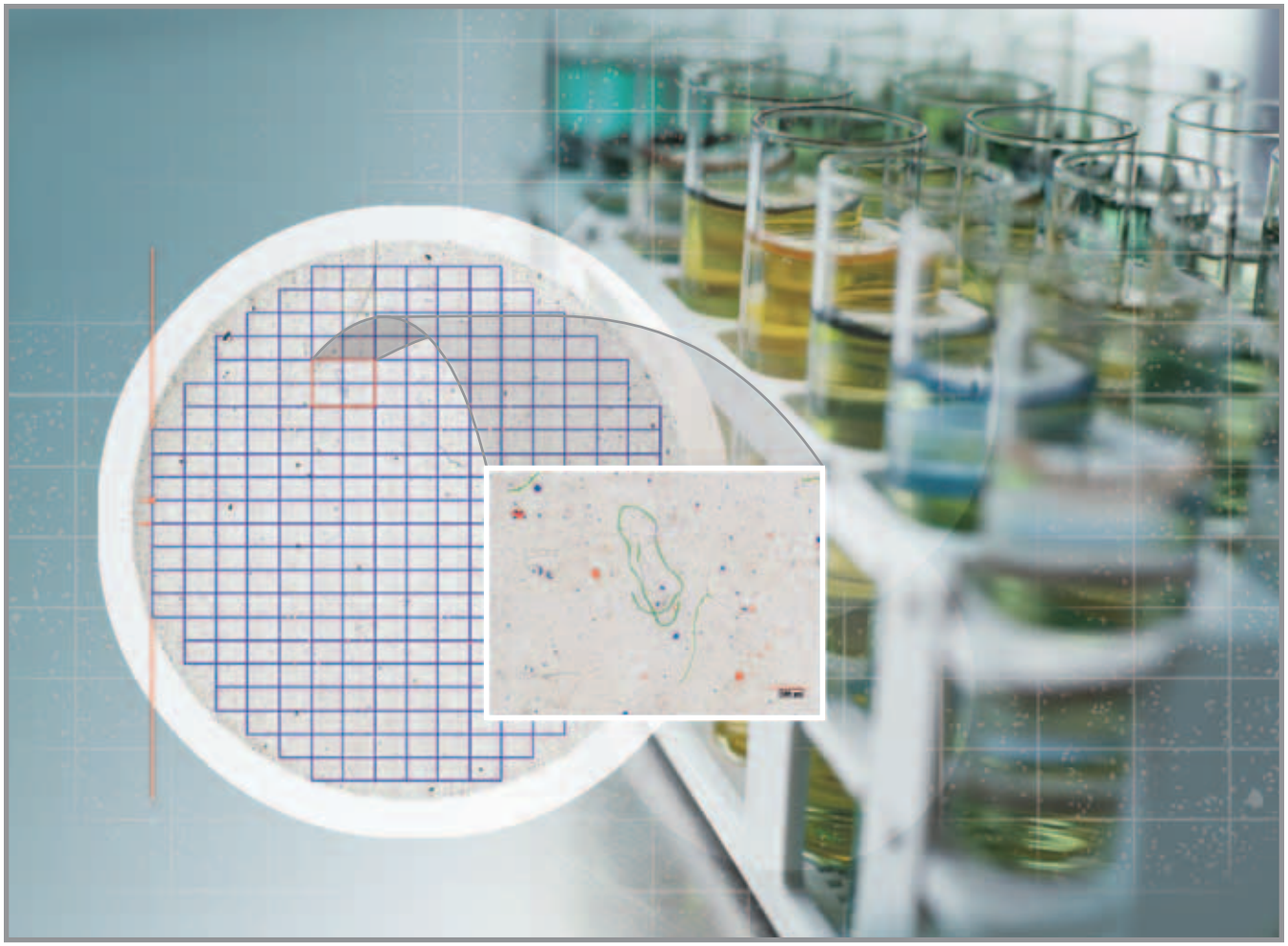
CLEMEX intelligent microscopy

Quantification of Particulate Contamination

by Automated Image Analysis



Quantification of Particulate Contamination
by Automated Image Analysis

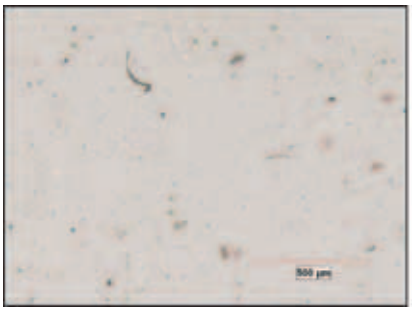
Introduction

The quantitative determination of particulate contamination is of prime importance for assessment of cleanliness in various environments from air in clean rooms to hydraulic fluids in mechanical components.

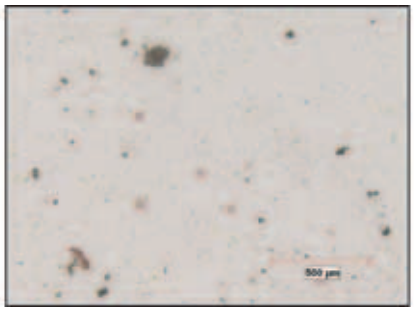
Manufacturers and quality control labs are finding it increasingly essential to guarantee the purity and uncontaminated state of components and fluids. Diverse industries depend on particle analysis measurements that are both reliable and reproducible. Information this critical must be delivered through proper documentation that is customized to the specific requirements of the internal audience and to industry standards; in this application we used the ISO 4407 standard.

The analysis process of paper filter residue is simple: fluids, such as oils or solvents, are filtered through a circular membrane. The collected residue is caught by the filter. One method commonly used to observe particulate contamination is by counting and measuring particulates collected on filters using optical microscopy. In quality control laboratories, Automated Image Analysis allows the user to save time and money as well as eliminate subjectivity due to fatigue. The challenge of Automated Image Analysis is detecting particles of different reflectivity and fibers whose length exceeds the field of view, within a reasonable amount of time.

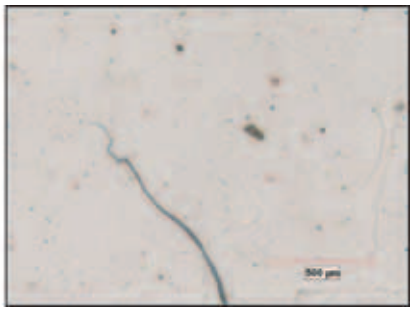
Once the particles and fibers are detected accurately, the particulate contaminants are separated from the fibers and are classified by size and/or color.



Typical field on paper filter.
50X total mag.



Typical field on paper filter.
50X total mag.



Typical field with section of a fiber.
50X total mag.

Purpose

Although image analysis algorithms are becoming more and more standard, various approaches are possible, making use of the numerous tools. The challenge lies in programming the application in order to obtain the precision and level of detail needed on the features of interest, without cumbersome and unrelated details. Because there are many ways to achieve the same results, different methods must be tested and compared in order to select the most suitable one, based on quality of the output, relevance of the information given and time of analysis.

Purpose (con't)

Most particles of interest lie in the range of 3 to 400 microns with fibers that can measure over 5 mm. In standard optical microscopy Image Analysis methods, measurements are usually done on the objects in each field of view and the results are cumulated for the area covered. The challenge lies in the fact that the fibers generally overlap two or more fields of view, and therefore the fiber is measured in sections when the standard method is used. *Figures a* and *b* show four fields of view with an overlapping fiber. The different colors illustrate that the fiber is measured as four different objects when each field is examined individually. *Figure c* shows the fibers zoomed in on a Mosaic image.

The purpose of this paper is to compare the Tiling and the Mosaic methods. The two methods will be compared on the basis of time of execution, precision of measurement and memory space required.

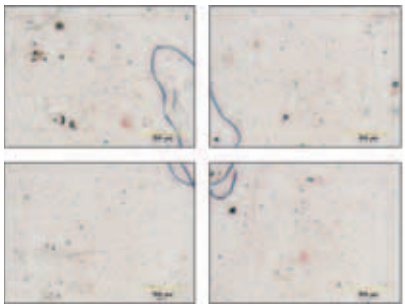


Fig a: Four fields of view with sections of a fiber. (50X)

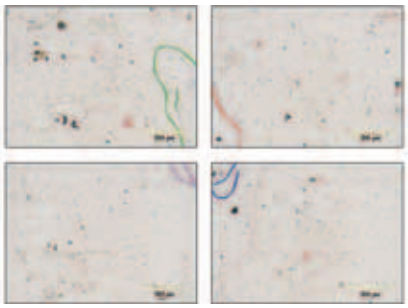
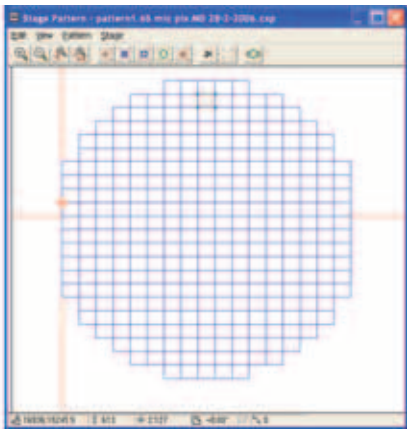


Fig b: Four fields of view with sections of a fiber detected as single features. (50X)

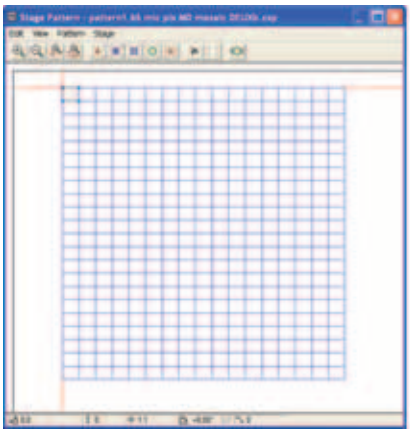
Fig c: Same fields of view in with whole fiber. (50X)

Tiling and Mosaic Methods

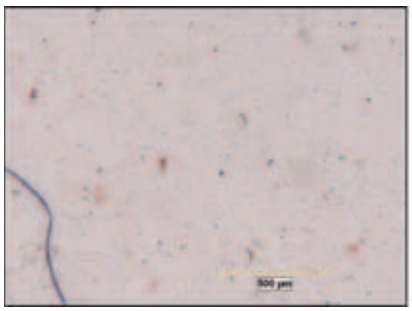
The Tiling method uses a circular stage pattern to cover the exact area of the filter; image analysis in binary operations is performed on each field of view. The Mosaic method uses a square stage pattern to scan over a larger area than the filter; the image of the whole sample is rebuilt and the analysis is performed on the resulting image. Each method has its limitations with respect to time of analysis, precision and memory space required. Usually gains in one area are offset by losses in another.



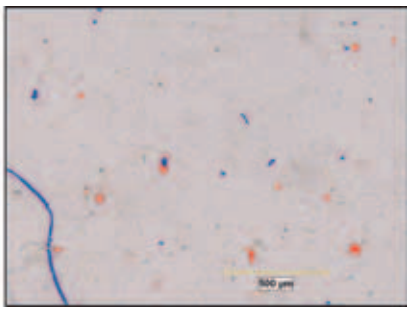
Custom circular stage pattern used in the Tilling method.



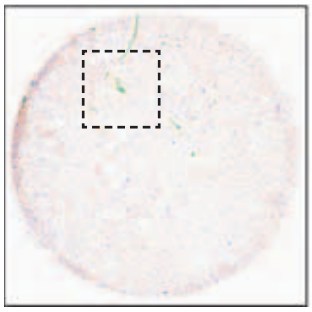
Square stage pattern used in the Mosaic method.



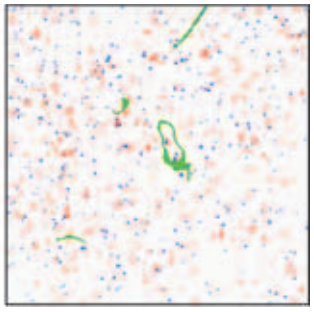
Typical field with three types of particulates. (50X)



Typical field with three types of particulates detected in separate bitplanes. (50X)



Final binary image showing all particles and fibers in three separate bitplanes.



Zoom in on reconnected fiber.

Tiling

This method is used with a predefined circular stage pattern, which corresponds to the area of the filter where the particulates are collected. The Tiling method involves two steps of measurements; first, in each field of view the particulates are separated from the fibers based on size and shape factors and the nonfiber particulates are measured. The fibers are transferred by a Tiling function into a cumulative bitplane. Finally, when the entire area of the sample is covered, the fibers are reconnected and measured.

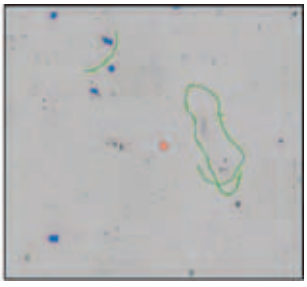
Mosaic

The Mosaic method consists of scanning over the whole area of the sample with a square stage pattern and storing all the original images. Once the whole filter area has been covered, the individual fields of view are stitched together with great precision and the image of the entire filter is assembled. The image analysis is done on the image of the entire sample, where the fibers are not cut into segments.

Mosaic image of the entire filter.

Mosaic image of the entire filter with binary detection of particulates.

Zoom in on fiber.



Detection of particles and fibers.

Procedure

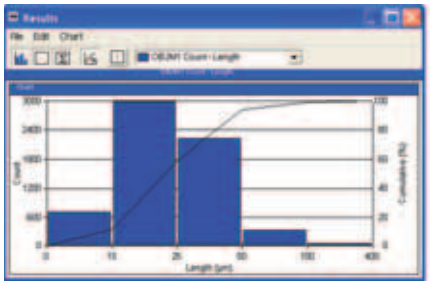
1. Sample:
A standard 47 mm circular filter with moderate particulate contamination was analyzed. The filter contained particles ranging from 10 microns to 400 microns and fibers as long as 5000 microns. The dry paper filter was placed between two glass slides to ensure absolute flatness and constant focusing distance. The sample was placed on a sample holder to prevent it from sliding on the plate with stage movement and to allow for precise matching of consecutive fields.

2. Instrument Parameters:
Illumination, intensity, color balance and calibration were set and remained constant between the runs. All analyses were performed with 50X total magnification, using a 3.1 megapixel color camera. The resolution of the image on the screen was 1.65 microns/pixel and 8.87 microns/pixel on the mosaic image.

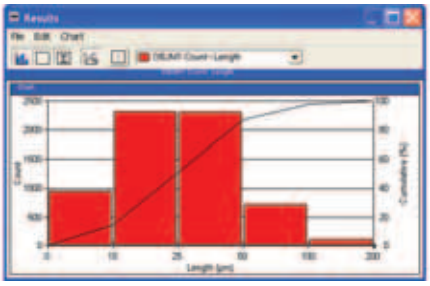
3. Objects Measured:
The particulate residue objects were measured using Length as required by ISO 4407 standard method. The fibers were identified as the objects with aspect ratio greater than 10 and measuring at least 100 microns in Length. There were two types of particles to be differentiated based on color: rust colored particles and grey particles.

Tiling Method: Results and Discussion

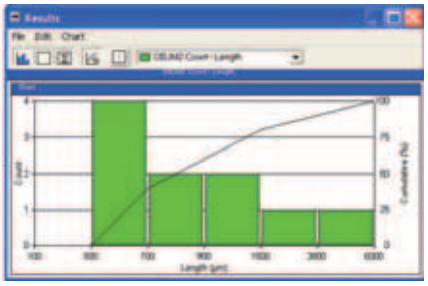
The execution of the analysis using the Tiling method took 5.5 minutes. The three resulting histograms show the particle size distributions for the dark particles (blue histogram), the rust colored particles (red histogram) and finally the results for the fibers are shown in the green histogram. The size of the smallest objects measured were in the 0-15 micron category in both colors of particles and the largest measured 308 microns, in the dark particles. A total of 10 fibers were detected and measured between 507 microns and 5302 microns.



Result histogram of size distribution for dark particles, using Tiling method.



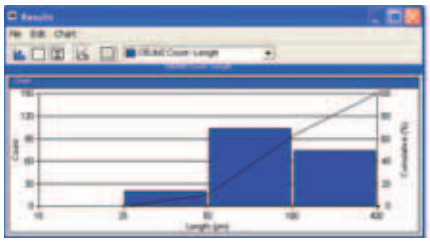
Result histogram of size distribution for rust particles, using Tiling method.



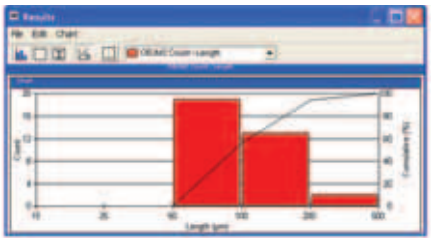
Result histogram of size distribution fibers, using Tiling method.

Mosaic Method: Results and Discussion

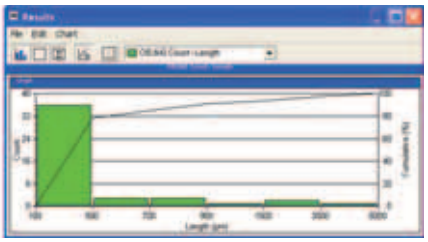
The execution of the analysis using the Mosaic method took 8 minutes. The three resulting histograms show the particle size distributions for the dark particles (blue histogram), the rust colored particles (red histogram) and finally the results for the fibers are shown in the green histogram. The size of the smallest objects measured were in the 25-50 micron category in the dark particles and the largest objects were found in the 200 – 500 micron category in both colors of particles. A total of 46 fibers were detected and measured between 134 microns and 5387 microns.



Result histogram of size distribution for dark particles, using Mosaic method.



Result histogram of size distribution for rust particles, using Mosaic method.



Result histogram of size distribution fibers, using Mosaic method.

Conclusions

The two methods show consistency in the results for the measurement of the large fibers, above 500 microns, however a larger number of fibers were identified with the Mosaic method, suggesting a higher precision in the detection of large fibers than with the Tiling method. In comparing the two methods for the measurement of the nonfiber particulates, we can observe that the results are not consistent. The Tiling method resulted in a large number of particulates detected in the 15 to 50 size range, as opposed to none in the Mosaic. Overall, the Tiling method detected a significantly higher number of particulates in general in all size ranges. However for the measurement of fibers, the Mosaic method was more efficient as it detected 46 fibers versus 10 with the Tiling method. As expected, the Tiling method is more precise for detection of the nonfiber particulates, due to the loss of resolution inherent to the Mosaic method.

As for the time required for the analysis, the Mosaic method took 8 minutes to complete the analysis compared with 5.5 minutes with the Tiling method; we can say that the difference is not significant. The Mosaic method offers the advantage of showing the entire filter and making it easy to visualize and correlate the objects measured to the real image; the binary detection and the image can be zoomed in and out. However it has the disadvantage of requiring large amounts of memory space and a high resolution camera in order to generate precise results. Insufficient available memory will cause instability of the system and possible loss of precious time and information.

Both methods succeeded in reconnecting the fibers and generating precise measurements; the Mosaic method by performing Image analysis on the high resolution stiched image, and the Tiling method by reconnecting binarized image of the fibers from the individual fields of analysis. The loss of fibers with the Tiling method is explained by the fact that some very small pieces of fiber, at the intersection of the fields of view, are cut and might not pass the shape test to be identified as fibers. In order to improve the detection of the fibers with the Tiling method, a guard frame should be introduced to correct the problem.

Both the Tiling and the Mosaic methods allow the return to the exact field of measurement. The difference between the two methods is that the Tiling returns to a single specific field per view while the Mosaic can show multiple fields in the same view by zooming in and out.

Conclusions (con't)

Summary of Results

Effective filtration diameter of membrane filter: 47mm Area of single field: 3584906 µm² Number of fields analyzed: 314						
Method of analysis	Tiling					
size range	0-15	15-25	25-50	50-100	100-400	Fibers (400-5300)
Dark particles	705	2,993	2,221	322	42	—
Rust particles	951	2,326	2,310	717	116	—
Total count	1,656	5,319	4,531	1,039	158	10
Total count, all	12,713					10

Effective filtration diameter of membrane filter: 47mm Area of single field: 3584906 µm² Number of fields analyzed: 314						
Method of analysis	Mosaic					
size range	0-15	15-25	25-50	50-100	100-400	Fibers (400-5300)
Dark particles	0	0	20	104	74	—
Rust particles	0	0	0	20	15	—
Total count	0	0	20	124	89	46
Total count, all	233					46

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