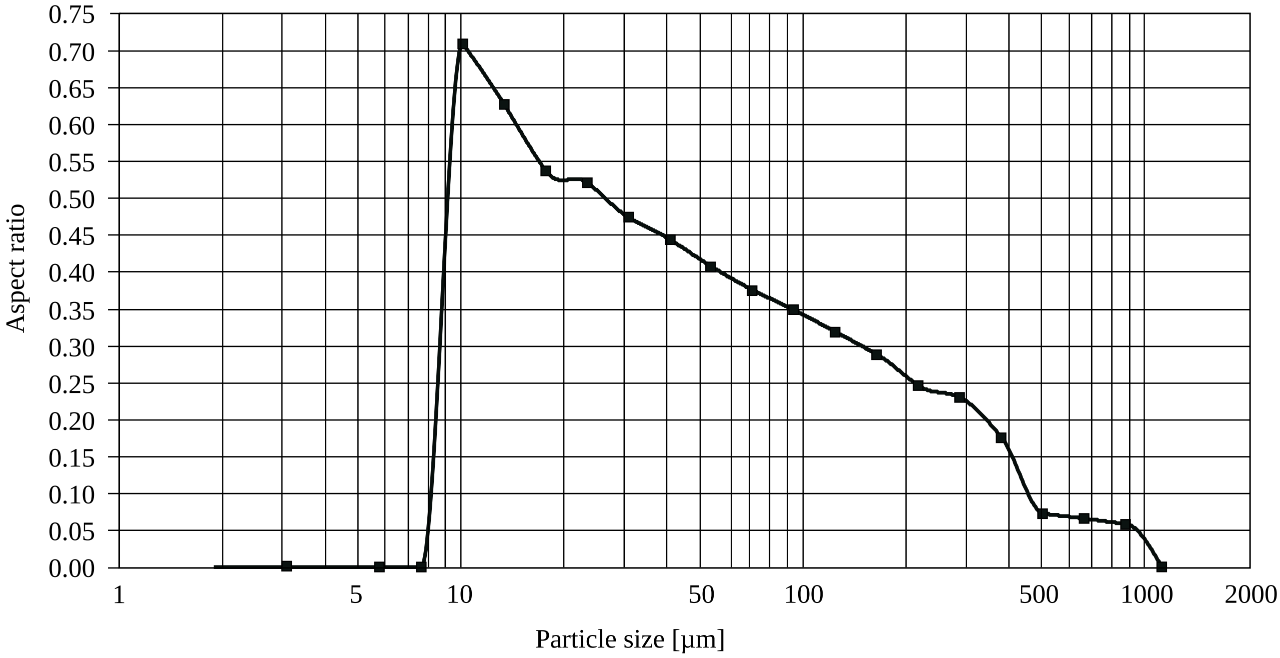

Figure 13:
QICPIC - Aspect ratio vs. LEFI. Typical for fibrously samples is the falling curve to bigger particles

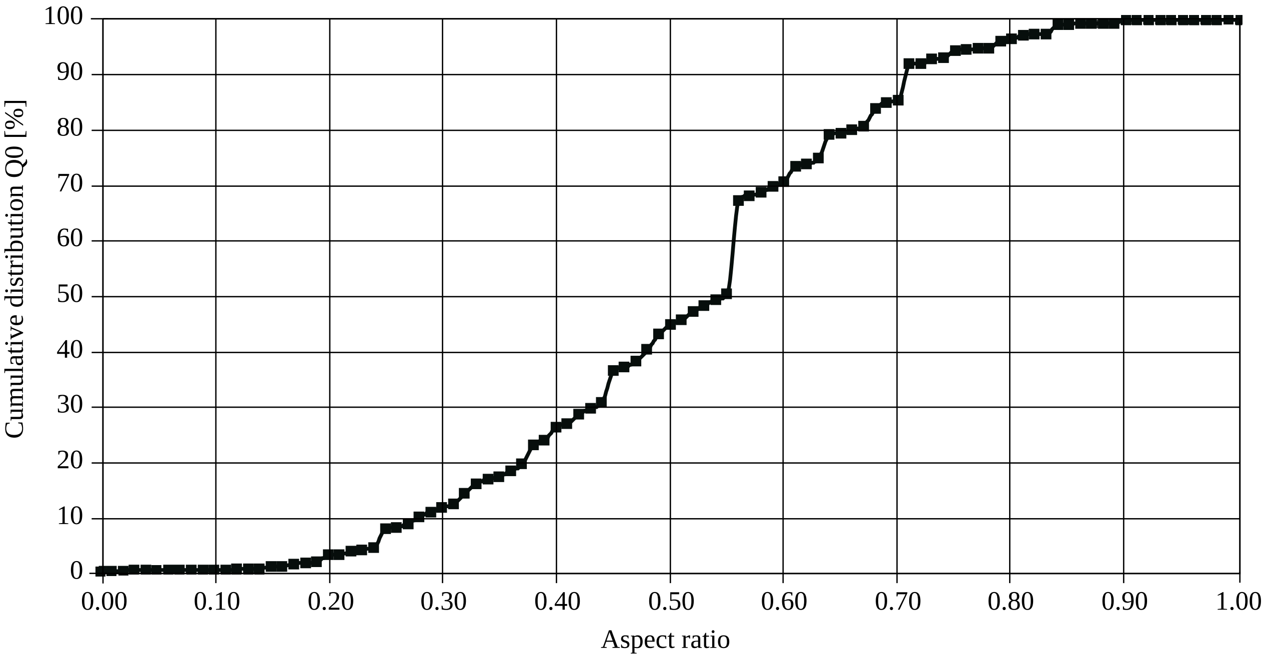

Figure 14:
QICPIC - Cumulative number distribution of aspect ratio. A flat curve shows the predominantly influence of fibres

Conclusion

First investigations in stable dust dispersed as suspension in dry isopropylic alcohol, show very positive results with Sympatec laser diffraction system HELOS with SUCELL that allow a suitable handling of this special material and gives reproducible results of particle size distribution. This realization has been transferred to the imaging system QICPIC with LIXELL. Its variously possibilities in the evaluation of stable dust lead from simple particle distributions in order to have an overview down to the discovering of single particles with very special user specified properties.

References

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For detailed informations about the laser diffraction system HELOS and the imaging system QICPIC please refer to www.sympatec.com (english side) or www.sympatec.de (german).