Automated SEM Image Analysis for the Determination of Diameter, Length and Morphology Distributions of CNTs

Dominic Kehren, John Moré, Asmus Meyer-Plath, Sabine Plitzko*

Federal Institute for Occupational Safety and Health (BAuA), Nöldnerstr. 40-42, 10317 Berlin, Germany

*kehren.dominic@baua.bund.de

Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

Motivation

An automated software based approach on the analysis of fibres can have several advantages over manual analysis. Especially measurements of workplace conditions require the analysis of a vast amount of pictures to give account to a certain analysed area/air volume. Therefore an automated process would save a lot of time. But, moreover, it can analyse the fibres on other different aspects, than only length and diameter, at the same time. Thus, giving more information about each specific sample, leading to a thoroughly analysis of the fibres also regarding their hazardous or harmful characteristics.

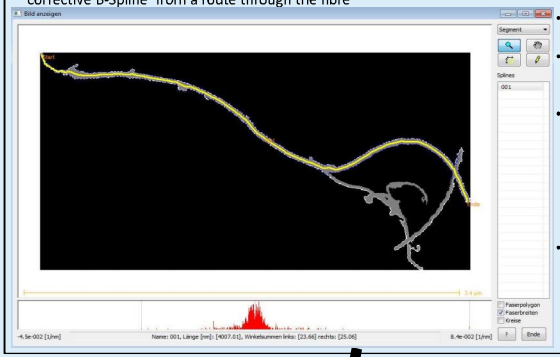
On this poster we present our attempt seize the challenge of detecting, recognizing and analysing fibres with a custom built software.

The presented fibre detection and analysis softer „FibreDetect" is able to recognize fibres and agglomerates automatically upon picture upload.

- Object recognition by thresholding with Zack`s triangular method
- Segmentation by contour tracing using the Moore neighbourhood of each pixel => encircling polygon

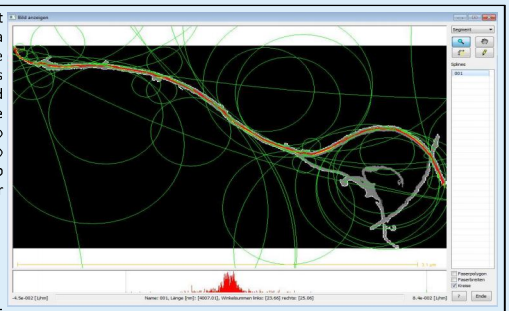
Determined values include:

- Diameter => histogram of the orthogonal distances of each point of the polygon to opposite border
- Length => Chain of Points with equal orthogonal distances to each side of the polygon (Spline) and corrective B-Spline from a route through the fibre

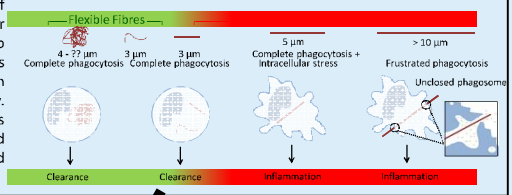


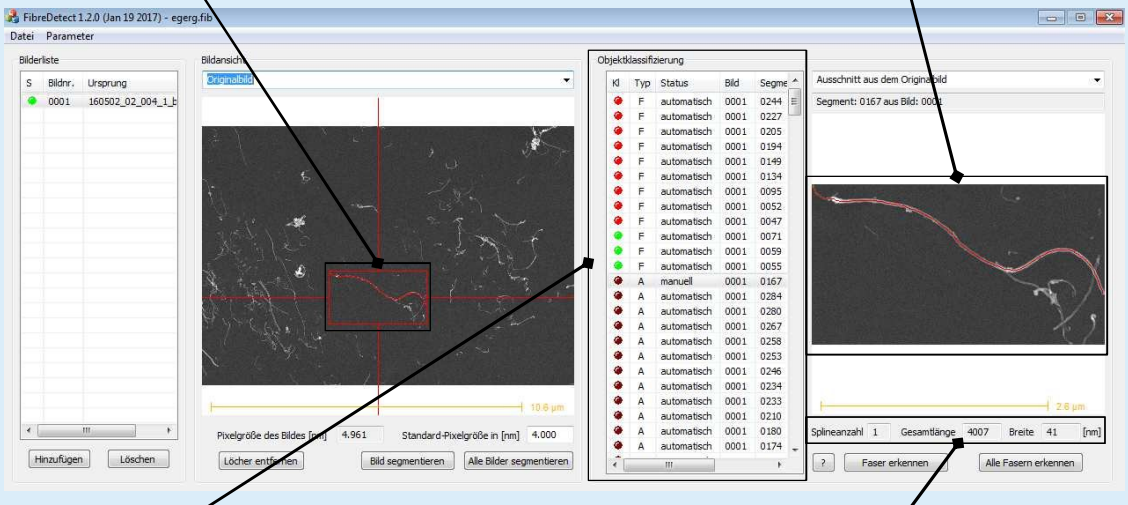
- The curvature at any given point
- Mean curvature/bending of the fibre
- A shape factor, here isoperimetric quotient: the ratio of the area of the shape to the area of a circle having the same perimeter
- Object classification using the data and our classification scheme

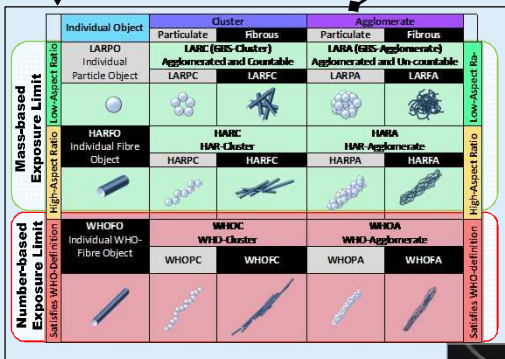
Using osculating circles at every point of the spline a detailed histogram of the curvature of the fibre is gained. The maximum and average curvature or degree of bending can be related to the rigidity of a fibre and to the force it was exposed to during processing or sampling.



The rigidity or flexibility of fibres, in other words their ability to be bender or to become a tangled coil plays a key role in the question regarding their toxicity. Longer and more rigid fibres can lead to frustrated phagocytosis, cell death and tend to be carcinogenic.





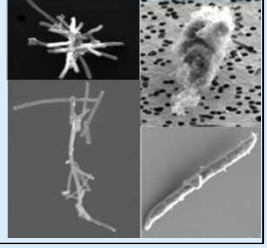


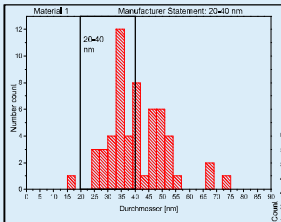
The morphology of a fibre object is linked to many other properties:

- Dustiness
- Toxicity
- Degradability
- Decomposabillity

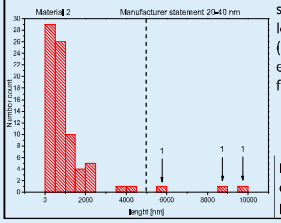
Especially the relation between morphology and dustiness is of great interest. Further details can be found on Poster xyz!

LAR (Low-**A**spect-**R**atio): Longitudinal to lateral dimension < 3. **HAR** (High-**A**spect-**R**atio): Longitudinal to lateral dimension > 3. **WHO** stands for **HAR** longitudinal dimensions > 5 µm and lateral dimensions < 3 µm. **O** (**O**bject), i.e., particle, tube, rod or fibre; **C** (Cluster); **A** (Agglomerate). **Clusters** are characterized by a low number of objects that could be individually distinguished, whereas **Agglomerates** contain objects in a higher concentration such that they overlap and can predominantly not be distinguished individually.

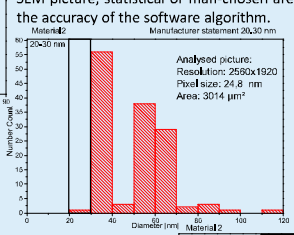




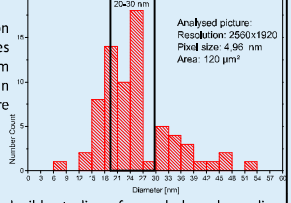
The shown data rises the question, if the materials are sufficient to be used in studies such as inhalation toxicology? Or if the apparently size depending effects might be caused by fibres longer or thicker than in the manufacturers statement.



A comparison between data provided by a materials manufacturer and a statistical analysis depends not only on the synthesis quality delivered by the manufacturer. But also on the preparation of the sample, magnification/pixel resolution of the SEM picture, statistical or man-chosen area of interest and on the accuracy of the software algorithm.



The length distribution shows a lack of fibres longer than 5 µm (WHO fibres) and an excess of short fibre fragments.



For Reliable and reproducible studies of morphology depending effects on fibre toxicity a better control of their fabrication process is inevitably necessary.