CAMSIZER® Characteristics

Basis of definition DIN 66141

Particle size distribution:

x_{area}	**Particle diameter calculated by the area of particle projection** $x_{area} = \sqrt{\frac{4A}{\pi}}$ **Diameter of the area equivalent circle with a volume of a sphere with the diameter of x_{area}**
$x_{c\ min}$	**Width, Breadth** **particle diameter which is the shortest chord of the measured set of maximum chords of a particle projection (for results close to screening/sieving)**
$x_{Ma\ min}$	**Width, Breadth** **particle diameter, which is the shortest Martin diameter, which is dividing the area of the particle projection into two halves (for results close to screening/sieving)**
$x_{Fe\ min}$	**Width, Breadth** **particle diameter which is the shortest Feret diameter of the measured set of Feret diameter of a particle projection**
$x_{Fe\ max}$	**Length** **particle diameter which is the longest Feret diameter of the measured set of Feret diameter of a particle (for results close to microscopy)**
x_{length}	**Length** **particle size, which is calculated from the longest Feret-diameter and the smallest chord or Martin– diameter of each particle projection** $x_{length} = \sqrt{x_{Fe\,max}^{2} - x_{c\,min}^{2}}$ **(suitable for display of length distributions of cylinders, which are orientated by a guidance sheet (e.g. to substitute optical measurement systems like light table, calliper, microscope or static image analysis systems)** **x_{length} is limited to the smallest $x_{c\ min}$ of this particle**
$x_{length2}$	**Length** **particle size, which is calculated from the longest Feret-diameter and the smallest chord or Martin– diameter of each particle projection** $x_{leng2} = \sqrt{x_{Fe\,max}^{2} - x_{c\,min}^{2}}$

$x_{stretch}$	**Length** particle size, which is calculated from the area of the particle projection of each particle divided by the smallest diameter (smallest Martin diameter) of the particle projection, interesting for bended extrudates and short extrudates $x_{Stretch}$ is limited to $x_{Ma\ min}$ of this particle
$x_{stretch2}$	**Length** particle size, which is calculated from the area of the particle projection of each particle divided by the smallest diameter (smallest of all maximum chords) of the particle projection, interesting for bended extrudates and short extrudates
$Q_3(x)$	**Cumulative distribution (% passing)**, based on volume: volume proportion of particles smaller than x in proportion to the total volume
$1-Q_3(x)$	**Cumulative distribution of residue** $1-Q_3(x)$, based on volume
$p_3(x_1,x_2)$	**Fractions** $p_3(x_1,x_2)$ – volume proportion of particles in the range (x_1,x_2): $p_3(x_1,x_2) = Q_3(x_2) - Q_3(x_1)$
$q_3(x)$	**Density distribution** $q_3(x)$ based on volume: 1. Derivative of $Q_3(x)$ $\quad q_3(x) = \frac{dQ_3(x)}{dx}$
$Q_0(x)$	**Cumulative distribution** $Q_0(x)$, based on number of particles: number of particles smaller than x in proportion to the total number of particles
$1-Q_0(x)$	**Cumulative distribution of residue** $1-Q_0(x)$, based on number of particles
$p_0(x_1,x_2)$	**Fractions** $p_0(x_1,x_2)$ - number of particles in the range (x_1,x_2): $p_0(x_1,x_2) = Q_0(x_2) - Q_0(x_1)$
$q_0(x)$	**Density (frequency) distribution** $q_0(x)$, based on number of particles: 1. Derivative of $Q_0(x)$ $\quad q_0(x) = \frac{dQ_0(x)}{dx}$

Characteristics:

$Q_3(x)$	Q_3 value, whereat a given particle diameter x is reached, based on volume
$x(Q_3)$	x value whereat which a given Q_3 value is reached, based on volume
$SPAN_3$	**Span value, based on volume:** $Span_3 = \frac{x(Q_{3,3}) - x(Q_{3,1})}{x(Q_{3,2})}$ Here the first index indicates that the values are based on volume. In the program the first index has been left off, since for $SPAN_3$ and $SPAN_0$ the same Q(x) values are used.

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U_3	**Non-uniformity**, based on volume: $$U_3 = \frac{x_{60}}{x_{10}}$$ x_{10}: x value for Q_3 = 10 % x_{60}: x value for Q_3 = 60 %
Q_0 (x)	Q_0 **value**, whereat a given particle diameter x is reached, based on number
$x(Q_0)$	**x value**, whereat a given Q_0 value is reached, based on number
$SPAN_0$	**Span value, based on number of particles** $$Span_0 = \frac{x(Q_{0,3}) - x(Q_{0,1})}{x(Q_{0,2})}$$ Here the first index indicates that values are based on the number of particles. In the program the first index was left off as for $SPAN_3$ and $SPAN_0$ the same Q values are used.
U_0	**Nonuniformity, based on number of particles** $$U_0 = \frac{x_{60}}{x_{10}}$$ x_{10}: x value for Q_0 = 10 % x_{60}: x value for Q_0 = 60 %

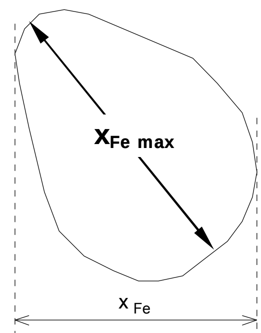
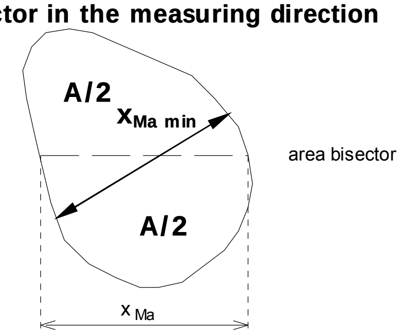
Indirect determination of the specific surfaces S_v and S_m:

S_V	**Specific surface** $$S_v = \frac{\text{surface of all particles}}{\text{volume of all particles}}$$
S_m	**Specific surface** for a given specific density $$S_m = \frac{\text{surface of all particles}}{\text{mass of all particles}}$$

RRSB characteristics:

n	Slope of the RRSB line
d'	x value, whereat the line reaches a value of 0.632
correlation	Correlation between the RRSB line and Q(x) in the range between Q_1 and Q_2

Shape characteristics:

x_{Fe}	**Feret diameter x_{Fe}** Distance between two tangents placed perpendicular to the measuring direction. For a convex particle the mean Feret diameter (mean value of all directions) is equal to the diameter of a circle with the same circumference. 
$x_{Fe\ max}$	The longest Feret diameter out of the measured set of Feret diameters.
$x_{Fe\ min}$	The shortest Feret diameter out of the measured set of Feret diameters.
x_{Ma}	**Martin diameter x_{Ma}** Length of the area bisector in the measuring direction 
$x_{Ma\ min}$	The shortest Martin diameter out of the measured set of Martin diameters.

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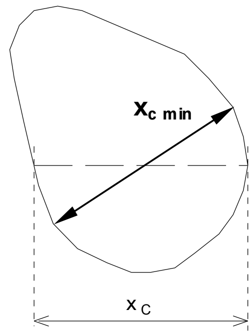
x_c

maximum chord x_c in measuring direction



$x_{c\ min}$

The shortest chord out of the measured set of max. chords x_c.
= breadth/width, which is very close to sieving.

$SPHT_{0,2,3}$

Sphericity $SPHT = \frac{4pA}{P^2}$ **= Circularity² (ISO 9276-6)**

P – measured perimeter/circumference of a particle projection
A – measured area covered by a particle projection

For an ideal sphere SPHT is expected to be as 1.
Otherwise it is smaller than 1.

$Symm_{0,2,3}$

Symmetry $Symm_{0,2,3} = \frac{1}{2}\left(1 + \min\left(\frac{r_1}{r_2}\right)\right)$

r_1 und r_2 are distances from the centre of area to the borders in the measuring direction. For asymmetric particles Symm is < 1.

If the centre of area is outside the particle i.e. $\frac{r_1}{r_2} < 0$ **Symm is < 0.5**

$x_{Ma} = r_1 + r_2$ **"Symm" is minimum value of measured set of symmetry values from different directions**

$b/l_{0,2,3}$

Aspect ratio $b/l_{0,2,3} = \frac{x_{c\ \min}}{x_{Fe\ \max}}$;

$x_{c\ min}$ and $x_{Fe\ max}$ out of the measured set of x_c and x_{Fe} values

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$(b/l)_{rec\ 0,2,3}$

$(b/l)_{rec\,0,2,3} = \min\left(\frac{x_c}{x_{Fe}}\right)$; **min quotient of perpendicular x_c and x_{Fe} out of the measured set of x_c and x_{Fe} values.**

$B/L_{0,2,3}$

$B/L_{0,3} = \frac{x_{Fe\ \min}}{x_{Fe\ \max}}$ **; $x_{Fe\ min}$ and $x_{Fe\ max}$ out of the measured set of x_{Fe} values**

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$(B/L)_{rec\ 0,2,3}$	$(B/L)_{rec0,3} = \min\left(\frac{x_{Fe1}}{x_{Fe2}}\right)$; min quotient of perpendicular x_{Fe1} and x_{Fe2} out of the measured set of x_{Fe} values.
$x_p = x_{mean}$	The Feret diameter, the Martin diameter, the max. chord and the sphericity for the various size classes are determined by calculating a mean value, based on the number of particles within a size class: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ As the objects within a class can be distributed unevenly, the mean equivalent diameter of circles equal in area, xp, should be used as reference value for class-related information.
PD_0, PD_3	Number of particle detections, measure of the statistical reliability of the shape characteristics. The larger PD the more reliable is the value of x_{Fe}, x_{Ma}, x_c and SPHT.
$Sigma(v)_0$	Standard deviation of the ratio $Sigma\,(v) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(1-v_i)^2}$ with the ratio $v_i = \frac{\max(x_{Fe}, x_c)}{\min(x_{Fe}, x_c)}$ of the particle no. i, in which the measuring directions of the Feret diameter and the maximal chord are perpendicular to each other.
$Q_0(SPHT) = NSP_0$ $Q_3(SPHT) = NSP_3$	Proportion of non-spherical particles, whose sphericity is smaller than a given threshold; based on number of particles or on volume
$Q_{0/2/3}$; Symm; b/l, $(b/l)_{(rec)}$ B/L, etc.	Proportion of particles or volume, whose symmetry, or various b/l-ratios is smaller than a given threshold
$Mv_{0/2/3}(x)$	Mean value of a chosen characteristic, weighted; $x_{1,r} = \sum x\, q_r(x)\, \Delta x$
Sigma(x)	Standard deviation $\sigma(x)$ from the mean value Mv(x)
$Conv_{0/2/3}$	Convexity = (square root) ratio of real area of the particle projection and convex area of particle projection (as if a rubber band was put around the particle projection)
$Trans_{0/2/3}$ $Transa_{0/2/3}$ $Transb_{0/2/3}$ $Q_{0/2/3}(trans)$ $Q_{0/2/3}(transa)$ $Q_{0/2/3}(transb)$	Trans(parency) = ratio of the bright area within the particle projection divided by complete filled particle projection Q(Transparency) = amount of sample below a threshold of the ratio between bright area of particle projection divided by complete filled particle projection. Characteristic "Trans" $Trans = \frac{A_1}{A}$ A= Area of the filled particle projection (without pixels at the edge of the projection). A_1= Area within the particle projection which has a brightness larger than "$Thresh_1$". $Thresh_1 = I_{min} + 0.25\,(I_{max} - I_{min})$

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	Characteristic "Trans a" $Trans = \frac{A_2}{A}$ **A= Area of the particle projection (without pixels at the edge of the projection). A_2= Area within the particle projection which has a brightness larger than "Thresh$_2$". Thresh$_2$ = I_{min} + 0.5 (I_{max} – I_{min})** **Characteristic "Trans b"** $Transb = \frac{\iint_{A3} (I(x,y) - I_{fix})dA}{(I_{max} - I_{fix})A}$ **A= Area of the particle projection (without pixels at the edge of the projection). A_3= Area within the particle projection which has a brightness larger than "Thresh$_3$". Thresh$_3$ = I_{fix} + 0.25 (I_{max} – I_{fix})** **I_{min} = minimum brightness within particle** **I_{max} = maximum brightness of particle** **I_{fix} = minimum brightness of the camera** **Trans and Trans a are depending on the brightness of the particle projection. Calculation of Transparency is done with the histogram of the particle brightness and the brightness of the surrounding area.**

Optional characteristics:

rD	**relative Density, mass of sample divided by the volume of the sample measured with the CAMSIZER®**
AFS	**American Fineness number, AFS number is a sand specific requirement and it is a figure that results in one number for a measured sample.**

The formula for this number is: $AFS = \frac{\sum p_{3i} * M_{3i}}{\sum p_{3i}}$

Where: p_{3i} is the fraction of the material in the class i and M_3 is an fixed multiplication factor for each class. There is a connection between the ASTM Mesh number and this M_3 multiplication factor (we do not know it).

Example:

Class	Fraction p3	Multiplication factor M3	P3 * M3
1 – 0,71	-	15	-
0,71 – 0,5	0,75	25	19
0,5 – 0,355	8,70	35	305
0,355 – 0,25	28,60	45	1287
0,25 – 0,18	30,05	60	1803
0,18 – 0,125	5,90	81	478
0,125 – 0,09	1,00	118	118
0,09 – 0,063	0,30	164	49
0,063 – 0,02	0,35	275	96
	75,65		4155

$$AFS = \frac{4155}{75,65} = 54,92 \approx 55$$

SGN	**Size Guide Number** **Calculated diameter of the "average particle", expressed in millimeters and multiplied with 100 (for example: d_{50} = 0.123 mm => SGN = 12.3)** $\mathbf{SGN} = \mathbf{100} \cdot \mathbf{x_{50}}$ **with** $x_{50} = x(Q_3 = 50\%)$ **in mm** **The calculation of SGN is based on the following size classes: 0.212, 0.300, 0.425, 0.600, 0.850, 1.18, 1.70, 2.36, 3.35, 4.75, 6.70mm** **If x_{50} falls into one of these size classes, than x_{50} is an interpolated value from the Q_3 value of the next lower and the next higher sieve. If x_{50} lies beyond 0.212 mm or 6.7 mm than x_{50} is the actual value determined by the CAMSIZER and is not interpolated.**
UI	**Uniformity Index** **ratio of the size of "SMALL PARTICLES" to "LARGE PARTICLES" in the sample, expressed in percentage;** **UI is the ratio, times 100, of the two extreme sizes in the range of large particles at the 90% Q_3 level and fine particles at the 5% Q_3 level. UI =100 means that the particles have the same size, perfectly uniform; UI = 50 means that the small particles are half the size of the large particles in the sample** $UI = 100 \frac{x_5}{x_{90}}$ **with** $x_5 = x(Q_3 = 5\%)$, $x_{90} = x(Q_3 = 90\%)$ **The determination of x_5 and x_{90} follows the determination of x_{50} for the calculation of SGN**
CV	**Coefficient of Variation** **the coefficient of variation is the standard deviation (SD) of the size distribution divided by the average; it is dimensionless** $CV = 50 \frac{x_{84} - x_{16}}{x_{50}}$ **with** $x_{84} = x(Q_3 = 84\%)$, $x_{16} = x(Q_3 = 16\%)$, $x_{50} = x(Q_3 = 50\%)$
MA	**Mean Aperture = D_{50} value = Median Diameter x_{50}**
PI	**Polydispersity Index** $PI(Q_1,Q_2) = \frac{x(Q_1)}{x(Q_2)}$
Q_1(V)	**Q_1 value, whereat a given particle volume is reached, based on volume**
Q_0(V)	**Q_0 value, whereat a given particle volume is reached, based on number**