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Image Analysis for Simultaneous Determination of Spherical and Fibrous Particles

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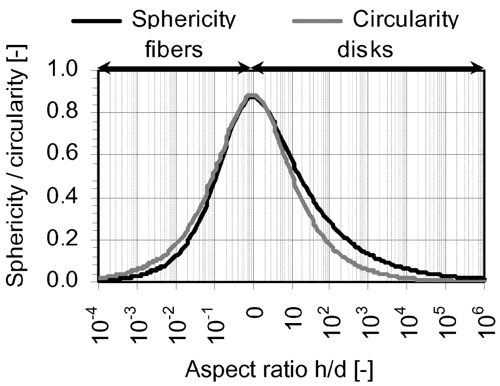
The characterization of short fibers is a challenging task. Most analyzing systems obtain feasible results only for more or less rounded particles. Even if systems are on the market, which can determine the length and the width of fibers, a satisfactory solution is not yet available. In particular in the field of recycling where frequently fibers are commingled with non fibrous particles further improvements are necessary. This communication evaluates the possibility of modifying a standard software tool for image analysis (ImageJ) aiming in a simultaneous determination of spherical and fibrous particles.

1. Introduction

Even if quick and accurate tools for determination of size, size distribution or shape are commercially available today the determination of fibers is still causing problems. Most image analysis systems are optimized for more or less rounded particles using statistical diameters such as Feret or Martin. Elongated particles can be described by parameters such as aspect ratio or circularity. Since fibers totally deviate from circular particle it seems quite futile to use such parameters. Figure 1 plots sphericity (Equation 1) and circularity (Equation 2) for fibers which are assumed to be cylinders with height h and diameter d. For both, disks as well as fibers similar values are obtained.



$$\psi_{Wa} = \frac{d_V^2 \cdot \pi}{S} \qquad (1)$$

$$\psi_c = \frac{d_p \cdot \pi}{D} \qquad (2)$$

ψ_{Wa} .... Sphericity
ψ_c .... Circularity
d_V .... Diameter of ball of same volume
S .... Actual surface
d_p .... Circumference projected equivalent area circle
D .... Actual circumference of particle projection

Figure 1: Sphericity and circularity (Wadell, 1932) of cylinders with height h and diameter d.

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Even if today, particle shape is alternatively described by mathematical shape functions (Zlatev, 2005) much more precisely, it seems indispensable to state the diameter as well as the length for a sufficient fiber characterization.

It has been demonstrated earlier (Pico and Bartl, 2009) that an optical image analyzer called Morfi is a useful tool to determine fiber width and length of short fibers. However, it shows distinct disadvantages such as fiber swelling and the impossibility for evaluate the non fibrous fraction. In this investigation an alternative method based on the freely available computer software ImageJ (Abramoff et al., 2004) was evaluated.

2. Materials and methods

2.1 Image acquisition and image interpretation

Table 1 compared the key parameters of the Morfi system serving as reference to the alternative method using ImageJ. The Morfi is a commercial tool which combines hard and software. The sample has to be dispersed in water and is then transferred to the tank. The system automatically pumps the suspension through the measuring cell, grabs and processes the images and finally plots the results. It is an automated system and the hard and software cannot be separated. The alternative method using ImageJ comprises three analyzing steps as described below.

1. The sample is dispersed to an object slide using a commercial vacuum disperser (OCCHIO VDD). For this, the sample is placed on a plastic membrane covering a hole on top of the dispersion chamber which is evacuated. The membrane automatically breaks at a certain differential pressure and is dispersed directly onto the sampler holder situated in the chamber. The system is very effective and sufficiently disperses fiber samples.
2. The object slide is place in a microscope. Depending on the magnification used various resolutions can be obtained. As shown in Table 1 for this investigation the resolution was 1.38 µm per pixel.
3. Finally the images are processed by the computer software ImageJ. Principally, the images might origin from variety of sources.

Table 1: Key parameters of the analyzing systems.

	Morfi	ImageJ
Dispersion method	Stirrer	OCCHIO VDD
Dispersion media	Water	Air
Sample placement	Measuring cell	Object slide
Image acquisition	CCD Camera	Microscope + CCD Camera
Resolution	4 µm/pixel	1.38 µm/pixel
Area	13 mm x 11 mm	2.18 mm x 1.58 mm
Software	Morfi	ImageJ

2.2 Reference Material

In order to evaluate the new analyzing procedure a sample of Polyester powder as spherical reference and a cut Viscose flock as fibrous reference as specified in Figure 2 have been used. The Polyester powder was ground with a ball mill and sieved whereas the fraction between 63 and 100 µm was taken.

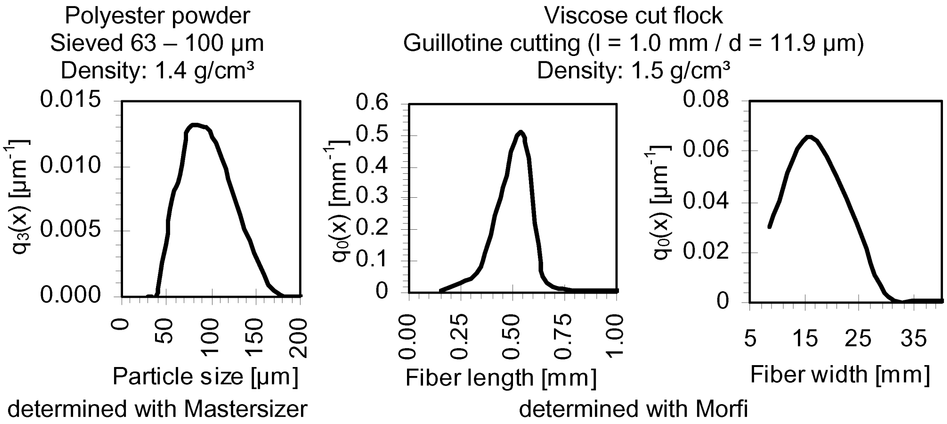

Figure 2: Particle size of Polyester powder determined with laser diffraction (Mastersizer) and length / width of flock determined with the Morfi analyzer.

The materials have been provided for the three following samples:

1. Pure spherical sample containing Polyester powder.
2. Pure fiber sample containing Viscose flock.
3. Mixed sample containing Polyester powder and Viscose flock (50 mass % each).

The new analyzing procedure as described in Chapter 2.1 was used to determine particle size as well as fiber length and width. Among a set of parameters which are computed by the ImageJ software the projected area (A) and the length (l) have been considered. Length was obtained by a modified algorithm from the plug-in Line 8 (Landini, 2010) using the skeletonize process. The width was calculated by Equation 3. A fiber was defined by two criteria. One the one hand the length as determined by the sketetonize process had to exceed 75 µm. On the other hand fiber length has to exceed the diameter by over 10 times. In case an individual did not comply with the criteria it was not considered to be a fiber.

$$d = \frac{A}{l} \qquad (3)$$

d .... Fiber diameter [µm]   A ... Projected area [µm²]   l ... Fiber length [µm]

3. Results

3.1 Particle Size

The first aim was to determine the particle size of Polyester powder. As shown in Figure 3 the distribution function obtained by the ImageJ software from sample #1 (pure powder) was in excellent agreement with the results of the laser diffraction (Mastersizer). The same powder measured together with the fibers (sample #3) resulted in a quite similar distribution function with only minor deviations. It is obvious that the used criteria for filtering the results are very effective and that it is possible to evaluate the non fibrous individuals exclusively.

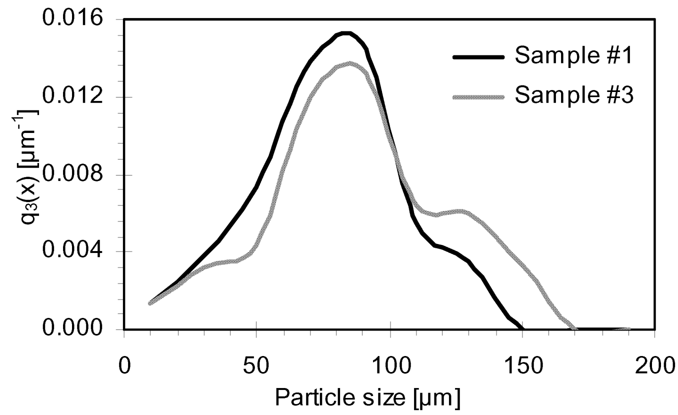

Figure 3: Particle size of Polyester particles determined in sample #1 and sample #3 using ImageJ software.

3.2 Fiber Length

The second task was to evaluate the fiber length again for a pure sample (#2) and sample #3 containing fibrous and non fibrous particles. As demonstrated in Figure 4 the distribution function determined with the ImageJ software fit excellent to the nominal length of 0.5 mm. It is also possible to measure the fiber length of the comingled sample. There is a slight difference of the distribution function, on particular a shoulder in the range between 200 and 400 µm which is significantly more pronounced that for the sure fiber sample. However, the filter criteria clearly exclude all Polyester particles since there is no fraction in the respective size range (30 – 180 µm).

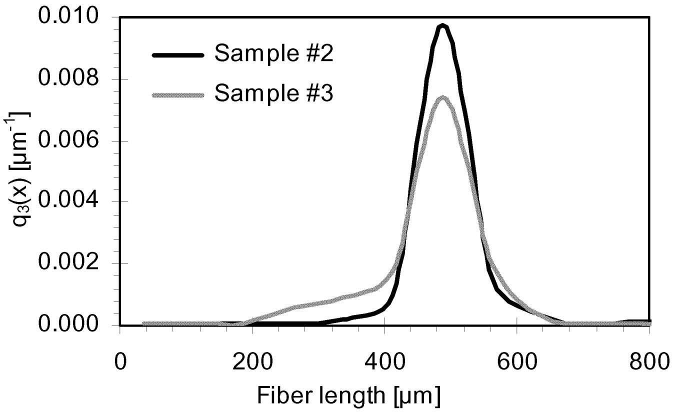

Figure 4: Fiber length of Viscose flock determined in sample #2 and sample #3 using ImageJ software.

3.3 Fiber width

Finally it was investigated if the the ImageJ is conveniant for the detremoination of fiber width. As shown in Figure 5 the distribution function is in excellent agreement with the nominal width of 11.9 µm in case of the pure fiber sample (#2). Compared to the Morfi analyzer the curve is slightly shifted to the left since the swelling in water does not occur. For the comingled sample (#3) there is a distinct shoulder at about 20 to 25 µm as well as low peak between 40 and 45 µm. However, the difference is rather small.

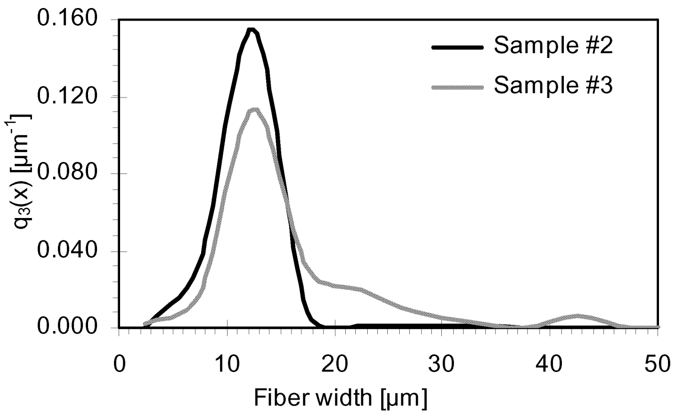

Figure 5: Fiber width of Viscose flock determined in sample #2 and sample #3 using ImageJ software.

4. Conclusions and outlook

An analyzing procedure comprising dispersion in air, image acquisition with a microscope and automated image analysis using ImageJ showed that it is possible to characterize samples containing fibrous and non fibrous particles at the same time. Figure 6 shows the mean values (median) of the particles size and fiber length/width. The deviation between the values determined for the pure samples (#1 and #2) and the comingled sample (#3) is below 11 %. It can be concluded that the new system is a proper tool for characterizing material containing both fibrous and non fibrous particles. Such samples can be frequently found in recycling processes. However, the method needs to be further improved. Currently a fully automated process is not possible demanding a large manual effort.

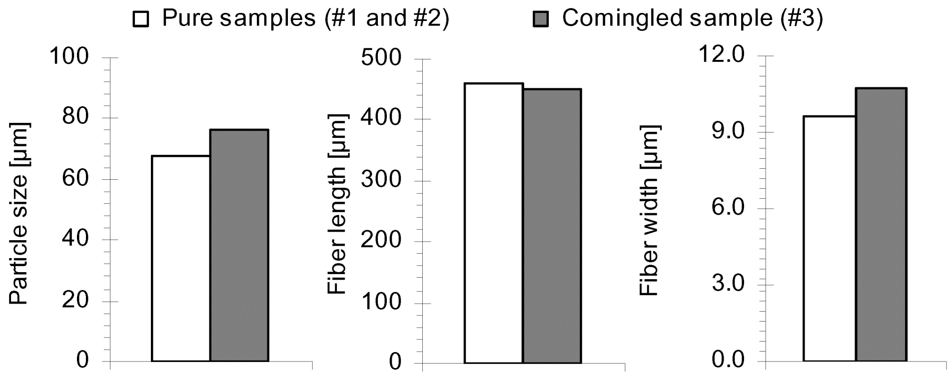

Figure 6: Average values of particle size (left), fiber length (middle) and fiber width (right) of pure samples (#1, #2) and comingled sample (#3) using ImageJ software.

References

Abramoff, M.D., Magelhaes, P.J., Ram, S.J., 2004, Image Processing with ImageJ, Biophotonics International, 11(7), 36-42.

Bartl A. and Pico D., 2009, Characterization of Short Fibers, Chemical Engineering Transactions, 17, 741 - 746.

Landini G. [Lines8_Plus 2.12] for ImageJ, available from http://www.dentistry.bham.ac.uk/landinig/software/software.html, accessed on 14 Sep. 2010.

Wadell H, 1932, Volume, Shape, and Roundness of Rock Particles, The Journal of Geology, 40, 443-451.

Zlatev M., 2005, Beitrag zur quantitativen Kornformcharakterisierung unter besonderer Berücksichtigung der digitalen Bildaufnahmetechnik, doctoral thesis, Technische Universität Bergakademie Freiberg, Germany.