Webinar

Basics in Component Cleanliness Analysis

Dr. Nicol Ecke
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 **during** or **after** 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

2D

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

- 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?

- 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?

- 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

<table>
<thead>
<tr>
<th>Standard</th>
<th>Application</th>
<th>Support Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 16232</td>
<td>Automotive</td>
<td>Direct Support</td>
</tr>
<tr>
<td>VDA 19</td>
<td>Automotive</td>
<td>Excel Template</td>
</tr>
<tr>
<td>ISO 4406/4407</td>
<td>Hydraulic Fluids</td>
<td>Excel Template</td>
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<tr>
<td>DIN 51455</td>
<td>Oil</td>
<td>Excel Template</td>
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<td>NAS 1638</td>
<td>Lubrication</td>
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<td>SAE 4059</td>
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<td>USP-788</td>
<td>Pharmaceutical</td>
<td>Excel Template</td>
</tr>
<tr>
<td>NF E48-655</td>
<td>Hydraulic Fluids</td>
<td>Excel Template</td>
</tr>
<tr>
<td>User Defined</td>
<td>Any</td>
<td>Direct Support</td>
</tr>
</tbody>
</table>
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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**

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**Size of one pixel**

*Theoretical calibration value*

- Pixel size camera: 4,6 µm
- \[ \sum \text{magnification} \]
- Particle of \( \geq 15 \, \mu m \) size

\[
\text{1,46 µm/Pixel}
\]

---

10 Pixel

*(Minimum required)*
Size of particles

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**Size of one pixel**
*Theoretical calibration value*

4,6 µm

5 x 0,63

Particle of ≥15 µm size

1,46 µm/Pixel

10 Pixel
*(Minimum required)*
Detection

Detection of particles:

- **Greyscale image**
- **Histogram**
- **Binary image:**
  - Everything below threshold in **RED** = will be measured
  - Everything 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 length 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$_{\text{max}}$) doesn't characterize the full damage potential.

**What is the width of a particle?**
- Length = longest feret
- Width = shortest feret

- Breadth is a critical dimension for particles adjusted in a **flow direction**.
- Injection pumps, pistons, spools
- Regarding the breadth the Feret$_{\text{min}}$ reflects the maximum potential damage

→ Does the Feret$_{\text{min}}$ reflects a damage potential of curved particles or fibres?
Identification of Risky Particles

- Breadth

**Minimum feret and maximum inner circle diameter** - Which one 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.

The 3D shape determines also the risk potential of the contamination.

2D information is not sufficient to estimate the risk potential of the contamination!
2D & 3D measurements

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

- Height measurement: 20x lens with low depth of field
  1. Focus on filter background
  2. Focus on the top of the particles

<table>
<thead>
<tr>
<th>Length (µm)</th>
<th>Area (µm²)</th>
<th>Breadth (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>483.03</td>
<td>5903.27</td>
<td>24.09</td>
</tr>
<tr>
<td>191.23</td>
<td>14397.53</td>
<td>121.92</td>
</tr>
</tbody>
</table>

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 $\Rightarrow$ 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)
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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
  - Histogram Maximum, e.g. 50 – 60 %

- Setup of image brightness (lamp voltage, exposure time)
  - Comparable images
User influence detecting an image

Is that objective?
Is there a recipe for a good detection?

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

\[ \text{Threshold 91} \]
53 µm cluster grey (class E)

\[ \text{Threshold 106} \]
280 µm cluster grey (class H)

\[ \text{Threshold 122} \]
410 µm cluster grey (class I)

Cluster black
191 µm (class G)

Cluster black
218 µm (class H)

Cluster black
236 µm (class H)
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

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)
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

1. Cleaning, extraction, filtration...

2. Analysis of the membrane...

3. Distribution of particles:

4. Relocation...
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:
Workflow for component cleanliness with DMS1000

Entry level solution

- Extraction, Filtration
- Detection, counting, classifying
- Relocate & Check
- react

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

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

<table>
<thead>
<tr>
<th>Max.</th>
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<tbody>
<tr>
<td>length [µm]</td>
<td>250</td>
</tr>
<tr>
<td>width [µm]</td>
<td>150</td>
</tr>
<tr>
<td>height [µm]</td>
<td>100</td>
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<tr>
<td>Refl./Non-refl.</td>
<td></td>
</tr>
<tr>
<td>potential of damage</td>
<td></td>
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<tr>
<td>source</td>
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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
- Intuitive SW
- Easy operating Mode
- Easy Reporting

STANDARDS
- 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?