Sensitivity of particle size & shape parameters with respect to digitization

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18,000 students - 2,000 PhD students
Largest network of spin-off companies in Belgium (>70)

GeMMe – Minerals Engineering,
Materials & Environment
Synopsis

• Introduction
  - Importance of size & shape indices
  - Emerging ISO Standards for IA
  - Exner « quality criteria »

• Material & Methods
  - Sub-pixel digitization
  - Simulated particles
  - Real particles
  - Area-Perimeter-Elongation-Bluntness

• Results
  - Accuracy of size/shape estimators
  - Practical implications

• Perspectives

ICS13
BEIJING
Introduction

- Importance of size & shape indices
- Emerging ISO Standards for IA
- Exner « quality criteria »
• Importance of Particle Size and Shape

- Non imaging methods (indirect)
  • Sieving
    » Weight of particles passing through a square mesh
  • Laser Diffraction
    » Inversion of a cumulated diffraction pattern as a distribution of spheres
  • ...

- Imaging methods (direct)
  • Image Analysis
    » Individual pictures of particles
    » No hypothesis on particle shape
    » Distributions in « volume » or number
Introduction

- **Maturity of Image Analysis based technologies**
  - Dedicated instruments
  - Coarse (50 µm - 5 mm) / Fine (500 nm - 200 µm) powders
  - Wet / Dry powders
**ISO Standards**
- ISO 13322-1 *Particle size analysis - Image analysis methods*
- ISO 9276-6 *Descriptive and quantitative representation of particle shape and morphology*

**ISO parameters are**
- A trade-off between manufacturers
- Ease of computation
- Simple definition

**No recommendations on**
- Image acquisition (magnification, resolution)
- Image segmentation (thresholding).
• **Quality of shape parameters**  

  Exner (1987)

  - Relevance
  - Robustness
  - Independence
  - Sensitivity
  - Additivity
  - Accessibility

  \[
  D_A = 2 \sqrt{\frac{A}{\pi}}
  \]

  *Not a physical dimension of the particle*

  *A lot of decimals… but no precision!*
• **Quality of shape parameters**  
  
  - Relevance  
  - **Robustness**  
  - Independence  
  - Sensitivity  
  - Additivity  
  - Accessibility  

  *Exner (1987)*

  *Robustness with respect to touching particles*

  $D_A$ is twice as large as $D_{IN}$!
• Quality of shape parameters
  
  Exner (1987)

  - Relevance
  - Robustness
  - **Independence**
  - Sensitivity
  - Additivity
  - Accessibility

\[ F = \frac{4\pi A}{P^2} \]

*Circularity (= shape factor F) is a function of elongation AND roughness*
• **Quality of shape parameters**  

  - Relevance
  - Robustness
  - Independence
  - Sensitivity
  - Additivity
  - Accessibility

*Exner (1987)*

\[ F = \frac{4\pi A}{P^2} \]
Material & Methods

- Sub-pixel digitization
- Simulated particles
- Real particles
- Area-Perimeter-Elongation-Bluntness
Material & Methods

• Simulation of particles
  - Geometric shapes
    • Grid density \textit{(resolution)}
    • Translation
    • Rotation
      » 16 x 16 subsampling grid
      » Grey level = Area coverage

• Threshold
Material & Methods

- Simulation of particles
  - Real shapes
  - Imaging at high resolution
    » 10 000 pixels/particle
  - Subsampling
    » 16 x 16 subsampling grid
    » Grey level = area coverage
    » down to 100 pixels/particle
Results

- Evolution of parameter with
  - pixel density
  - Rotation/translation
  - thresholding
Results

- Perimeter vs Resolution

Crofton’s perimeter equivalent diameter vs. theoretical diameter as a function of pixel density (from 1 to 20 pixels)
• Bluntness vs Resolution
• Practical Conclusions

- Pertinence of Exner’s criteria
  » Independence, Sensitivity,...

- Recommendations of min. resolution for ISO standards
  » 10 pixels for size
  » 200 pixels for aspect ratios
  » 2000 pixels for « roughness »

- Comparison of shape within narrow size ranges
  » Be aware of pseudo-correlations
    the « fine is smooth » effect

- More systematic work on analytical errors in Image Analysis