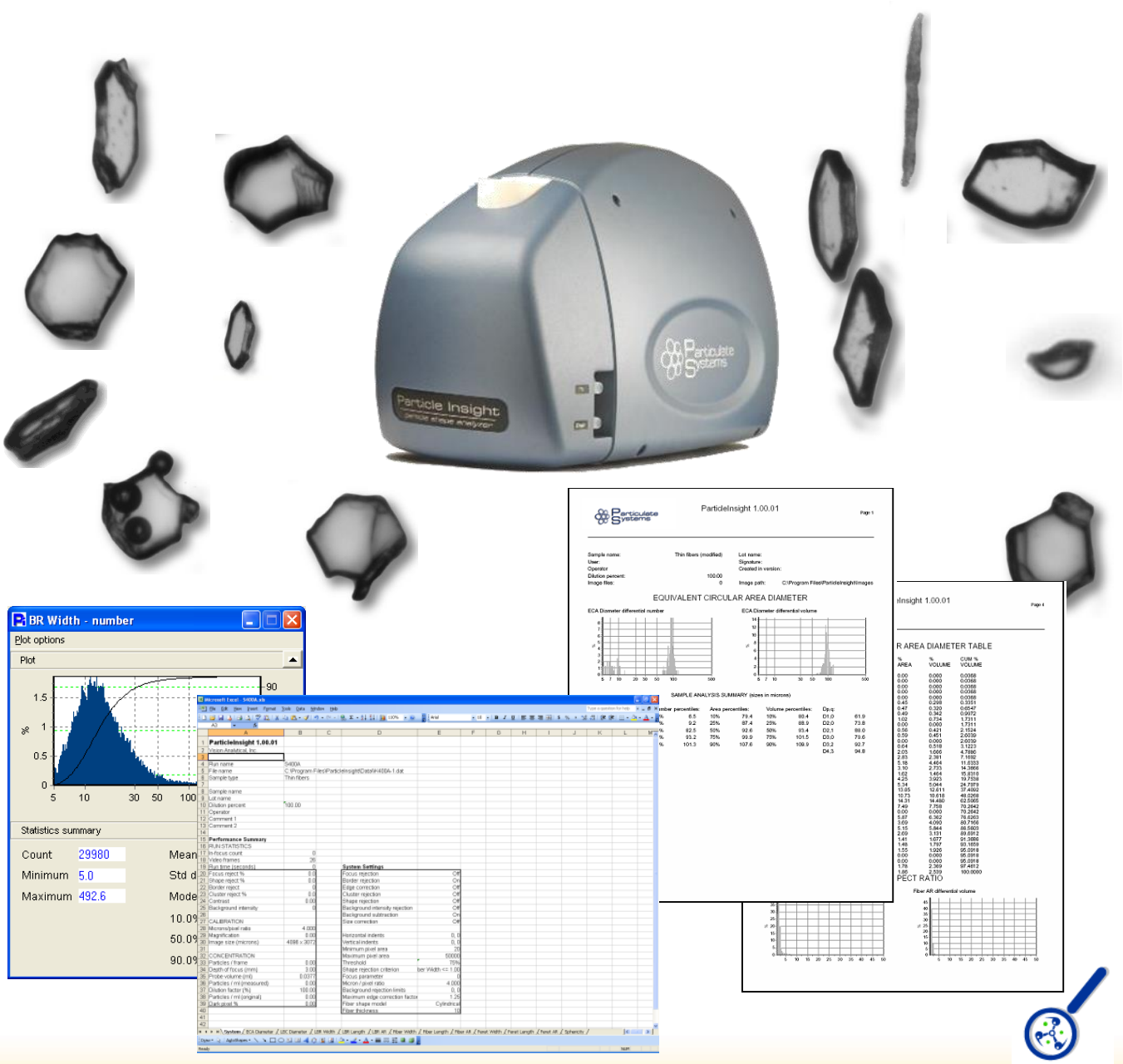
Particle Insight

Shape and Size Analysis

Measure Definitions



Why is Shape Measurement Important?

- Indirect size measurement techniques yield results that assume all particles are round. Most particles in industry are not round leaving the user with what can be an incorrect way to determine the behavior of their raw materials.
- Microscopy and Image Analysis are direct measurement techniques which allows the user to obtain more exact information and additional shape parameters about their particles. The added information enables the user to better understand the nature of their raw materials.

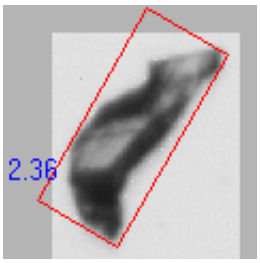
Indirect measurement techniques give results assuming that all particles are round. An incorrect assumption such as this can mislead the operator of the true nature of their raw materials.

In this case, this abrasive particle, being represented as a round particle, would lead one to believe that this is a 100.1µm particle.

When in fact, the understanding of other shape measures of this particle are critical to the performance of the final product. Abrasive pads for sanding in this case.

Smoothness of 0.509 where “1” would be a perfectly smooth particle.

Circularity of 0.321

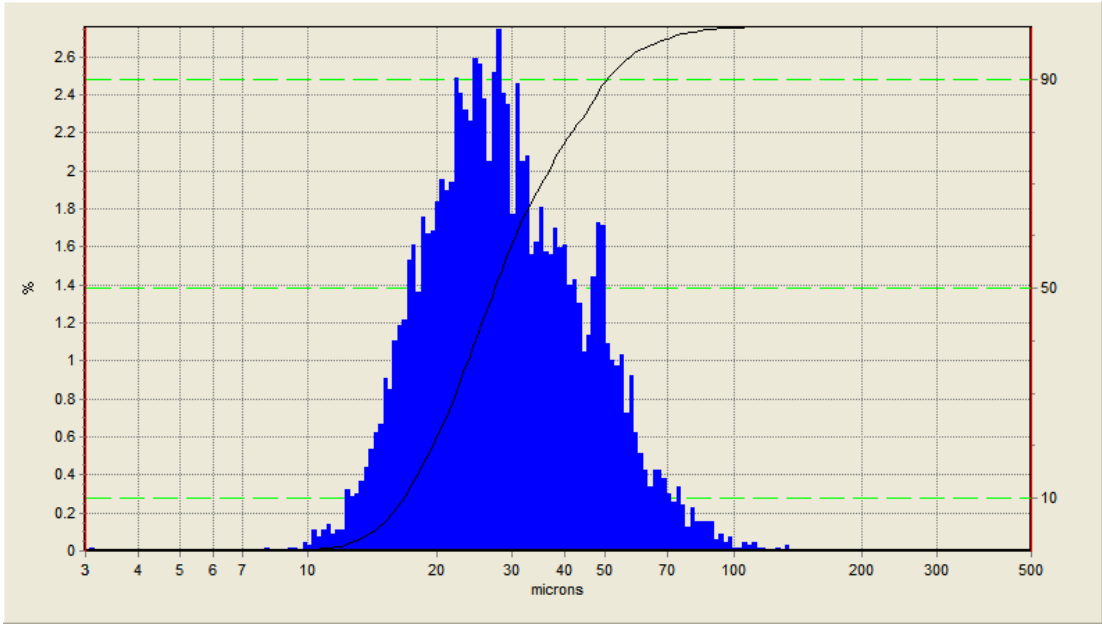


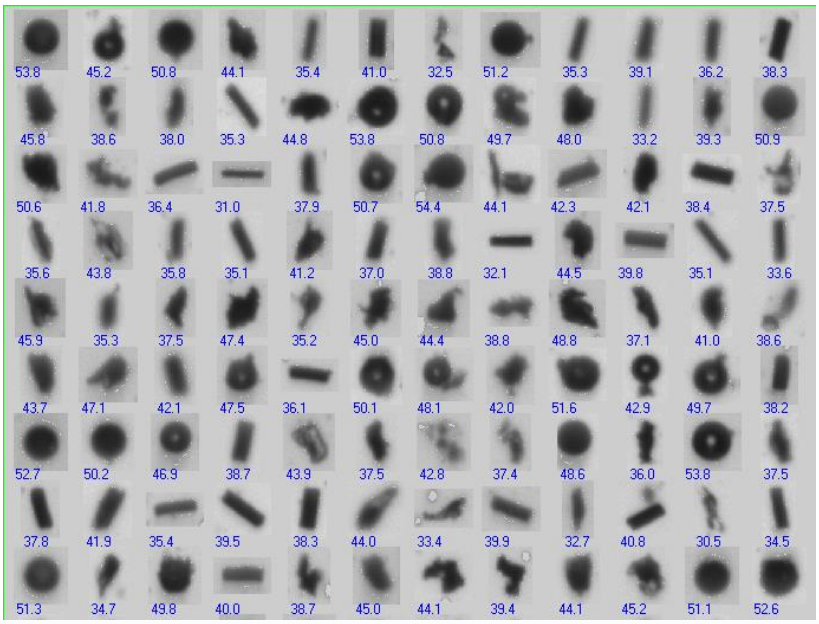
Particle Bounding Rectangle Width of 82µm, Length is 193.2µm and BR Aspect Ratio is 2.36.

Why is Shape Measurement Important?

Equivalent Circular Area Diameter

The Histogram below is a typical particle size distribution reporting the size assuming all particles are round leading one to understand that the analyzed particles are all generally the same and about 30µm in size





However, by looking at some of the saved particle thumbnails, it is clear that there are actually three different types of particles in this sample. They may all be reported the same if assumed that they are all round, but with Shape analysis, the operator can differentiate exactly what percentage of each sub-population there is in this mixed sample. Additional shape information leads to better decision making based on better insight saving the customer time and money.

Vision ANALYTICAL

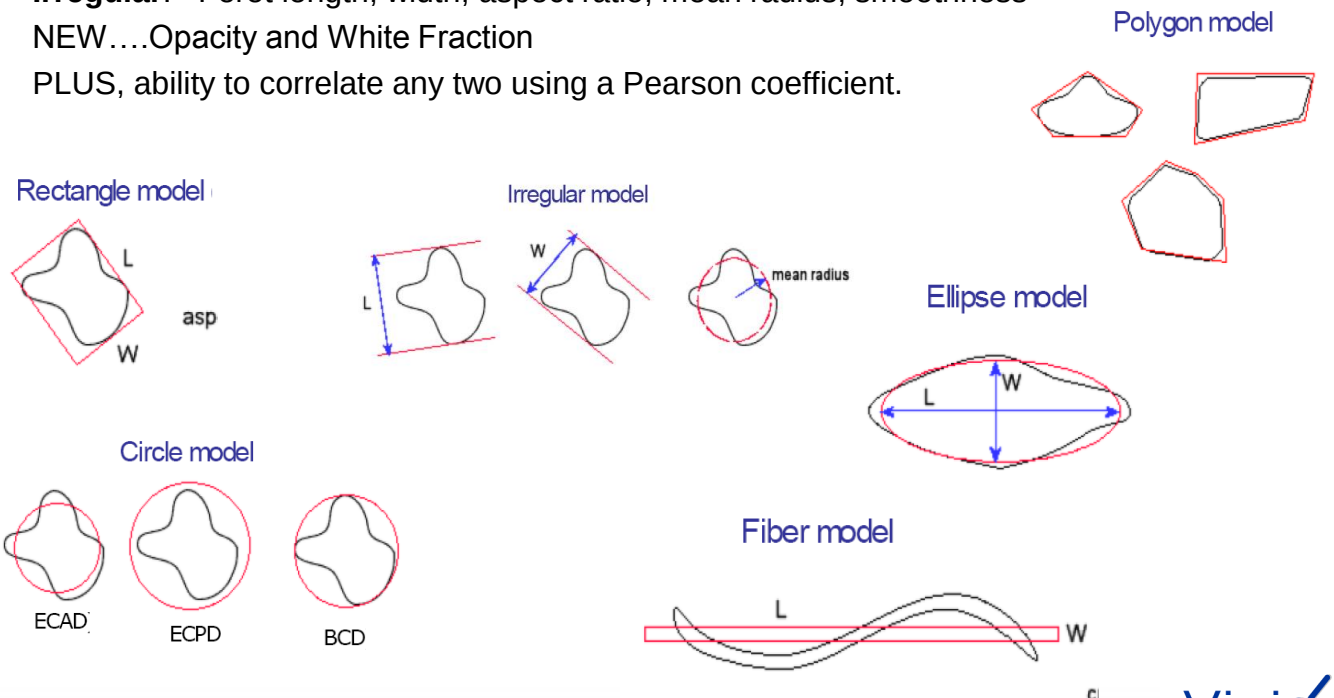
Listing of All Shape Measures

The Particle Insight has a total of 28 size and shape measures, within 6 different shape models, as well as the ability to correlate any two measures. Normally not all shape models are going to be of use to any one user for any one sample type. However it is very common to have one or more be of importance. For example, for a rod-shaped particle, the length and the aspect ratio may both be equally important. Or in the case of an abrasive powder, the Circularity and the Smoothness is important to monitor.

It is important to identify which set of the 6 shape models would best be suited to identify key performance measures for your particles. For example if your samples are a mixture of round and rod-like particles and they are separating or are not compacting well, then possibly the ratio of round (circular model) to long (length models) is important to monitor. Our in-house experts can help you with determining what models best help your area of concern.

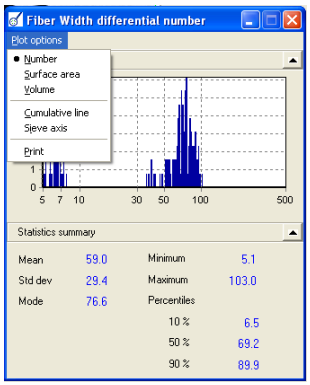
Particle characterization shape models and their measures:

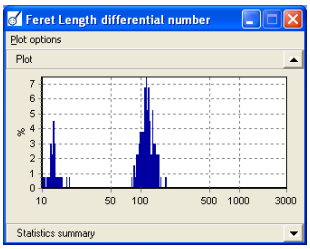
- **Circle:** equivalent area (Heywood) diameter, equivalent perimeter diameter, bounding circle diameter, circularity, form factor, compactness
- **Ellipse:** equivalent area diameter, bounding ellipse diameter, ellipsicity
- **Rectangle:** bounding rectangle length, width, aspect ratio; rectangularity
- **Polygon**: polygon order, convexity, interior angles
- **Fiber**: length, width, aspect ratio, curl
- **Irregular**: Feret length, width, aspect ratio, mean radius, smoothness
- NEW….Opacity and White Fraction
- PLUS, ability to correlate any two using a Pearson coefficient.

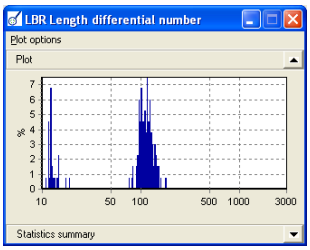


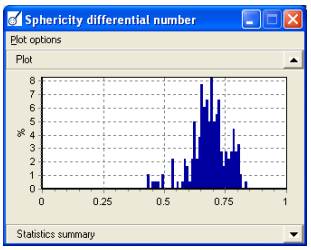
What results will you get…….

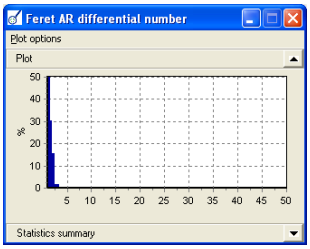
The Particle Insight will display a histogram for each of the 30 shape measures. Some measures will be size related, length, width, diameter, etc., where the size range will be along the X-axis. Some measures will be aspect ratio measures, ranging from 1 to X, X being the user defined upper aspect ratio value. And lastly some measures will be fraction measures that range from 0 to 1, such as Opacity, Circularity, Smoothness, etc.

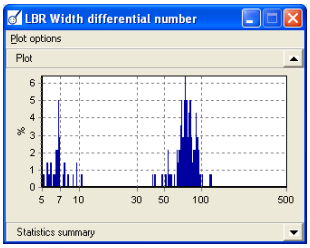


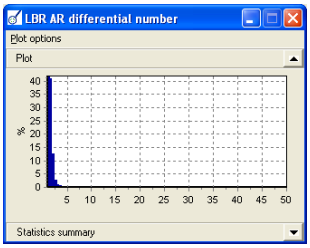


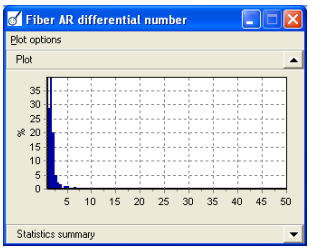


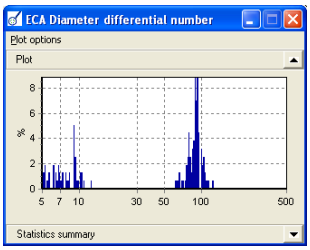


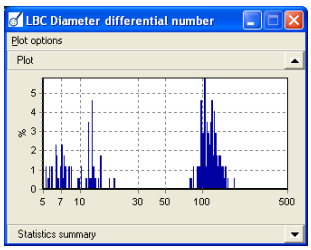


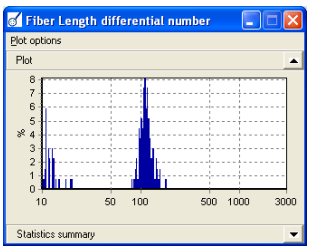










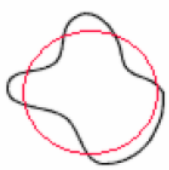


Circle Models…….

The Particle Insight has the capabilities of performing real-time analysis of particles for numerous shape measures. Several of the measures, or models, are size related, however many are not. Below is a partial listing with practical applications of the available shape measures for the Particle Insight.

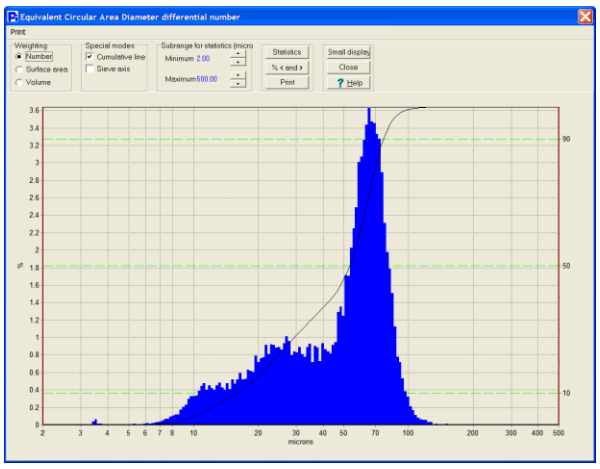
Equivalent Circular Area Diameter (ECAD)

Explanation – Equivalent Circular Area Diameter (ECAD) characterizes the size of a non-spherical shape with a single number. With typical particle shapes that are not fibrous, ECAD represents the diameter of a sphere that would have a volume close to the actual volume of the particle. Since the software has access only to a flat shadow or silhouette of the particle, ECAD is defined in terms of the silhouette area. It is defined as the diameter of a circle that has the same area as the silhouette.



Practical Use – ECAD is a measure that is commonly used to compare results of the Particle Insight to results available from other particle size analyzers that report equivalent diameter. Note that the ECAD for the Particle Insight can report Number weighted mean diameter (D[1,0]), Volume weighted mean diameter (D[4,3]), as well as Surface weighted mean diameter (D[3,2]), Length weighted mean diameter (D[2,1]), Mean volume (D[3,0]), and Mean surface (D[2,0]).

In addition to this, the ECAD measurement in the Particle Insight will show cumulative curves real-time and give real-time correlation to Sieve data.



ECAD graph shown with cumulative line for Number weighted mean

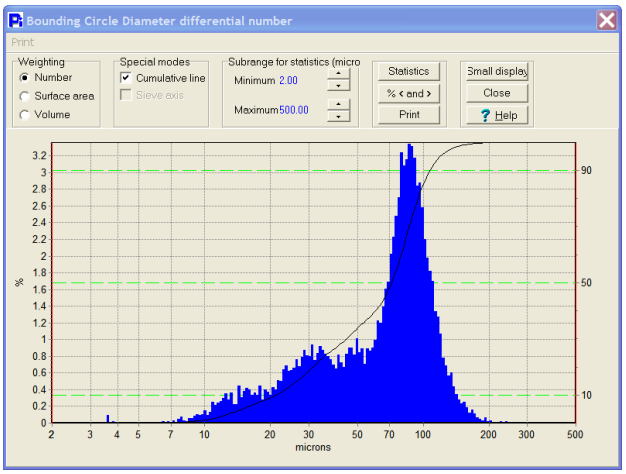
ECAD of a 100.1µm abrasive particle

Circle Models…….

Bounding Circle Diameter (BCD)

Explanation – Bounding Circle Diameter (BCD) is also a single diameter value. But instead of being an "average" or representative diameter, it characterizes the "largest diameter" of a particle. It is defined as the diameter of the smallest circle that encloses but does not intersect the particle.

Practical Use – BCD is a measure that can be used to monitor and control a process based on the maximum diameter of a particle. By monitoring the smallest circle that can encompass a particle in a process, the end user can ensure particle clogging or trapping in a process is controlled.



Typical BCD graph. Results can be displayed in Number weighted distribution, Volume weighted distribution as well as Surface Area weighted distribution. All can be displayed real-time with a Cumulative line.

Abrasive particle.
173.4µm BCD

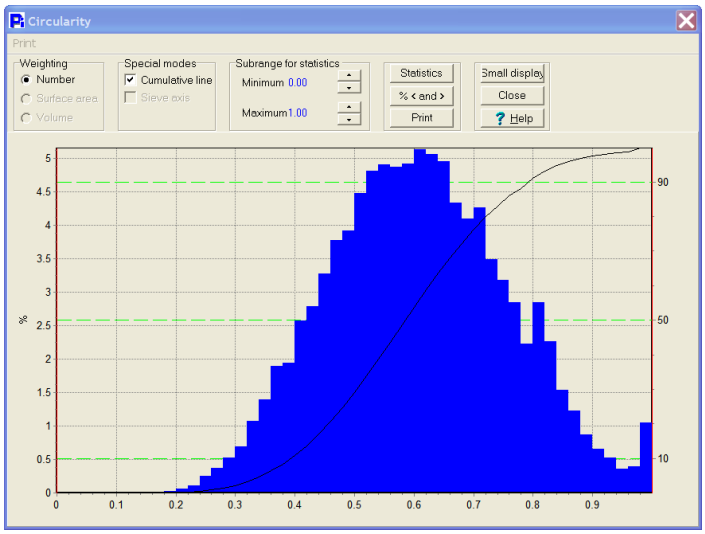
Circle Models…….

Particle Insight – Circularity

Explanation – Circularity is a commonly-used measure of roundness and by inference, particle sphericity. It is a fractional measure, equal to 1 for a perfect circle. It can be thought of as the fraction of the bounding circle's area covered by the actual shape. Circularity is not affected by small irregularities in the perimeter and errors in perimeter measurement. It is not affected by any systematic size bias in perimeter determination. Circularity is computed from area (A) and bounding circle diameter (D_{BC}).

$$\text{Circularity} = 4A / \pi (D_{BC})^2$$

Practical Use – Circularity I a measure that can be used to assess flow-ability of a particle in a process or, in the case of multi-component particles, how each particle will interact with others. Particles that are more circular in nature will flow and mix better. Particles with a lower circularity can get hung up with other particles or feeders which will impact mix-ability and flow-ability.



Typical Circularity graph. Results are shown in Number weighted distribution only and can be displayed real-time with a Cumulative line.

Abrasive particle. 0.321 Circularity

Note that a distribution with circularity close to “1” would indicate mostly round particles in the sample population. In the case of these abrasive particles, circularity is not close to “1” which is expected.

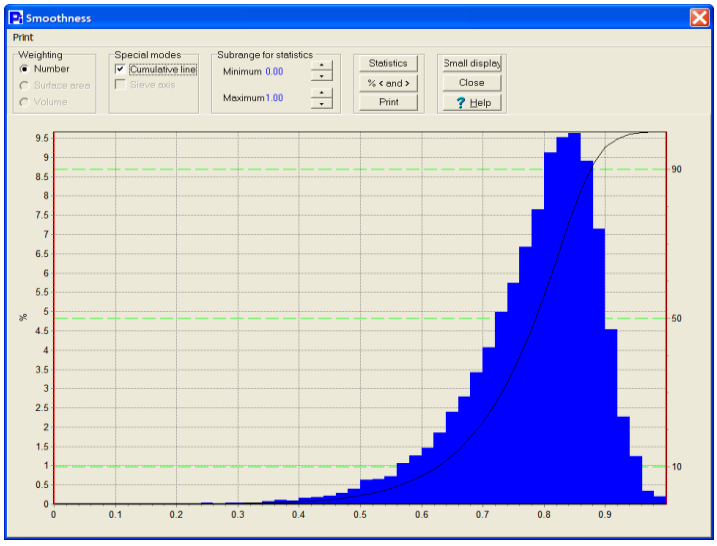
Circle Models…….

Particle Insight – Smoothness

Explanation – Smoothness is calculated from area (A) and perimeter (P) of the particle projection. It is a number between 0 and 1, a perfect circle having Smoothness equal to 1. Like circularity, smoothness is affected by the degree of out-of-roundness of the general shape. It is also affected by irregularity of the perimeter, which by inference is an indication of surface roughness.

$$\text{Smoothness} = 4\,\pi\,A\,/\,P^{2}$$

Practical Use – Smoothness is a measure that can be used to monitor surface roughness. This can affect the performance of an abrasive particle and can also have an impact on how pharmaceutical powders flow and mix prior to granulation.



Typical Smoothness graph. Results can be displayed in Number weighted distribution, Volume weighted distribution as well as Surface Area weighted distribution. All can be displayed real-time with a Cumulative line.

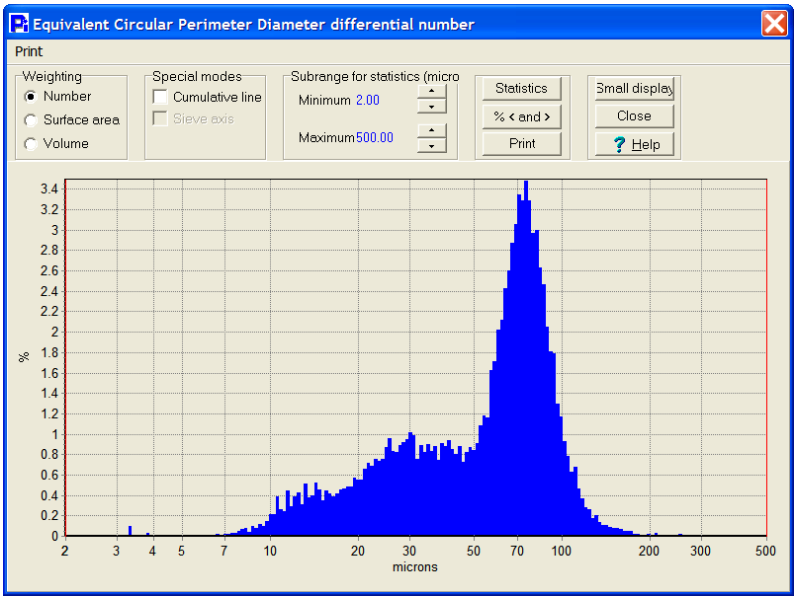
Abrasive particle. 0.509 Smoothness where “1” would be a perfectly smooth particle. Note that Smoothness is not affected by particle size. Only surface roughness.

Circle Models…….

Particle Insight - Equivalent Circular Perimeter Diameter (ECPD)

Explanation – Equivalent Circular Perimeter Diameter (ECPD) is the diameter of a circle having the same perimeter as the actual shape. Whereas ECAD relates to a particle's likely volume, ECPD relates more to its surface area.

Practical Use – ECPD is a measure that can be used to determine the surface area of the silhouette of a particle. A practical application of this would be particle coating. In such a case, the amount of coating a particle will require may be relatively controlled by monitoring the changes in ECPD. If ECPD is increasing in size, that means the greater the surface area of the particle and, therefore, the more required coating.



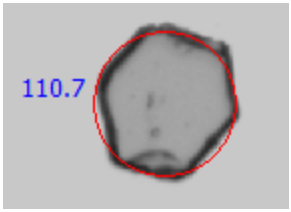
Typical ECPD graph. Results can be displayed in Number weighted distribution, Volume weighted distribution as well as Surface Area weighted distribution. All can be displayed real-time with a Cumulative line..

Abrasive particle.
134.7µm ECPD

Circle Models…….

Mean Radius Diameter

Explanation – Mean radius is determined by averaging 48 radi from the centroid equally spaced in an angle. Mean radios diameter is then computed as 2x the mean radius.



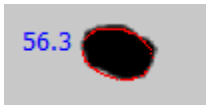
Compactness

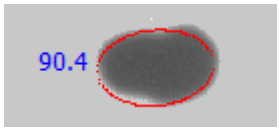
Explanation – Compactness is computed as the square root of Circularity and does not vary as much as Circularity.

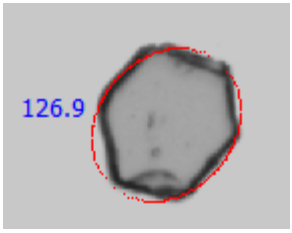
Elliptical Models…….

Equivalent Elliptical Area Width, Length and Aspect Ratio

Explanation – EEAW and EEAL are the width and length of an ellipse equal in area to the original shape and with an aspect ratio the same as that of the bounding rectangle. EEAR is the Equivalent Elliptical Aspect Ratio which is the ratio of Length to Width.

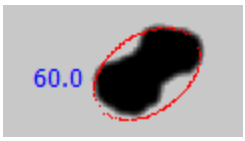


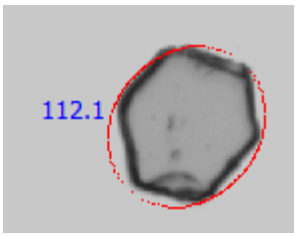




Bounding Ellipse Width and Length

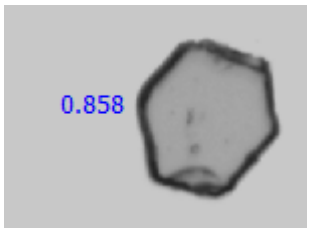
Explanation – Bounding Ellipse Width and Length is the width and length of a minimal area ellipse that bounds the shape





Ellipsicity

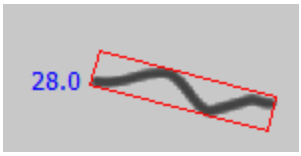
Explanation – Ellipsicity is the actual shape area divided by the bounding ellipse area. This is a measure of how closely the shape conforms to the ellipse model.

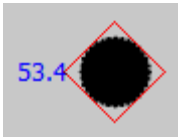


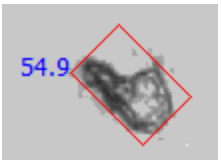
Rectangle Models…….

Bounding Rectangle Width, Length and Aspect Ratio

Explanation – Bounding Rectangle Width and Length are the dimensions of the smallest rectangle (in area) that encloses the projected particle's silhouette. BRAR (aspect ratio) is the ration of the bounding rectangle width and length. BR Width results can also be shown with Sieve equivalent results to enable comparable results to historical Sieve data. This would enable users to estimate which particles, if passed through a sieve via its narrowest dimension (BR Width), what would pass through each sieve.







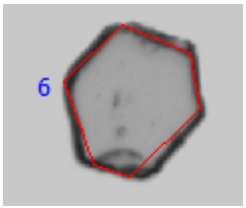
Rectangularity

Explanation – Rectangularity is the fraction of the bounding rectangle's area occupied by the actual shape. It measures how closely the shape conforms to the rectangle model.

Polygon Models…….

Polygon Order

Explanation – Polygon Order is the number of sides of the fitted polygon. Sides that subtend an angle smaller than the Minimum central angle set by the user will not be counted.



Convexity

Explanation – Convexity is the ratio of the actual shape area to the area of the polygonal convex hull. Convexity is the most accurate with larger particle sizes (above 200 in pixel area).

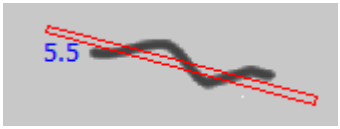
Interior Angles

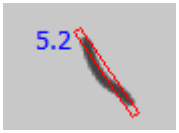
Explanation – Polygon Interior Angles measure will accumulate statistics on the objects that are larger than the minimum size entered for Polygon Order. Since this is a multi-valued measure for each particle, it is not available in places that require a single value. For example when analyzing a single image, it will not appear in the analysis table.

Fiber Models…….

Fiber Width, Length and Aspect Ratio

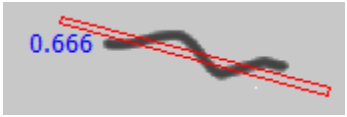
Explanation – Fiber Width, Length and Aspect Ratio models reshapes fibers into a straightened rectangle prior to making the measurements. Aspect ratio is the ratio between the fiber width and length.

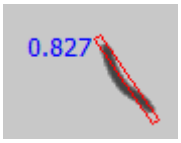




Fiber Curl

Explanation – Fiber curl is the ratio of Bounding Rectangle Length to Fiber Length. It is a fractional measure equal to 1 for a straight fiber. A smaller value means a greater degree of curl.

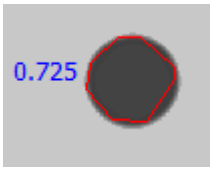




Pixel Intensity Models…….

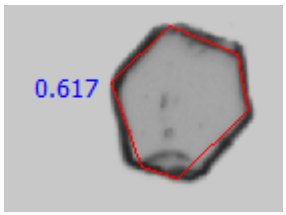
Opacity

Explanation – Particle intensity mean is calculated as a value between 0 (black) and 255 (white). Opacity is then computed as (256 – (intensity mean)) / 256. A value of 1 is fully opaque and 0 is fully transparent.



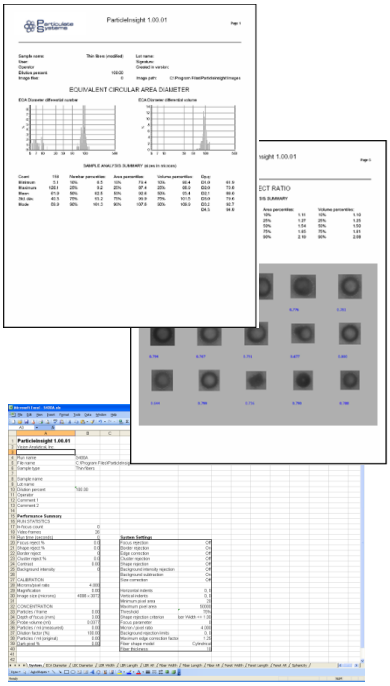
White Fraction

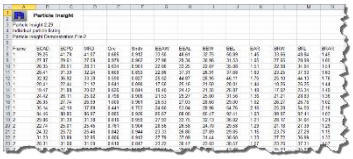
Explanation – White Fraction is the fraction of the particle area that is lighter than the Dark Threshold in the Analysis options.



Report and Data Outputs…….

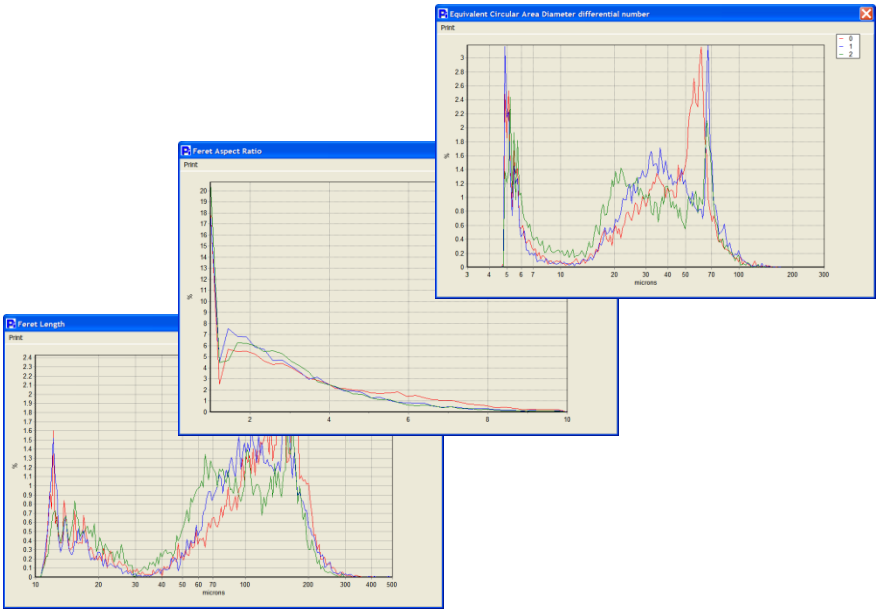
The Particle Insight has the ability of reporting data in many different ways.





Printed reports can show all the statistical histograms, data and thumbnails from the analysis performed. Report formats can be formatted by the customer. Excel reports and data listings also are also available

Comparing different lots of samples can be done easily with Multiple Run Summaries. This allows the comparison and contrast of sample runs not only by size, but also by all the available shape measures.



Vision ANALYTICAL

Other Literature Available…….

Visit the Particulate Systems website for other literature available such as brochures, posters, videos and application notes…www.ParticulateSystems.com

www.ParticleShape.com

More information Available…….

More information is also available from the Vision Analytical website….www.ParticleShape.com