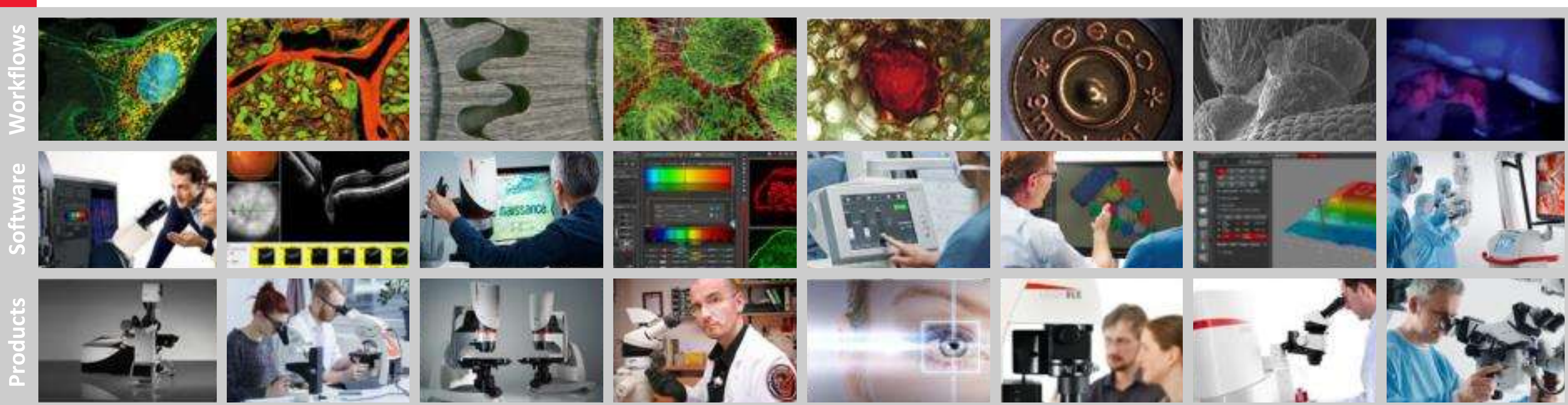
From Eye to Insight

Leica MICROSYSTEMS



Webinar

Basics in Component Cleanliness Analysis

Dr. Nicol Ecke

Science Lab

Topics

- Why component cleanliness is important
- Fields of application, requirements and standards
- Critical dimension and measurement parameters
- Attain objective, accurate and reproducible results (VDA19 standard analysis)
- Workflow based solution Leica & Pall
- Dedicated solutions fitting to each need

Why is component cleanliness of importance?

Technical component cleanliness has its **origins** in the **automotive and car manufacturer industry**. The cleanliness of the components has an influence on the quality, functionality, and longevity of these automobile systems.

1. In the worst case, particular contamination may be the reason for a system failure.
2. All suppliers have to prove the cleanliness of their components.

Cleaning & extraction –
An essential part of the process

- Components are cleaned **<u>during</u>** or **<u>after</u>** production

Washing cabinet/Cleaning process

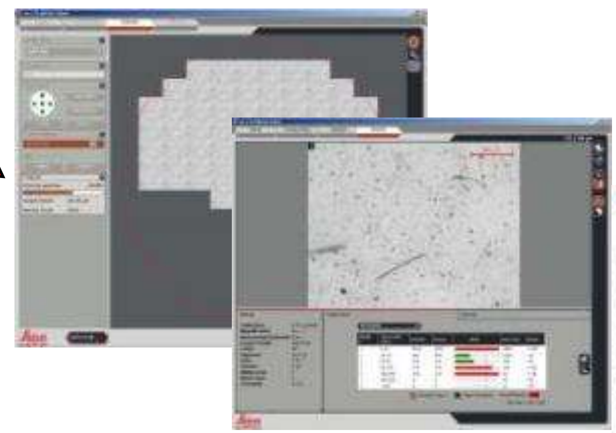
- Particles have to be extracted from the components, e.g. in cleanliness cabinets
- The cleaning fluid is poured through a filter
- The filter is dried in an oven.

Analyse filter

Particles on the filter can be analysed with an optical device

- After preparation the filter is mounted on the microscope for inspection

- Automatic analysis: Scan-analyze-inspect-document



- Easy, reliable, reproducible software solution

Analysis systems for component cleanliness

DMS1000 system solution

- Measurement & Documentation
- Coded **zoom** optics
- **VDA19 Standard Analysis: 50 µm**
- Daily analysis of particles above **30 µm**
- ISO16232, USP788,… user defined
- **2D** analysis

DM4/6 system solutions

- Measurement & Documentation
- Fully automated & coded microscope (**fixed optics**)
- **VDA19 Standard & Extended Analysis**
- Daily analysis of particles above **5 µm**
- **3D** analysis (length, breadth, height)
- **Oil analysis** (ISO4406, DIN51455)
- ISO16232, USP788,… user defined

Zoom — Optics — *fixed*

Macro — Size of structures — *Micro*

2 D — Properties of particles/Damage potential — *3D* *Material*

The Cleaning procedure – Sample preparation an essential part of the process

- Filter preparation for automated image analysis system has to fulfill some criteria to count, measure and quantify particles.

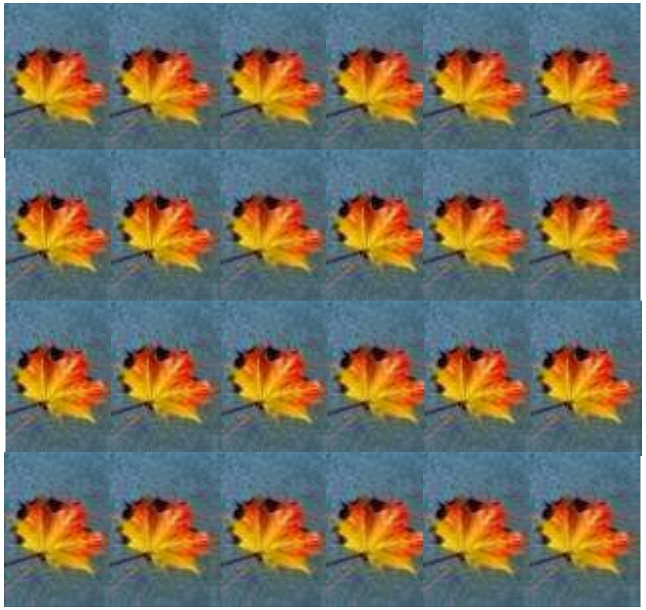
What is similar for all these products?




At these conditions they can‘t be counted.

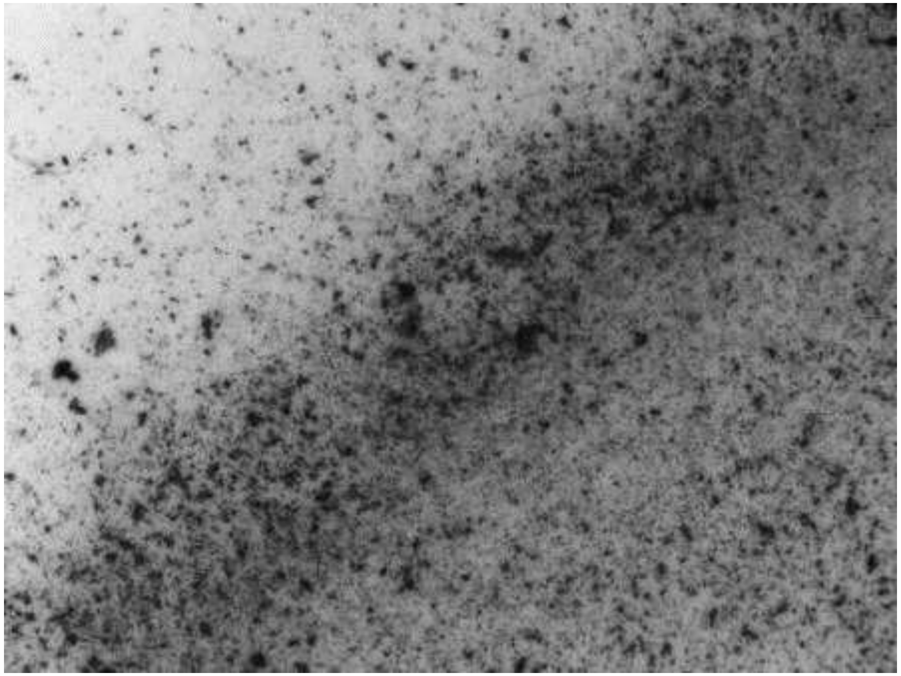
…and certainly not measured!

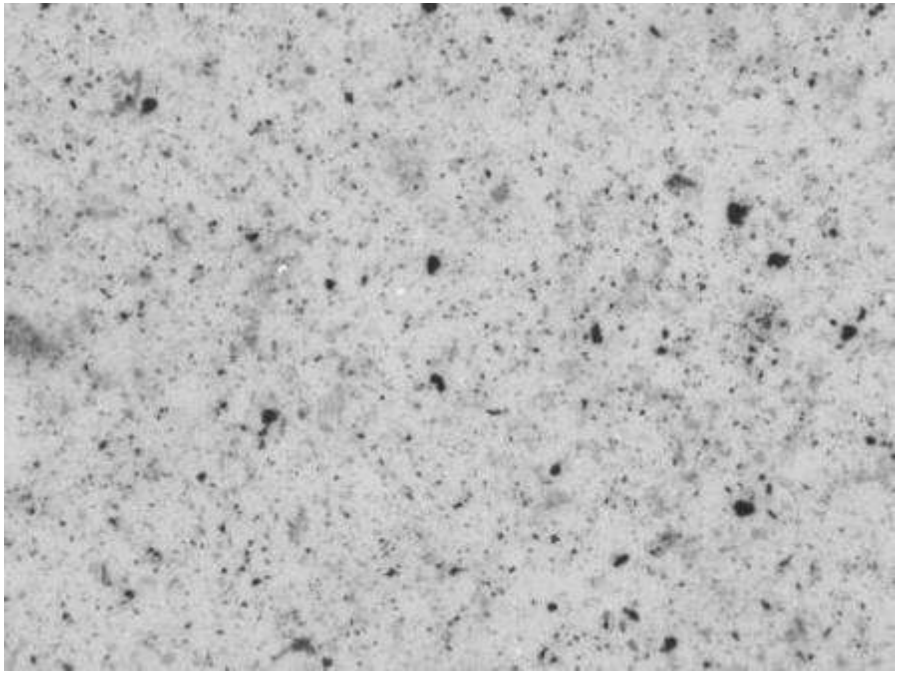
The Cleaning procedure – Sample preparation an essential part of the process



They must be separated!

The Cleaning procedure – Sample preparation an essential part of the process





- Reliable and reproducible counting of particles on these filters is very problematic!
- Particles must be distributed separately onto the filter by adjusting the filtration process properly before they can be counted!

A suitable filter membrane must be selected!

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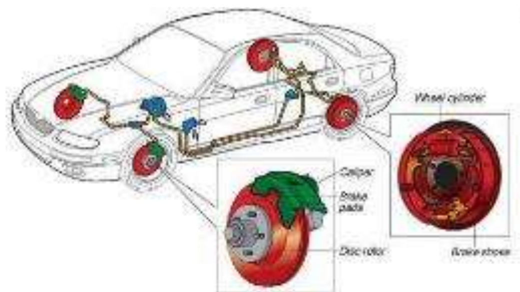
Fields of application (beside automotive)

- Aviation

- Hydraulic fluid and oil



- Electronics

- Optics

- Micro mechanic

- Medical devices

Requirements and Agreements

Agreements

Parameters

- What should be measured? (length, breadth, height,…)?
- What is useful for my product?
- Which parameter should be used for classification?
- Differentiation of reflective and non reflective particles?
- Hardness of materials (Shore hardness). Is that feasible?
- Differentiation of particles and fibres?

Size of particles and classes

- From which size up particles should analysed?
- What is meaningful for my product?
- Which class limits should be used?
- Do we follow a standard, e.g. VDA19 or ISO16232?

Control and documentation of the results

- Re-localisation and control of particles?
- Clean-up and editing of particles?
- Documentation of settings, results, images, Diagrams,…?

Standards

VDA 19 (2004) & ISO 16232:

- Not related to daily work
- Not enough parameters
- Not precise enough
- More pictures, figures, examples
- Bad comparability between analysis systems and users

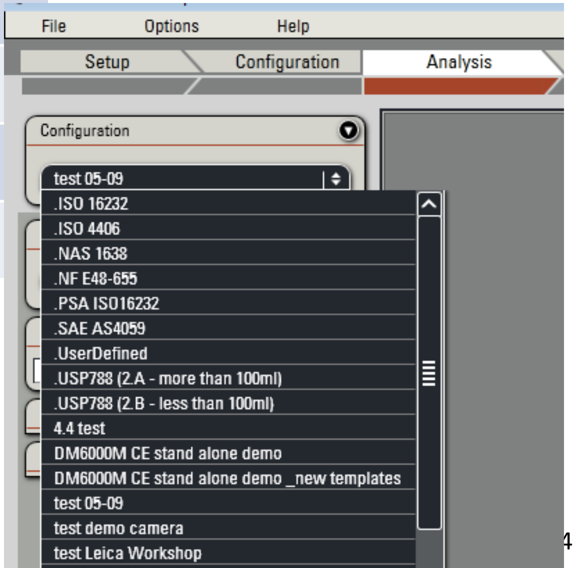
Revision of the VDA 19 (2015) & ISO 16232:

- More related to daily work
- Comparability between analysis systems and users
- ‚cooking recipe‛ for analysis
- **Standard analysis** with fixed parameters, size of particles, classes, length, breadth, image settings, threshold, fibre criteria
- **Extended analysis**: e.g. height measurement of particles, characterisation of the material of particles

Cleanliness Standards and Applications

Many Standards Have Been Developed for Specific Applications

Standard	Application	Support Level
ISO 16232	Automotive	Direct Support
VDA 19	Automotive	Excel Template
ISO 4406/4407 DIN 51455	Hydraulic Fluids Oil	Excel Template Excel Template
NAS 1638	Lubrication	Excel Template
SAE 4059	Hydraulic Fluids	Excel Template
USP-788	Pharmaceutical	Excel Template
NF E48-655	Hydraulic Fluids	Excel Template
User Defined	Any	Direct Support



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Size of particles

Length of particle have to be build up by 10 pixels

Size of 1 pixel = calibration value of the system, e.g. 5µm/pixel

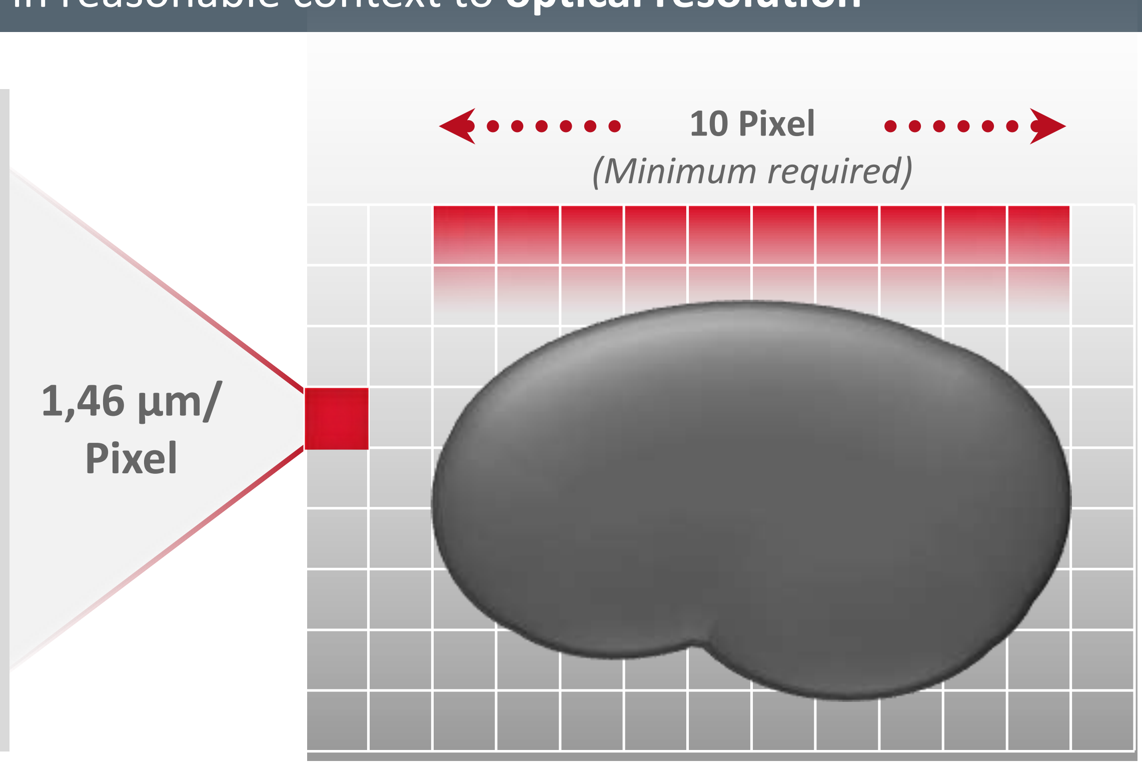
Important:
calibration value have to be in reasonable context to **optical resolution**

Size of one pixel
Theoretical calibration value

Pixel size camera
4,6 µm

∑ magnification
5 x 0,63

Particle of
≥15 µm size



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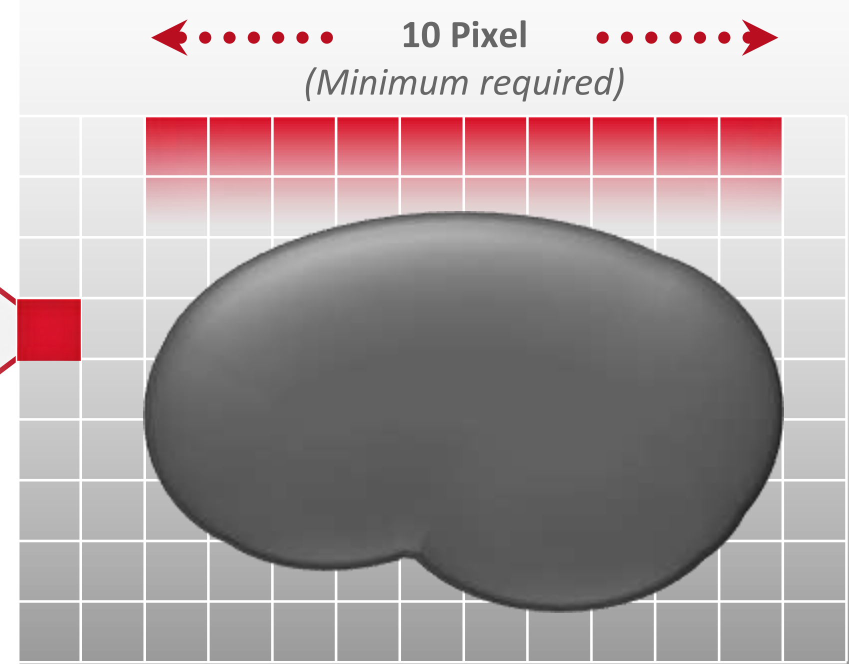
Size of one pixel
Theoretical calibration value

$$\frac{4{,}6\ \mu m}{5 \times 0{,}63}$$

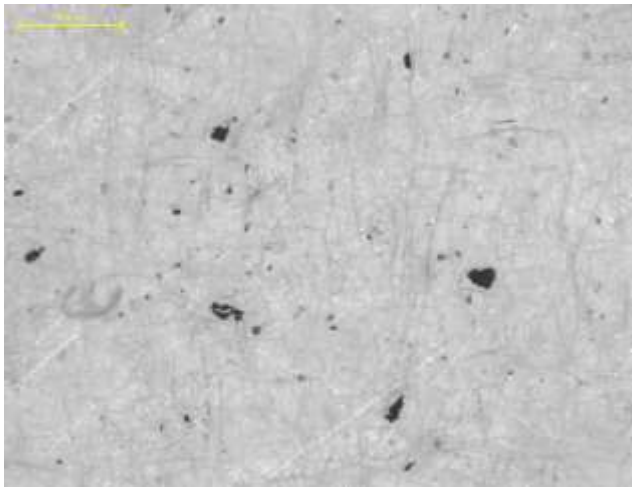
Particle of ≥15 µm size

1,46 µm/ Pixel

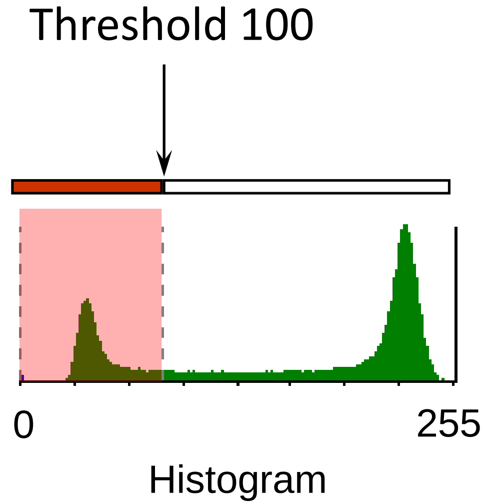


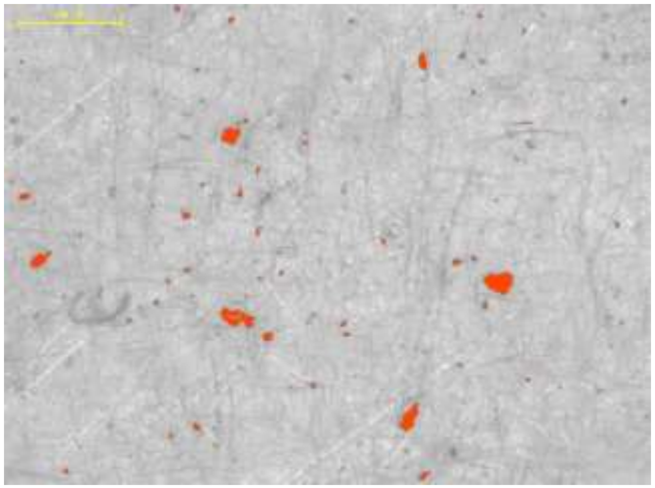
Detection

Detection of particles:



Greyscale image

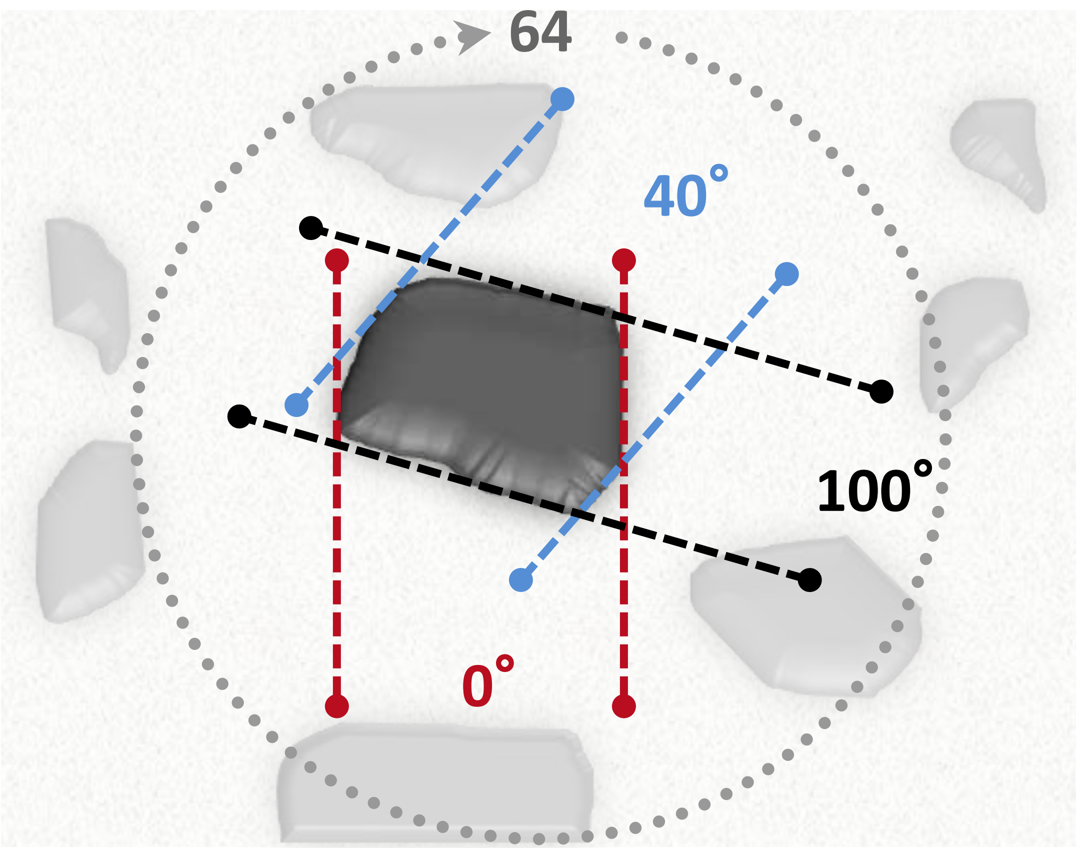




Binary image:

- Everthing below threshold in **<u>RED</u>** = will be measured
- Evrything above threshold will not be measured

Measurement parameters



Size, length, breadth, boundary, shape, etc.

Feret measurement: Distance between two parallel lines touching the object (caliper)

Precision: 64 different angularities

Feret lenght and breadth: max. and min. Feret distance of a feature, respectively

The critical dimension…

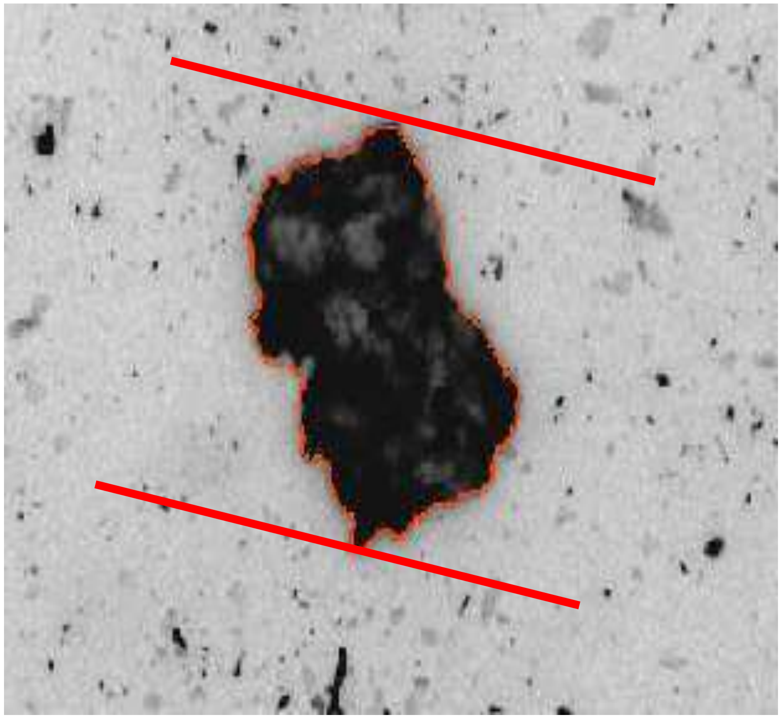
Damage potential

Critical dimension: length

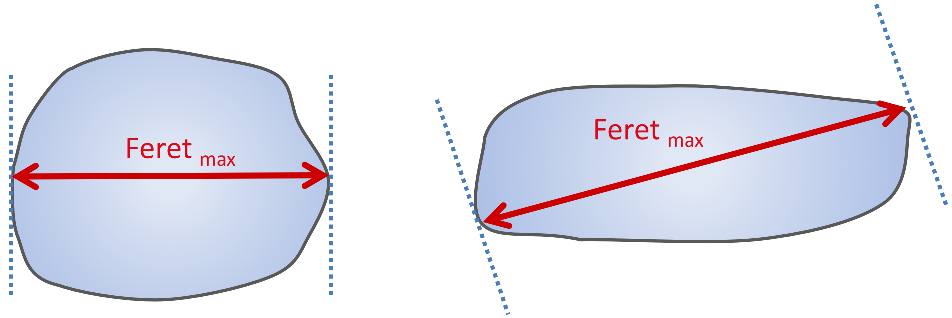
Identification of Risky Particles

- Critical dimension: **length**

Length of the particle is the standard dimension for the classification.



- Length = longest ferret
- Maximum damage potential of a particle
- This is true for compact particles



Long particles will be orientated parallel to the **flow direction**.

➔ **Is the particle length still the critical dimension?**

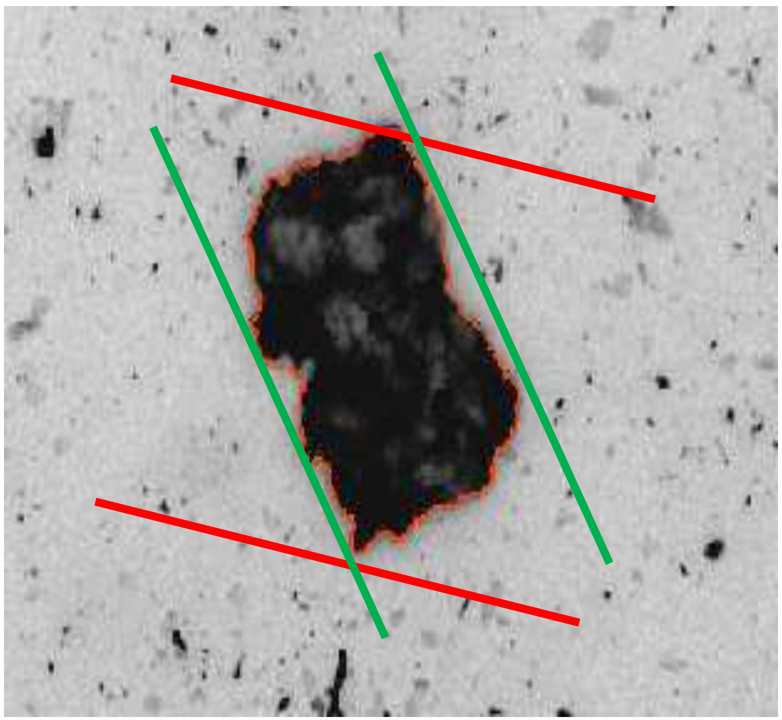
Damage potential

Critical dimension: breadth

Identification of Risky Particles

- Critical dimension: breadth

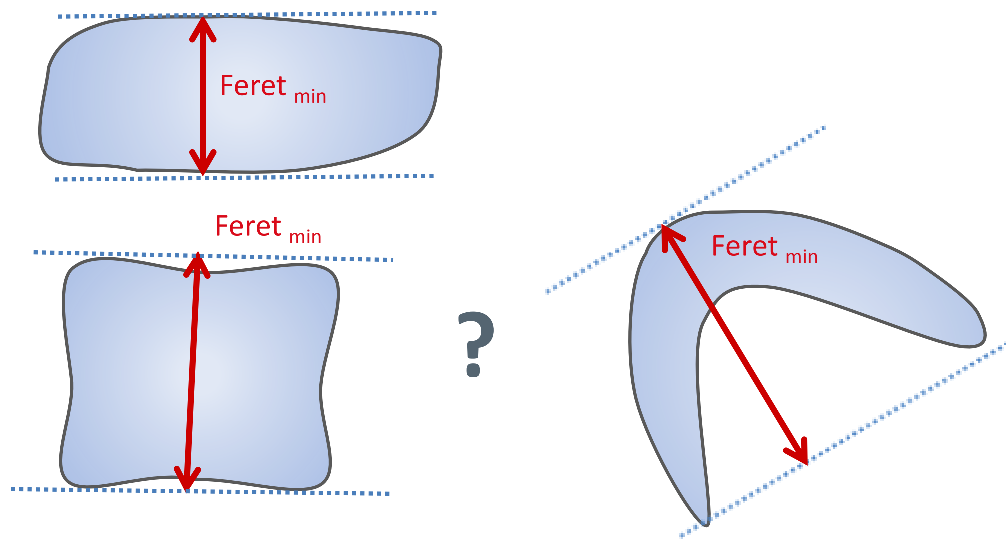
Size: Only length (Feret $_{max}$) doesn‘t characterize the full damage potential.



What is the width of a particle?

Length = longest feret

Width = shortest feret



- Breadth is a critical dimensions for particles adjusted in a **flow direction**.
- Injection pumps, pistons, spools
- Regarding the breadth the Feret min reflects the maximum potential damage

→ Does the Feret min reflects a damage potential of curved particles or fibres?

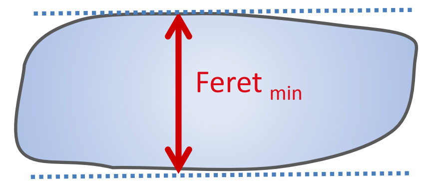
Identification of Risky Particles

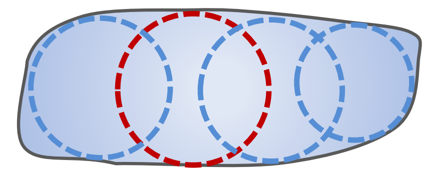
- Breadth

Minimum feret and **maximum inner circle diameter** - Which on is better?

Case 1: Particles is compact and convex

min. feret ≈ max. inner circle diameter

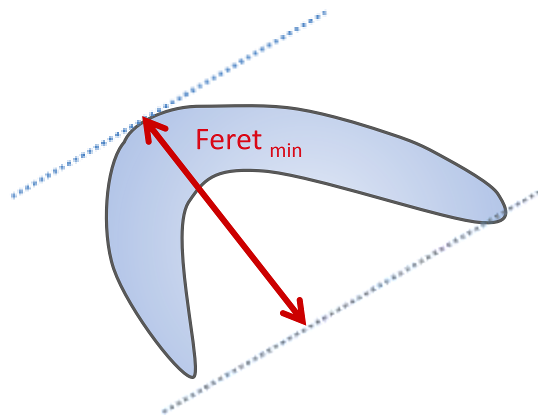


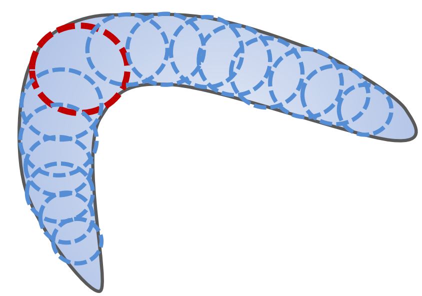


Case 2: Particles is elongated and curved

min. feret >> max. inner circle diameter

max. inner circle dia. represents the actual width of the particle

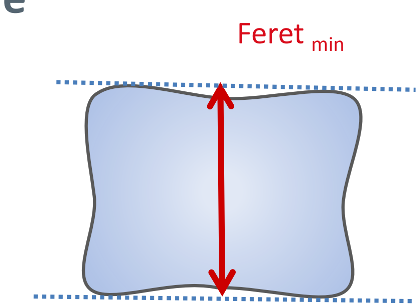


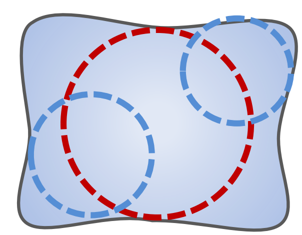


Case 3: Particles is compact and concave

min. feret > max. inner circle diameter

min. feret represents the critical dimension





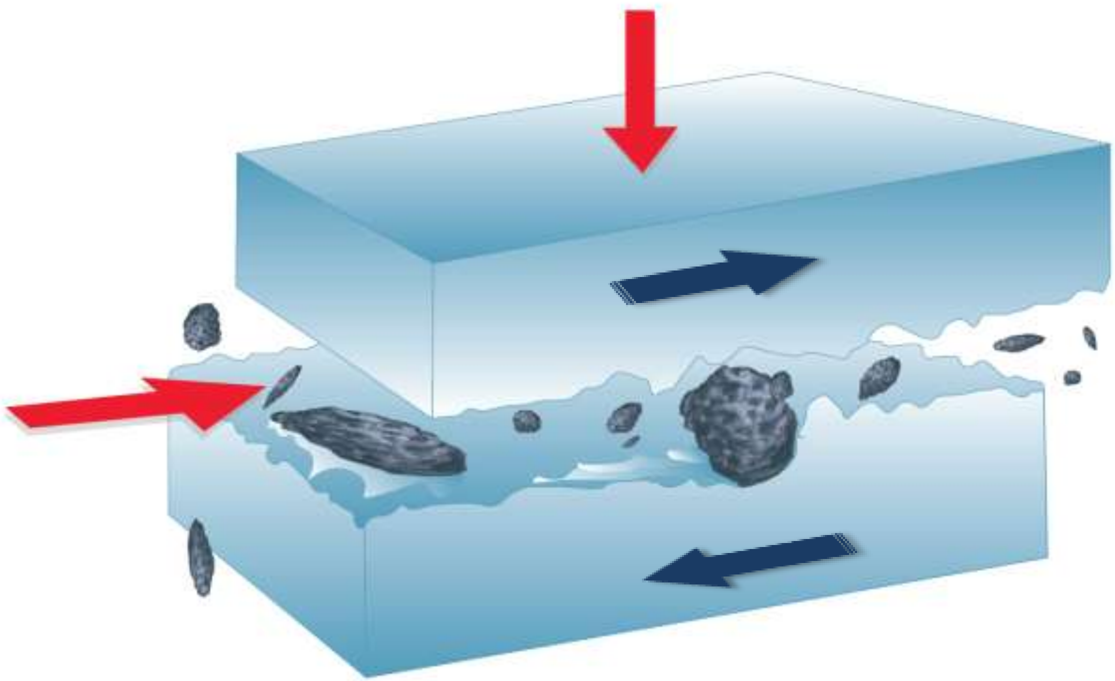
Damage potential

Critical dimension: height

Identification of Risky Particles

- Thin and large particles can be less dangerous than small but round particles.

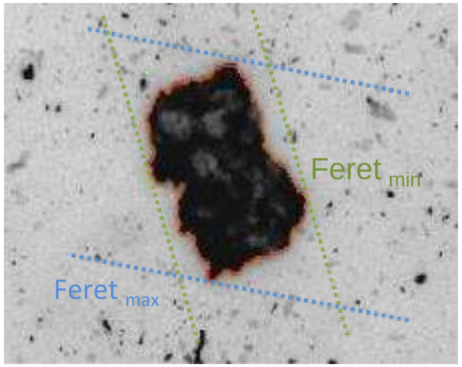
<u>The 3D shape determines also the risk potential of the contamination</u>.

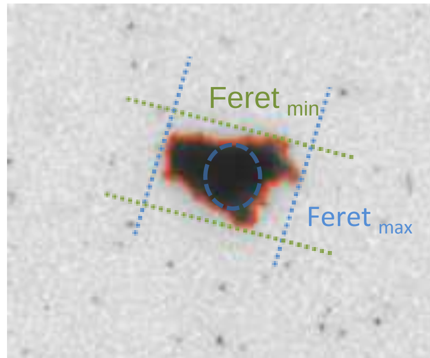


<u>2D information is not sufficient to estimate the risk potential of the contamination!</u>

2D & 3D measurements

- 2D Measurement: 2.5x/5x/10x lenses with high depth of field

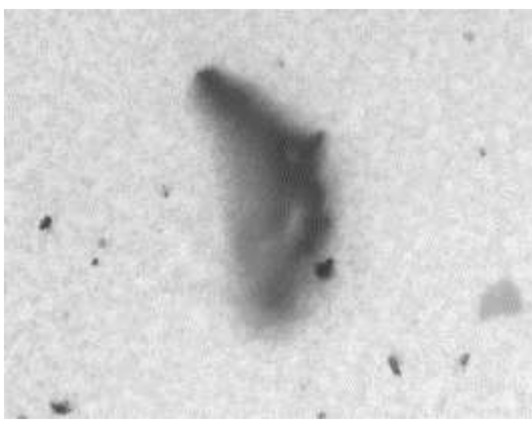


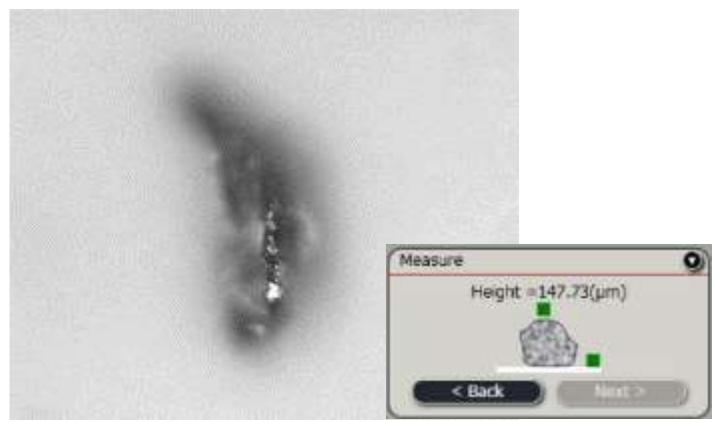


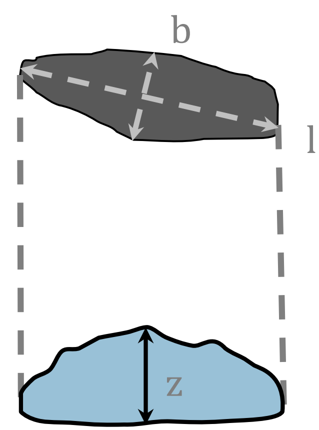
Length (µm)	Area (µm²)	Breadth (µm)
483.03	5903.27	24.09
191.23	14397.53	121.92

- Height measurement: 20x lens with low depth of field

1. Focus on filter background
2. Focus on the top of the particles







Length, Width and Height:
Damage potential in 3 dimensions!

Nature of particles

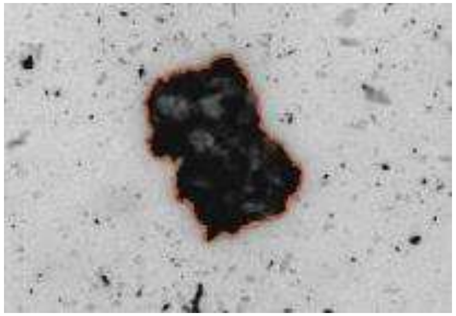
Damage potential: hard and conductive particles

- Hard particles have higher damage potential, e.g. metallic particles, grinding material (corundum, carbide)
- Metall particles are conductive ⇒ damage of electronics, electronic boards
- Reflexes on particles are an indicator for metals
- Automatic differentiation of metallic and non-metallic glance in one scan

Differentiation particles and fibres

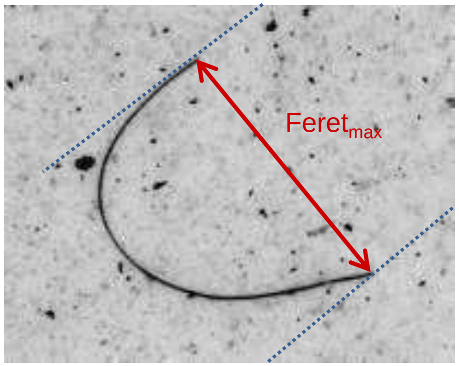
- Fibres are soft and have low damage potential
- Separation of particles and fibres (length/breadth ratio)

Feretlength 1270 µm
Fibre length 2460 µm



Particle POL Modus

Metall. particle brightfield: reflexes



Fibre length (Feret) POL Modus

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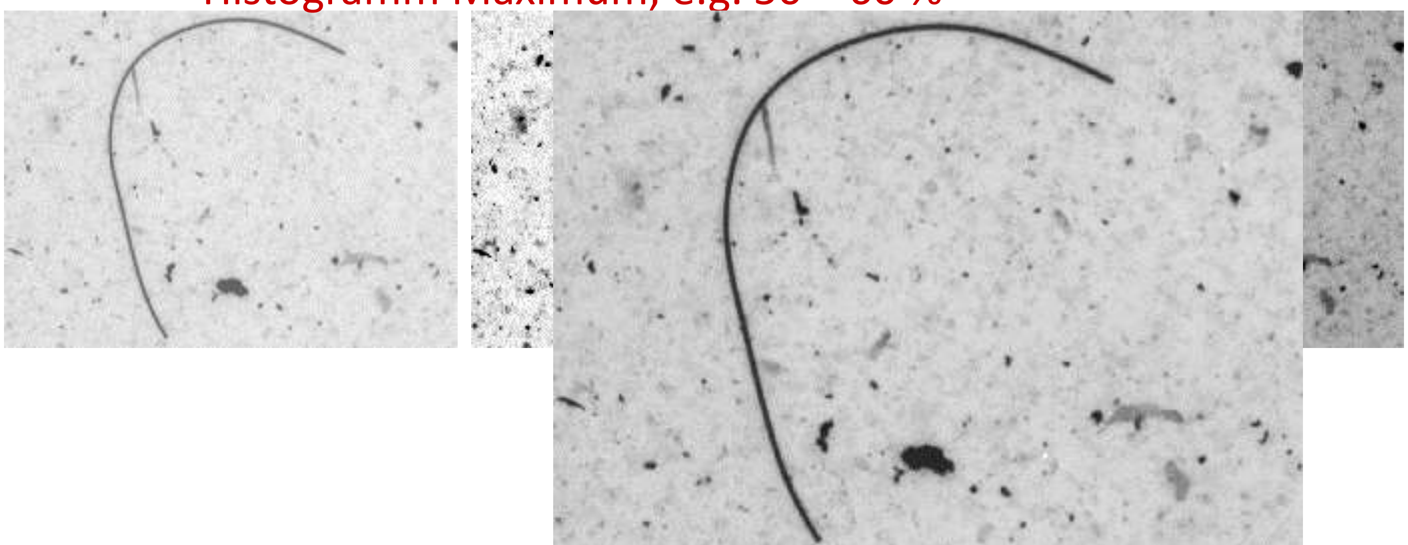
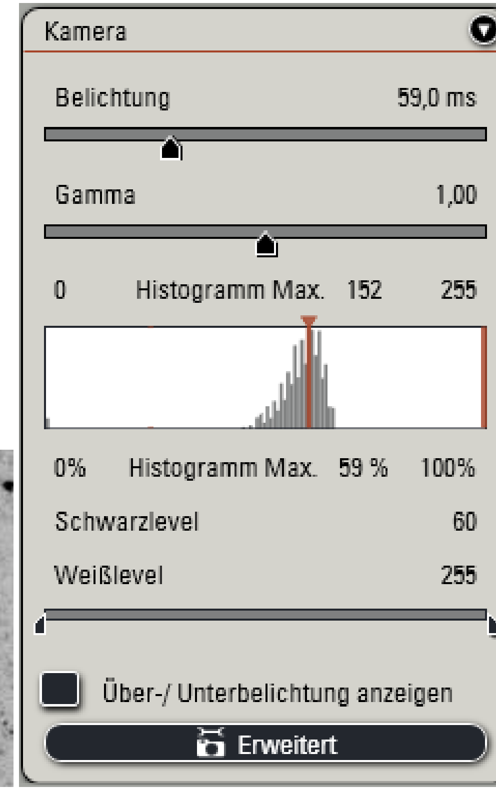
Image settings

How to create a good image? Which criteria can be used? Is it objective? Is there a kind of recipe?

- Gamma, dynamic range, resolution
  - ✓ Clear definition, e.g. Gamma 1, complete dynamic range
- Setup of image brightness (lamp voltage, exposure time)
  - ✓ Histogramm Maximum, e.g. 50 – 60 %



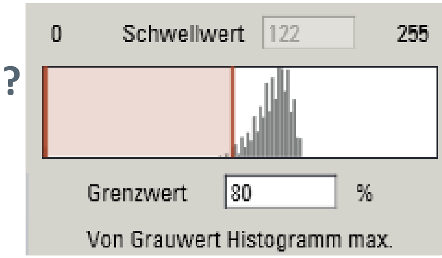


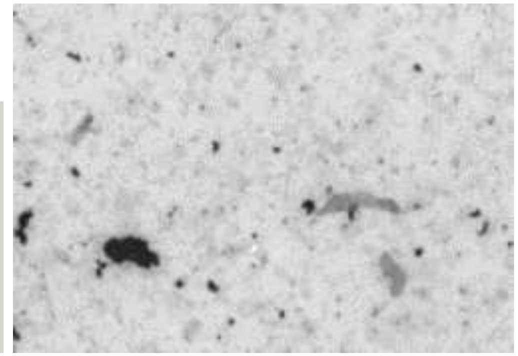
Comparable images ✓

User influence detecting an image

Is that objective?

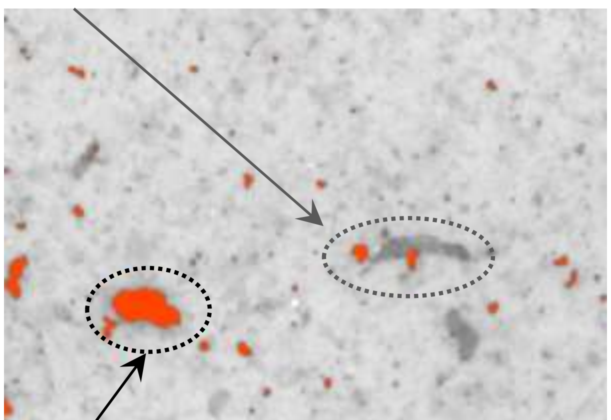
Is there a recipe for a good detection?





Threshold 91

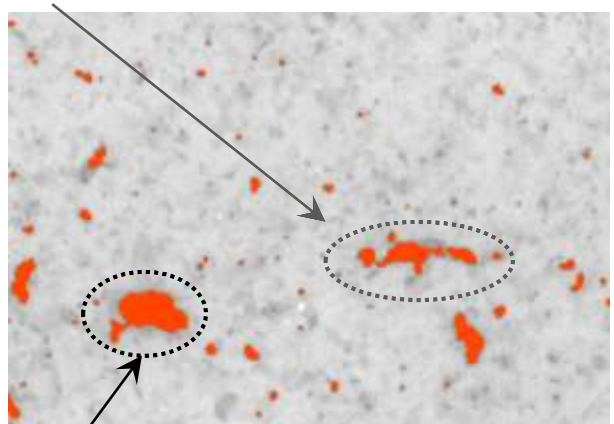
53 µm cluster grey (class E)



Cluster black
191 µm (class G)

Threshold 106

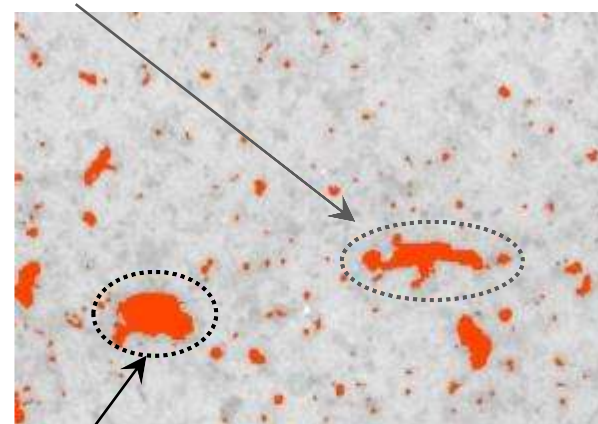
280 µm cluster grey (class H)



Cluster black
218 µm (class H)

Threshold 122

410 µm cluster grey (class I)



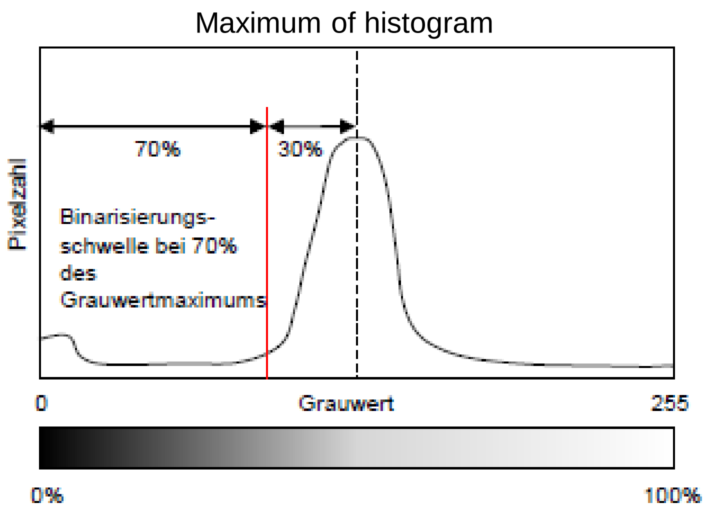
Cluster black
236 µm (class H)

- Different results for particle size, especially in clusters
- Different classification in VDA classes (50 µm, 100 µm, 150 µm, 200 µm, 400 µm)

What is a relative threshold?

- A relative threshold has clear definition
- The relative threshold is connected to the maximum of the histogram

e.g. 70% of the histogram maximum

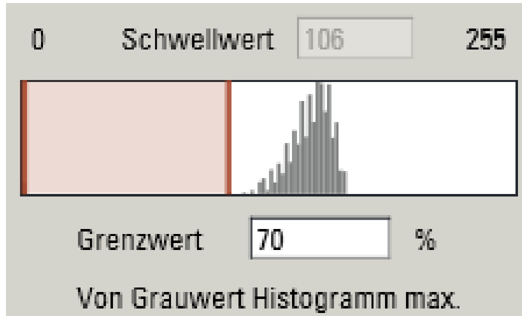


VDA 19: Abb. 8-4: Einstellung von Bildhelligkeit und Binarisierungsschwelle bei Lichtmikroskopen mit Polarisatoren

Clear definition:

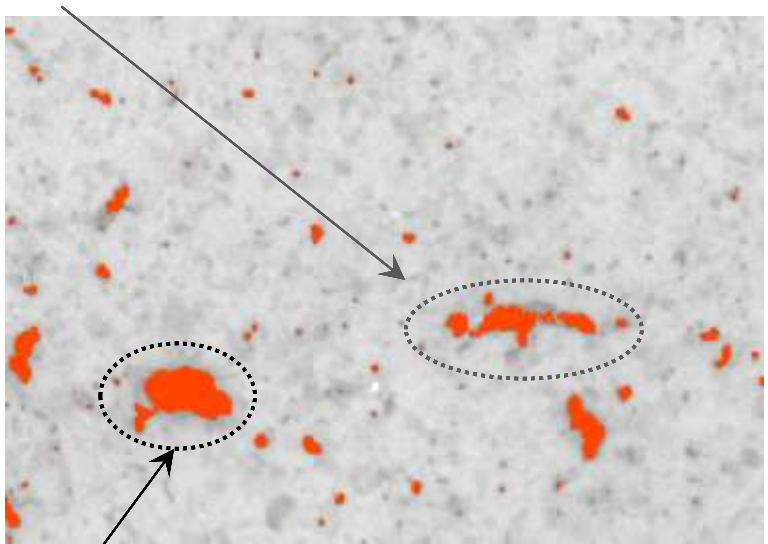
Due to the relative threshold there is no user influence ✓

Relative threshold



Threshold 106

280 µm cluster grey (class H)



Cluster black:
218 µm (class H)

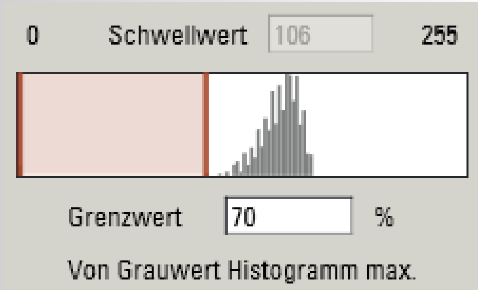
ISO 16232 Classes

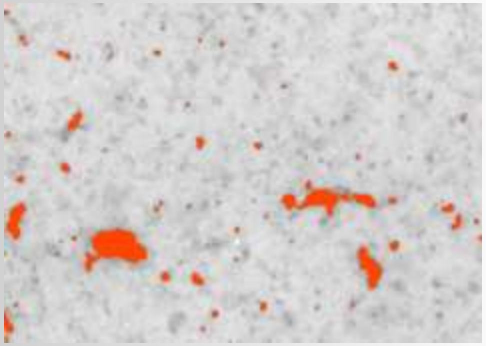
Size Class	Size Limits (µm)
B	5 - 15
C	15 - 25
D	25 - 50
E	50 - 100
F	100 - 150
G	150 - 200
H	200 - 400

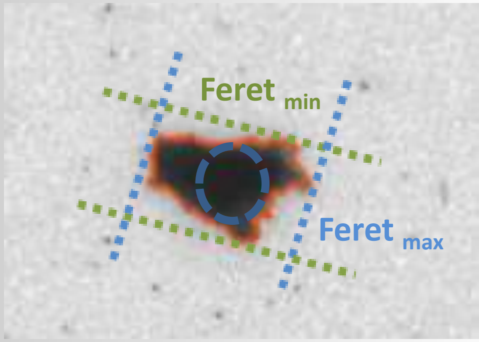
Klasse	Länge (µm)
H	218
H	280

VDA 19 guideline for component cleanliness - Standard analysis

- Size of particles
  above 50 µm, 10 PIXELCRITERIA
- Contrast method microscope
  CROSSED POLARIZERS
- Parameter image setup
  HISTOGRAM MAXIMUM 50-60%
- Detection of particles
  RELATIVE THRESHOLD 70%
- Measurement parameter (length, breadth, fibre length & breadth)
  FERETmax, FERETmin, MAX. INNER CIRCLE DIAMETER
- Definition of particles and fibres
  ELONGATED FIBRELENGTH/MAX. INNER CIRCLE DIAMETER







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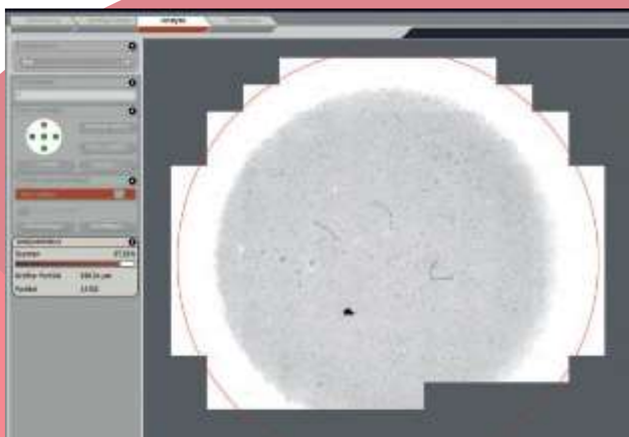
Workflow technical cleanliness analysis

Pall Corporation

1. Cleaning, extraction, filtration…

2. Analysis of the membrane…



3. Distribution of particles:

Weight	Size Limits (µm)	Number	Particles per 100cm²	Xcount	100%	Max Limit	Result
1	15-25	3239	6478	6478		0	n.OK
1	25-50	1455	2910	2910		200	n.OK
1	50-100	239	478	478		200	n.OK
2	100-200	24	48	48		100	OK
5	200-400	4	8	8		20	OK
10	>400	2	4	4		5	OK

Contamination: 10042 Include Class 1 Neg Cumulative Overall Result:

Max Size: 481,43 (µm)

4. Relocation…

Workflow technical cleanliness analysis DMS1000

7. Evaluation:

Particle metallic: hard

Length: 210 µm o.k.

Width: 95 µm n. o.k.

Height: 60 µm n. o.k.

Damage potential: high

Source of contamination:
residues of a tool

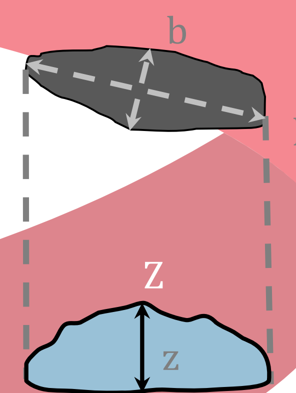
6. Identification:
Metallic glance

5. Properties:

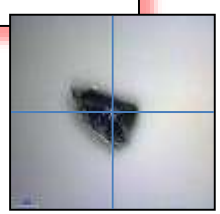
Length: 210 µm

Width: 95 µm

Height: 60 µm



4. Relocation:



Id	Z	Entfernen	Faser	Länge (µm)	Fläche (µm2)	Breite (µm)
9293				203,54	4181,76	67,83
6193			✓	146,13	4290,71	68,21
9241				136,05	1993,91	36,64
3861			✓	135,14	3608,64	83,49
9179				130,90	3362,40	70,11

Workflow for component cleanliness with DMS1000

Entry level solution

Extraction, Filtration → Detection, counting, classifying → + Relocate & Check → + react

	Max.	Ist	
length [µm]	250	225	i. O.
width [µm]	150	134	n.i.o.
height [µm]			
Refl./ Non-refl.	reflective		
potential of damage			high
source	metallic tool		

The digital microscope solution with smartly integrated high quality optics

Recommended for daily analysis of particles **above 30 µm** or
VDA 19 Standard Analysis (above 50 µm)

- **High quality** coded zoom optics for safe and reliable results. Automatic readout of zoom position = no wrong calibration
- **Macroscopic beam path** for exact 2D measurement = no parallax error (vs. stereo mic.)
- **Flex Aperture** = constant brightness throughout all Zoom positions
- **Safe and reliable results:** All changes during or after the analysis are documented in the report, e.g. camera settings, threshold, deletion of particles, editing of particles = highest traceability of results

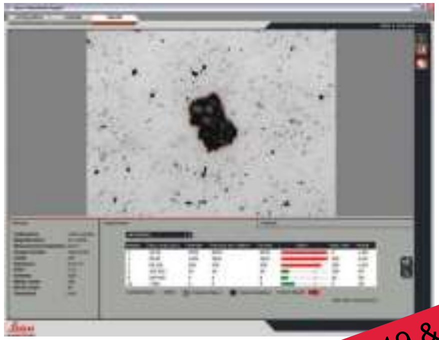
Open and upgradeable solution

- Open platform for documentation, measurement and *analysis.* Easy, intuitive microscope software to capture pictures.

Workflow for component cleanliness with DM6

Advanced system solutions

Extraction, Filtration → Detection, counting, classifying → + Relocate & Check → + react



VDA 19 & ISO 16232

VDA 19 & ISO 16232

	Max.	Ist	
length [µm]	250	225	i. O.
width [µm]	150	134	i. O.
height [µm]	100	115	n. i. O.
Refl./ Non-refl.	reflective		
potential of damage			high
source	metallic tool		

The digital microscope system DM6

Recommended for standard and advanced analysis including daily analysis of particles **above 5 µm**

- **Fully automated microscope system** enables fast and reliable results = no wrong settings and measurements
- **Highest optical performance:** measuring small and big particles in one step
- **3D measurement capabilities** to identify the damage potential of particles
- **Safe and reliable results:** All changes during or after the analysis are documented in the report, e.g. camera & microscope settings, threshold, deletion of particles, editing of particles = highest traceability of results
- **Open and upgradable solution:** Metallography, 2D & 3D analysis, mosaic images, image analysis, documentation….

  …and coming soon material analysis

Leica Solution

ACCURATE AND REPRODUCIBLE Counting of Particles

FLEXIBLE

Systems for each Need

Zoom & autom. microscopes systems

Open and upgradeable solution (documentation, 2D & 3D measurements, Image Analysis, Metallography)

USER AUTHORIZATION

Supervisor

Operator

WORKFLOW

Easy guided

Intuitive SW

Easy operating Mode

Easy Reporting

STANDARDS

Regional and International

VDA 19,
ISO 16232,
ISO 4406,
DIN 51455
NAS 1638,
NF E48-655,
SAE AS4059,
USP-788
User defined

EXPERTISE

+30 years

+10 European Experts

Dedicated experts from Pall & Leica

This was the first Webinar in our trilogy Component Cleanliness.

If you are interested in sample & filter preparation and workflow solution we suggest our joined Pall-Leica Webinar

Don’t miss the date of our third Webinar where we will present exciting news for advanced particle analysis

Thank You for Your Attention!

Any Questions?