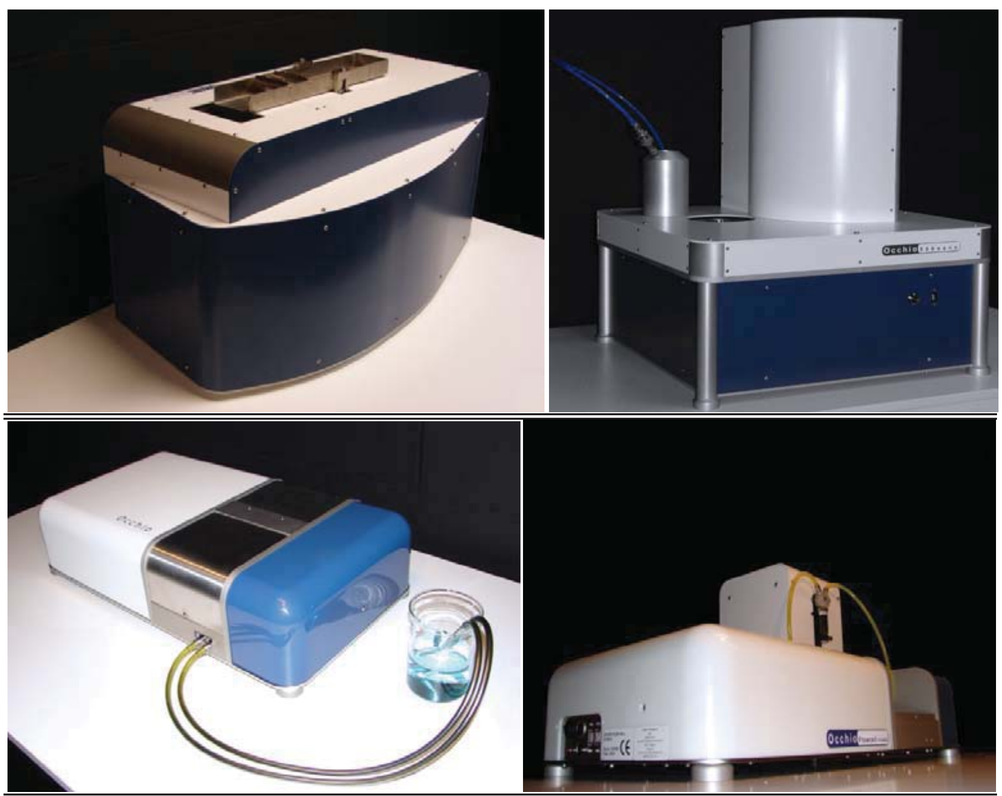
Occhio

Imaging solutions

SIZE & SHAPE PARAMETERS DEFINITIONS FOR OCCHIO PRODUCTS



QAQC LAB

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Imaging solutions in particle analysis

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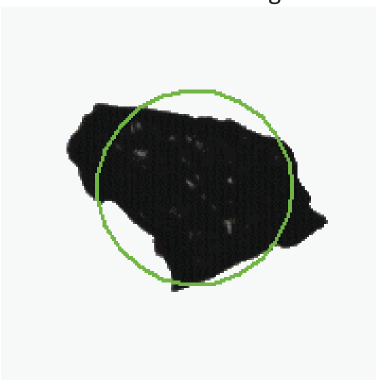
Area based parameters

1. Pixel Count

Short Name: Pix
Type: Other
Formula$\sum(x\ End - x\ Start + 1)$:
The sum is made on all runs that belong to the particle.
X End is the x coordinate of the end of the run
X Start is the x coordinate of the beginning of the run

2. ISO Area Diameter

Diameter of a disk having the same projection area as the particle



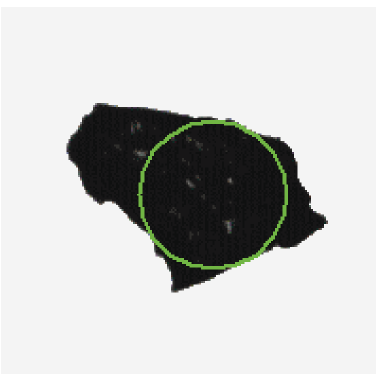
Short Name: DA
Type: Size Parameter

Formula: $\sqrt[2]{(4 \times \frac{AREA}{\pi})}$

Area is the sum of particle run length in pixel (Pixel Count)
The area of a particle is easily estimated from the sum of all its pixels. It is an indication of the amount of material the particle is made of and as such will be an important weight factor for the particle size distribution. Moreover it has been proven that the area found by segmentation is an unbiased measured of the particle area. So the area equivalent diameter computed on it is a robust parameter.
Nevertheless this is an equivalent size parameter and, as can be seen from the pictures, it does not correspond to a physical dimension of the particle. Moreover, when two particles are in contact, the resulting area is doubled and this might severely impact the whole particle size distribution.

3. ISO Inner Diameter

The Inner Diameter is the diameter of the maximum inscribed disc.



Short Name: Dimax

Type: Size Parameter
Formula: $(2 \times Erosion\ Number) - 1$
Erosion number, it's like the peeling of an onion but with layers of pixel. The erosion number is the number of layers to be removed until nothing left.

The inscribed disc diameter corresponds to a true physical dimension of the particle.
If particles are properly oriented (resting on a plane perpendicular to the optical axis) this diameter is strongly correlated to the probability of passing through a sieve and hence can be termed "sieving diameter".
A corollary of making use of this diameter is that it is less sensitive to touching particles in poorly dispersed samples. The largest of the two particles remains properly sensed.
This is on these considerations that Occhio has always promoted this parameter for the size estimation. For accuracy, It is computed with the Euclidean Distance Transform.

4. Ell. Width

Short Name: XLmin
Type: Size Parameter

Formula: $4 \times \sqrt[2]{fSigYY}$ default value of 1 if fSigYY <= 0

5. Ell. Length

Short Name: XLmax
Type: Size Parameter

Formula: $4 \times \sqrt[2]{fSigXX}$ default value of 1 if fSigXX <= 0

6. ISO Solidity

Short Name: Sld
Type: Shape Parameter

Formula: $\frac{Pixel\ Count - 0.5}{Convex\ Area}$

7. Ell. Elongation

Short Name: El.El
Type: Shape Parameter

Formula: $1 - \frac{Ell.Width}{Ell.Length}$ default value of 1 if Ell. Length = 0

8. Ell. Ratio

Short Name: Ell.Rt
Type: Shape Parameter

Formula: $\frac{Ell\ Width}{Ell\ Length}$

9. Ell. Roundness

Short Name: El.Rnd
Type: Shape Parameter

Formula: $2 * \frac{fSigYY}{(fSigXX + fSigYY)}$

10. Volume

Short Name: V
Type: Other

Formula: $\frac{\pi}{6} \times \text{ISO Area Diameter}^3$

11. Weight

Short Name: Wg
Type: Other

Formula: Weight parameter depends of WeightParam value of the registry. Default value is 5 for the **Volume**. Other used value is 4 for the **Pixel Count** (Area). There is no limit; every parameter could be used as Weight factor.

<u>**Perimeter based parameters**</u>

1. **Perimeter**

Short Name: Perim
Type: Other
Formula: $\text{Nhv} + \sqrt{2} * \text{Nd}$
Nhv is the number of horizontal and vertical pixel
Nd is the number of diagonal pixel

2. **Convexity**

Short Name: Cvx
Type: Shape Parameter

Formula: $\frac{Perimeter}{Convex\ Perimeter}$

Where Perimeter is the perimeter length computed by adding 1 for horizontal and vertical pixel links and $\sqrt{2}$ for other links

And Convex Perimeter is the sum of the length of convex perimeter segments. If the convex perimeter contain only 3 segments or less; convex perimeter equal 1. If Convex perimeter is shorter than Perimeter, Convexity equal

3. **Contour vs Area**

Short Name: CpA
Type: Shape parameter

Formula: $\frac{Perimeter}{Pixel\ Count}$

4. **Perim Diameter**

Short Name: XP
Type: Size Parameter

Formula: $\frac{Perimeter}{\pi}$

5. ISO Geodesic length

Short Name: XLG
Type: Size Parameter

Formula: $\frac{Perimeter + Ro}{4}$

Where $Ro = \sqrt{Perimeter^2 - 16 * Pixel\ Count}$

6. ISO Fiber Thickness

Short Name: XE
Type: Size Parameter

Formula: $\frac{Perimeter - Ro}{4}$

Where $Ro = \sqrt{Perimeter^2 - 16 * Pixel\ Count}$

7. ISO Eccentricity

Short Name: Ecc.
Type: Shape Parameter

Formula: $\frac{ISO\ Fiber\ Thickness}{ISO\ Geodesic\ Length}$

8. ISO Circularity

Short Name: Circ
Type: Shape Parameter

Formula: $\pi * \frac{Area\ Diameter}{Perimeter}$

Distance between pixels based parameters

1. Width

Short Name: W
Type: Size Parameter

Formula: $minimum\ (f32ParWidth\ , f32PerWidth\ )$

Where f32ParWidth is the projection of the particle inertia box onto X principal axes of the particle and f32PerWidth is the projection of the particle inertia box onto the Y principal axes of the particle.

2. Length

Short Name: L
Type: Size Parameter

Formula: $maximum\ (f32ParWidth\ , f32PerWidth\ )$

Where f32ParWidth is the projection of the particle inertia box onto X principal axes of the particle and f32PerWidth is the projection of the particle inertia box onto the Y principal axes of the particle.

3. Feret length

Short Name: FL
Type: Size Parameter

Formula: It's the maximum size of the particle projected in all possible orientation.

4. Feret min

Short Name: FM
Type: Size Parameter

Formula: It's the conjugate diameter of Feret length.

5. Mean Diameter

Short Name: Dm
Type: Size Parameter

Formula: $2 \times \frac{\sum \text{Radius}}{\text{Contour count}}$

The sum is made on the number of pixel that belongs to the outline of the particle.
Radius is the distance between the gravity center to a pixel that belong to the outline of the particle
Contour count is the number of pixel that belong to the outline of the particle

6. ISO Max Distance

Short Name: Dmax
Type: Size Parameter

Formula: It's the maximum distance between pixels that belong to the convex perimeter.

7. ISO AspectRatio

Short Name: Asp. Rt
Type: Shape Parameter

Formula: $\frac{Feret\ Min}{Max\ distance}$

Remark: if Feret min is < 0 then it is replaced by Inner Diameter

8. O. Elongation

Short Name: El
Type: Shape Parameter

Formula: $1 - \frac{Width}{Length}$

9. ISO Straightness

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Short Name: Str.
Type: Shape Parameter

Formula: $\frac{ISO\ Max\ distance}{ISO\ Geodesic\ Length}$

Remark: Value between 0 and 1

10. ISO Roundness

Short Name: Rnd
Type: Shape Parameter

Formula: $\frac{4 * Pixel\ Count}{\pi * ISO\ Max\ distance^2}$

Remark: If ISO Roundness > 1 then the value is 1

11. ISO Compactness

Short Name: Cpt
Type: Shape Parameter

Formula: $\frac{\sqrt{\frac{4 * Pixel\ Count}{\pi}}}{ISO\ Max\ distance}$

12. ISO Extent

Short Name: Ext.
Type: Shape Parameter

Formula: $\frac{Pixel\ Count}{ISO\ Max\ distance * Feret\ Min}$

Remark: if Feret min is < 0 then it is replaced by Inner Diameter

Calypter based parameters

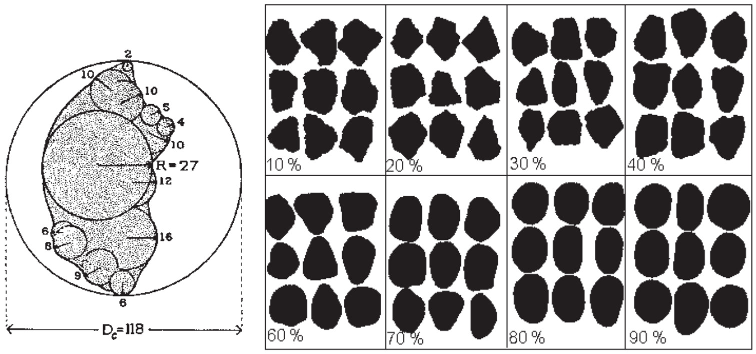
1. O. Bluntness

Short Name: O.Blunt
Type: Shape Parameter

Formula: The computation of Occhio Bluntness is based on Eric Pirard Thesis; this parameter is linked to the variability of the distribution of the particle caliper. The caliper is the distribution of radius of circles that are tangent to outline pixels and included into the particle.

The way particles wear down during abrasion is of major interest to scientist and engineers. The very first who tried to quantify this were geologists aiming at tracing back the time of residence of particles in a sedimentary system. In other words, they wanted to learn from the outer shape of a sand particle for how long it had travelled downwards a river.
Wentworth in 1919 and later Wadell observed the way cubes of rock wore down in a tumbler. From their observations, they suggested to measure the curvature of asperities and compute an average value after normalisation by the radius of the maximum inscribed disc. At that time, measures had to be done by hand… so, in order to spare precious time many authors designed visual charts inspired by those concepts. The most popular morphological chart is the one by Krumbein 1941. Since then, it has been of widespread use under many variants

in various industrial and scientific sectors where shape characterization is a critical issue (mechanics, petroleum exploration, abrasive production, mining, …).



Wadell's original drawing to illustrate the average curvature of asperities and Krumbein's chart representing particles grouped into different classes of roundness.

What was once a tedious process of drawing discs with a compass to fit each and every asperity of a particle is nowadays a fully automatic measure that can be performed within a few milliseconds. But the step towards automation is not as easy as it may seem and it required the development of very powerful algorithms implementing new advances in discrete geometry and more specifically in mathematical morphology.

Basically, the idea is to push further the concept of filling a particle with maximum inscribed discs and do it for every point of the contour. An easy analogy is to imagine a child stepping from pixel to pixel along the contour and blowing at each step a perfectly circular balloon until it hits another point of the contour and can't be inflated any further without being deformed.

Once this has been done for each and every pixel, we end up with a descriptor (called Calypter) giving us the centre and radius of each maximum inscribed disc. Interested readers might have noticed the similarity with the concept of skeleton and the idea of performing openings as known in mathematical morphology.

An essential property of the calypter is that its definition is unequivocal and does not require any input on behalf of the operator. Its powerful concept can also be extended to 3D using spheres.

2. O.Roughness

Short Name: O.Rough
Type: Shape Parameter

Formula: The computation of Occhio Roughness is based on Eric Pirard Thesis. This parameter measures the relative proportion of particle area that is not covert by caliper circles with a radius bigger than 50% of the maximum circle.

3. Satellity

Short Name: Satellity
Type: Shape Parameter

Formula: $1 - \frac{1}{nSatelitCnt+1}$

Where nSatelitCnt is the number of round satellite detected on the particle.

4. Outgrowth

5. Short Name: Outgrowth

Type: Shape Parameter

Formula: $1 - \frac{1}{nOutgrowthcnt+1}$

Where nOutgrowthcnt is the number of outgrowth detected on the particle.

Pixel value based parameters

1. Porosity

Short Name: Por.
Type: Shape Parameter

Formula: $\frac{Pixel\ Hole}{Pixel\ Particle + Pixel\ Hole}$

Pixel Hole is the count of pixels that belong to the particle with a grey level higher than the threshold
Pixel Particle is the count of pixels that belong to the particle with a grey level lower or equal than the threshold

2. Luminance

Short Name: Lum
Type: Shape Parameter

Formula: $\frac{Mean\ Pixel\ Value}{255}$

Where Mean Pixel Value is the mean value of pixels that belong to the particle.

3. Luminance RSD

Short Name: LumRSD
Type: Shape Parameter

Formula: RSD of pixels values that belong to the particle.

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