Image Analysis Sample Submission Form

3230 N. Susquehanna Trail, York, PA 17406

For assistance in completing this form, contact your sales representative or Microtrac.

Please complete this form and include with sample and SDS. Payment method must be included. Provide hard copy if using PO.

PRIMARY CUSTOMER CONTACT INFORMATION		PAYMENT INFORMATION AND PURCHASING CONTACT *Not Required if Samples are submitted for Instrument Purchase Evaluation*			
Company		Company			
Contact Name		Contact Name			
Shipping Address		Mailing or Billing Address			
City, State, ZIP		City, State, ZIP			
Phone Number		Email Address			
Email Address		Phone Number			
FAX Number		PO# or Credit Card # and Type (AMEX, etc)			
Signature		Credit Card Expiration Date		Security Code	
☐ Samples submitted for evaluation of instrument purchase: *Up to three samples - no charge.*	Sales Rep:		Sales Rep Company:		

Type of Service	Charge	Sample Return Information	
☐ 10 Business Day	List Price	☐ Please Return Sample ☐ Hold Sample 90 Days ☐ Discard Sample	$50 minimum charge if no Shipping Account Number provided for Return
☐ 3 – 5 Business Day	List + 30%		
☐ 24 Hour	List + 75%	Shipping Account Number and Carrier	
☐ Same Day	List + 100%	If shipping account number is not available, charges will be assessed to cover additional costs of handling and shipping.	

Special data are required for fluid measurements (PartAn SI) as shown below. Dry powder measurements *do not require* this information. Comments can be entered on the next page.

Material Type Please use another sheet if more than 3 samples are being submitted	Enter Your Sample ID Microtrac Will Enter Lab Tracking # in Blue Box Below	Analysis Code from Price List	Expected Size Range (µm or mm) and Dry or Fluid	For SI fluid only. If mixed with fluid, what is fluid?	For SI fluid only. Can sample be mixed with water?	For SI fluid only. Treat with Ultrasonic for full dispersion	SI Fluid Measure with S3500 Diffraction
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

Select instrument and 5 parameter values from the list below. See next pages for definitions. Please comment on use and purpose of data on next page.

Select values below	Select Instrument →	☐ PartAn 3D Dry Powder	☐ PartAn SI (In Fluid)	

These are the most commonly used imaging parameters. *See following page for definitions and others that are available by request.*

☐ Area	☐ Ellipse Width	☐ Feret Thickness (3D)	☐ Ellipticity	☐ T/L Aspect Ratio (3D)
☐ D_A - Area Equiv. Diam.	☐ Ellipse Thickness (3D)	☐ Rectangularity	☐ Angularity	☐ Convexity
☐ D_P - Perim.Equiv. Diam	☐ Feret Length	☐ Sphericity	☐ Ellipse Ratio	☐ Solidity
☐ Ellipse Length	☐ Feret Width	☐ Circularity	☐ W/L Aspect Ratio (2D)	☐ Concavity
			☐ Krumbein Roundness	☐ Transparency

Microtrac will complete the following. . .

Date Rec'd	File Number	Lab ID	Log-in by:

Contacts: Ph:888-643-5880 Toni Weigel, Ext 214 (Toni.Weigel@Microtrac.com) or Jason Barsotti Ext 220 Jason.Barsotti@Microtrac.com).

Image Analysis Sample Submission Form

3230 N. Susquehanna Trail, York, PA 17406

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contact your sales representative or Microtrac.

Please add any comments below (SOP#, special preparation, etc.) for the Microtrac analyst.							
Material Type Please use another sheet if more samples are being submitted	**Enter Your Sample ID** Microtrac Will Enter Lab Tracking # in Blue Box Below	Analysis Code from Price List	Expected Size Range (µm or mm) and Dry or Fluid	For SI fluid only If mixed with fluid, what is fluid?	For SI fluid only. Can sample be mixed with water?	For SI fluid only. Treat with Ultrasonic for full dispersion	SI Fluid Measure with S3500 Diffraction
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
					☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

Data will be presented as linear scale (µm or mm) and volume percent unless otherwise requested.
Provide sieve sizes desired if mesh size is desirable.

Customer Comments or Requests: Special parameter calculation. Provide sieve or other size or parameter data if available.

State units to be used (um, mesh, etc.). Attach extra sheet if more space is needed.

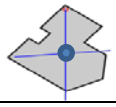
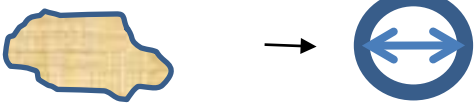
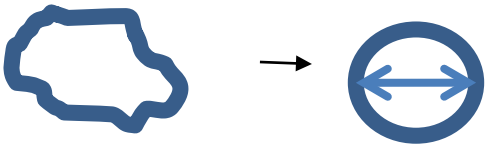
General Considerations: The information below is offered to assist in the selection of five (5) *notations* on the previous page.

- ***Amount of Material.*** For fluid (SIA) measurements, volume amount of solid or slurry: 25mL to allow for proper determination of sample preparation. Mass (weight) may be used if a powder. Density X 25mL. For dry powder measurements 500mL to 1 liter. For 3D large amount of material may be required due to large sizes – contact Microtrac or sales representative.
- ***Size:*** Various parameters are used to show length, width, thickness (3D only), and area. E=Legendre Ellipse, F= Feret. The parameters include **Da, Dp, ELength, EWidth, EThickness (3D), FLength, FWidth, and FThickness (3D).**
- ***Form (Shape)Descriptor*:** Parameters other than those for size are dedicated to form/shape. Size values, from above, may be used for calculation of form, shape or roughness parameters. Generally the parameters for shape indicate how closely the particle is shaped like a circle. Values termed **Sphericity, Circularity, and Roundness** have a scale of 0 to 1.0, where 1.0 represents a perfect circle or square. A change in circle shape factors is a function of either a change in form (shape), or roughness, or both. Indicates how the shape diverges from a circle in overall form/shape. This category includes various ratios. See information on calculations for complete descriptions. There are also calculations for special applications.
- ***Surface Roughness*:** Indicates how the shape diverges from a smooth surface, regardless of form. The terms include **Convexity, Solidity, and Concavity**. The values for **Convexity** and **Solidity** are 0 to 1.0, where 1.0 indicates a smooth surface with no indentations. The third, **Concavity**, also has a scale of 0 to 1.0, where 1.0 indicates a very "spikey" surface, with many and pronounced indentations.
- ***Other:*** Transparency and curvature are used primarily for spheres.

Size, Shape, Form Parameters Available

General Definitions and Size Parameters

The following table describes the basic parameter calculations of the measured particles.

Notation	Description, units
Area	Area, μ^2 
Perimeter	Perimeter, µ 
Volume	Volume, μ^3 
Centroid	Center of gravity or the x,y point on image. Only used for Legendre Ellipse calculations 
Da	Area Equivalent Diameter, µ 
Dp	Perimeter Equivalent Diameter,µ 

List of Available Parameters

Note 1: The letter "F" refers to Feret calculations. The letter "E" refers to Legendre Ellipse calculations. See explanations below for more details.
Note 2: Values containing Thickness (T) are not available in PartAn SI.. Thickness is only available in PartAn 3D model.

Total List Microtrac Morphological Parameters (May contain parameters <u>available but not shown</u> on Sample Request Form) According to Primary Descriptor Groups			
** Indicates often used parameter.			
Size	**Shape/Form**	**Surface Roughness**	**Other**
Da**	Sphericity**	Convexity**	Transparency**
Dp	Circularity**	Solidity	Curvature
FLength**	Roundness	Concavity	
FWidth**	Krumbein Roundness		
FThickness** (3D Only)	Extent		
ELength**	Ellipse Ratio**		
EWidth**	W/L Aspect Ratio**		
EThickness** (3D Only)	T/L Aspect Ratio (3D Only)		
Area	L/T Ratio (3D Only)		
Volume	L/W Ratio		
Perimeter	T/W Ratio (3D Only)		
Surface Area	W/T Ratio (3D Only)		
CHull Area	Ellipticity		
CHull Surface Area	Angularity		
Sieve (3D Only)	Rectangularity (3D Only)		
Cylinder Diameter (3D Only)	Compactness		
Cylinder Length (3D Only)			
Fiber Length			
Fiber Width			

Size Parameters

Size Parameters indicate dimensions of the outside of particles.

Basic Size Parameters used for other calculations	2D Description For Basic Size Parameter	3D Calculation from Series of Tracked, Individual Particle	Result Presentation
	Area = Area of the projected image	Average area of the sequence of 3D images.	**Area:** Basic size parameter and used in other subsequent calculations
Convex Hull Area	**CHull Area**= Area of the convex hull of the image. The convex outline of a projected shape having concavities. If a rubber band is placed around the image, it will describe the Convex Hull. The area is then calculated. 	Average convex hull area of the sequence of 3D images.	**CHull Area:** Not normally used as a parameter, but is a basic size parameter and used in other subsequent calculations
Perimeter	**Perimeter** = Perimeter of the projected image for 2D.	Average perimeter of the sequence of 3D images.	**Perimeter:** Basic size parameter and used in other subsequent calculations
Convex Hull Perimeter	**CHull Perimeter** = Perimeter of the convex hull of the image. If a rubber band is placed around the image, it will describe the Convex Hull. The perimeter is then calculated. 	Average convex hull perimeter of the sequence of 3D image shapes.	**CHull Perimeter:** Not normally used as a parameter, but is a basic size parameter and used in other subsequent calculations

Legendre ellipse calculation

Determination of the moments of inertia of the shape coordinates Definition of intermediate terms $\alpha = \frac{1}{2}$

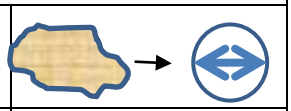
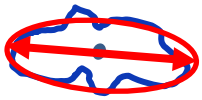
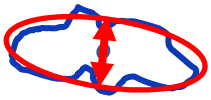
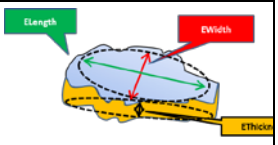
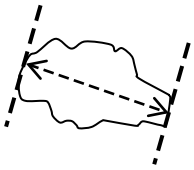
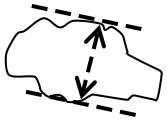
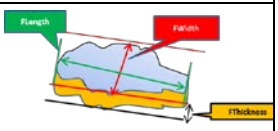
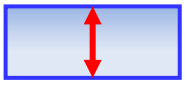
$(\sigma_{xx} + \sigma_{yy})$ $\beta = \sqrt{(\alpha - \sigma_{xx}\ \sigma_{yy} + \sigma_{xy})}$

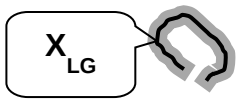
$\sigma_{xx} = 1/n\ \Sigma\ (x_i - \bar{x})^2$ $\sigma_{yy} = 1/n\ \Sigma\ (y_i - \bar{y})^2$ $\sigma_{xy} = 1/n\ \Sigma\ (y_i - \bar{x})\ (x_i - \bar{x})$

Determination of the lengths of the axes of an ellipse with equivalent inertia

Length of the major axis Length of the minor axis

ELength = $4\ \sqrt{(\alpha + \beta)}$ EWidth = $4\ \sqrt{(\alpha - \beta)}$

Size Parameter Calculations	2D Calculation for Individual Particle	3D Calculation from Series of Tracked, Individual Particle	Result Presentation	Related drawing
** Often used parameter		Also, see Legendre Ellipse calculations on last page to explain "E" parameters.		
Area Equivalent diameter **	**Da** = $(4\text{Area}/\pi)^{1/2}$	Area = average Area in sequence of 3D images	**Da**	
Equivalent perimeter diameter	**Dp** = Perimeter /π	Perimeter = average Perimeter in sequence of 3D images	**Dp**	
Legendre Ellipse Length**	Measured length of the major axis of an Legendre ellipse whose center is the centroid of the particle shape. The moments of the Legendre ellipse and shape are the same up to the second order.	ELength = max ELength in sequence of 3D images	**ELength**	
Legendre Ellipse Width**	Measured length of the minor axis of an Legendre ellipse whose center is the centroid of the particle shape. The moments of the Legendre ellipse and shape are the same up to the second order.	EWidth = maximum EWidth in sequence of 3D images	**EWidth**	
Legendre Ellipse Thickness**	*Not available* in 2D.	EThickness = minimum EWidth in sequence of 3D images	**EThickness (3D Only)**	
Feret Length**	**FLength** = Maximal distance between parallel tangents	FLength = maximum FLength in sequence of 3D images	**FLength**	
Feret Width**	**FWidth** = Minimal distance between parallel tangents	FWidth = maximum FWidth in sequence of 3D images	**FWidth**	
Feret Thickness**	*Not available* in 2D.	FThickness = minimum FWidth in sequence of 3D images	**FThickness (3D Only)**	
Sieve	*Not available* in 2D.	**Sieve =** (Sieve Coeff x FWidth) + ((1- Sieve Coeff) x FThickness) (3D only)	**Sieve** - Used when Sieve Size Calculation option is chosen under Particle Measurement in SOP. Sieve data required	Sieve
Cylinder Diameter	*Not available* in 2D.	**CylDia** = Distance parallel to shortest edges of the above Rectangularity minimum rectangle (3D only)	**CylDia** - Used when Cylinder calculation option is chosen under Particle Measure in SOP	

Cylinder Length	*Not available* in 2D.	**CylLength =** Distance parallel to longest edges of the above Rectangularity minimum rectangle (3D only)	**CylLength -** Used when Cylinder calculation option is chosen under Particle Measurement in SOP	
Fiber Length	$\mathbf{X_{LG} = ¼ (P + \sqrt{P^2 - 16A})}$ A= Area LG = length	*Not available* in 3D	**Fiber Length**	
Fiber Width	$\mathbf{W = A/X_{LG}}$ _ X_{LG}	*Not available* in 3D.	**Fiber Width**	

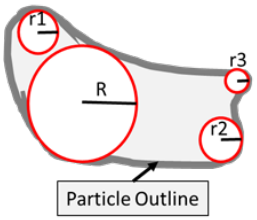
Surface Area and Volume Calculations

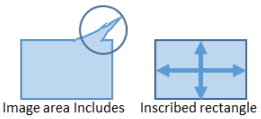
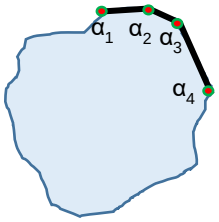
Surface Area Parameter	2D Calculation for Individual Particle	3D Calculation from Series of Tracked, Individual Particle	Result presentation
Surface Area (Sphere)	**Surface Area** = π * $(Da)^2$	Da calculated from average Area of the sequence of 3D images.	**Surface Area –** Not BET measurement
CHull Surface Area (Sphere)	**CHull Surface Area** = π*$(Dca)^2$	Dca (CHull Area) calculated from the average CHull Area in the sequence of 3D images.	**CHull Surface Area -**
Volume Parameter			
Volume	Calculated from the Area Equivalent Diameter, Da. **Volume** = π $(Da)^3$ / 6 (2D)	Calculated from actual 3D size parameters. **Volume** = FLength x FWidth x FThickness = Maximum FLength x Maximum FWidth x Minimum FWidth Best indication of volume since 3 dimensions being used.	**Volume**

Shape Parameters

Form indicators in that they diverge further from a sphere to other shapes. All are ratios that use the above values to elucidate shape features. For instance, Surface Roughness parameters (convexity, etc.) can identify poor flowability/compaction and agglomerated particles. This chart uses values from Appendix I table to provide special calculations to assist defining shape characteristics. 3D refers to 3Dimensional imaging data. 2D refers to 2Dimensional imaging data. When thickness (T) is applied to a formula, only 3D calculation is available.

Shape Parameter	2D Calculation for Individual Particle	3D Calculation from Series of Tracked, Individual Particles	Result presentation
Ellipse Ratio** Note that "E" values are based upon the Legendre ellipse.	**Ellipse Ratio** = EWidth / ELength (2D)	**Ellipse Ratio** = EThickness/ELength. (3D) Minimum EWidth / ELength	Measure of overall form. As it decreases, measures of circularity decrease. Ratio of Width to Length, 0 to 1 (square to circle). Uses Legendre ellipse calculation.
Compactness	**Compactness** = $(4Area/\pi)^{1/2}$ / FLength	Area = average Area of a sequence of 3D images FLength = max FLength in the series of images	Less sensitive but more robust, than Roundness . Values 0 to 1 (circle).

Roundness	**Roundness** = 4Area / π (FLength)^2	Area = average Area of a sequence of 3D images = FLength = max FLength in the series of images	Measure of proximity to circle, 0 to 1 (circle). Sensitive to elongated deviations from a circle. Overall shape indicator.
Krumbein Roundness	<u>Krumbein RND –</u> Krumbein RND = avg(r_1,r_2,r_3,…,r_n) /R R = Radius of largest inscribed circle in the shape. r_1, r_2, r_3, …. , r_n = radius of all turns in the shape (where r_n is less than R) Uses: Proppants and materials showing protrusions and sharp angles such as abrasives.	Average of a sequence of 3D images General explanation: The largest circle that can be inscribed in the particle is determined. Turns in the particle shape are identified and the radius of each is calculated.. The average of the radii of all turns is calculated. The average is divided by the radius of the inscribed circle.	Calculation used for proppants and materials having protrusions and sharp angles. A perfect, circularly shaped particle will provide a value of "1" 
T/L Aspect Ratio	<u>*Not available*</u> in 2D.	T/L Aspect Ratio = FThickness / FLength (3D) = Minimum FWidth / Maximum FLength in the series of images	FThickness and FLength from the sequence of 3D images of the same particle. Value range = 0 to 1 where 1 represents sphere.
L/T Ratio	<u>*Not available*</u> in 2D.	**L/T Ratio** = FLength / FThickness (3D) = Maximum FLength / Minimum FWidth in the series of images	FLength and FThickness from the sequence of 3D images of the same particle. Value range = 1 to infinity where 1 represents sphere.
W/L Aspect Ratio (2D) ** W/L Ratio (3D)	**W/L Aspect Ratio** ** = FWidth / FLength (2D)	**W/L Ratio** = FWidth / FLength (3D) = Maximum FWidth/ maximum FLength in the series of images	For 2D, FLength and FWidth are from one particle image. 3D uses from the sequence of 3D images of the same particle. Value range = 0 to 1 where 1 represents sphere.
L/W Ratio	**L/W Ratio** = FLength / FWidth	**L/W Ratio** = FLength / FWidth = Maximum FLength / maximum FWidth in the series of images	For 2D, FLength and FWidth are from one particle image. For 3D, FLength and FWidth are from the sequence of 3D images of the same particle. Value range = 1 to infinity where 1 represents sphere.
T/W Ratio	<u>*Not available*</u> in 2D.	**T/W Ratio** = FThickness / FWidth (3D) = Minimum FWidth / Maximum FWidth in the series of images	FThickness and FWidth from the sequence of 3D images of the same particle. Value range = 0 to 1 where 1 represents sphere.
W/T Ratio	<u>*Not available*</u> in 2D.	**W/T Ratio** = FWidth / FThickness (3D) = Maximum FWidth / Minimum FWidth in the series of images	FWidth and FThickness from the sequence of 3D images of the same particle. Value range = 1 to infinity where 1 represents sphere.
Extent	**Extent** = Area / (FLength x FWidth) (2D)	**Extent** = Area / (FLength x FThickness) (3D) = Area / (Maximum FLength x Minimum FWidth)	Value of 1 describes the degree to which the actual area takes up maximum possible area based on product of the two largest perpendicular dimensions.
Circularity**	**Circularity** = (4πArea/Perimeter)^2 = (Da / Dp)^2	Area = average Area of a sequence of 3D images Perimeter = average Perimeter of a sequence of 3D images	Measure of proximity to a circle. More sensitive, less robust, than Sphericity. Range of values 0 to 1 (value of 1 equals a perfect circle).
Sphericity**	**Sphericity** = 4πArea/Perimeter = Da / Dp	Area = average Area of a sequence of 3D images	Measure of the proximity to a circle Values range 0 to 1(value of 1 equals a perfect circle)

		Perimeter = average Perimeter of a sequence of 3D images	
Solidity	**Solidity** = Area / CHull Area	Area = average Area of a sequence of 3D images CHull Area = average Convex Hull Area	Measure of surface roughness, 0 to 1. Value of 1 describes very smooth surface. Ratio of area of the particle to the area of the convex hull.
Concavity	**Concavity** = (CHull Area – Area) / CHull Area	Area = average Area of a sequence of 3D images CHull Area = average Convex Hull Area	Measure of surface roughness, 0 to 1. In this case, a value of 1 describes an extremely rough, spikey surface
Convexity**	**Convexity** = CHull Perimeter / Perimeter	Perimeter = average Perimeter of a sequence of 3D images	Measure of surface roughness, 0 to 1 (smooth). As roughness increases, measures of circularity decrease.
Rectangularity	*Not available* in 2D.	Rectangularity = Maximum ratio of Area of image in 3D row divided by Area of maximum rectangle that can be inscribed within that image. (3D only)	Chosen when Cylinder calculation option is chosen under Particle Measurement in SOP. 
Angularity	First the outline is reduced to be expressed by a fewer number of points. Angle at each point is calculated, α_1, α_2 … α_n Change in angle at each point is calculated: $\beta_n = \alpha_n - \alpha_{n+1}$ Angularity Index is calculated, where e is 0, 10, 20 … 170 for class in $AI = \frac{\sum_{e=0}^{e=170} eP(e)}{n}$ Where $P(e)$ is the frequency of β_n in each interval 0-10, 10-20 … 170-180	**Reference:** Evaluation of Aggregate Imaging Techniques for the Quantification of Morphological Characteristics, Wang, Sun, Tutumluer, Druta (Paper Submitted August 1, 2012 for Presentation at the 2013 TRB Annual Meeting and Publication in the Transportation Research Record: Journal of the Transportation Research Board). **Uses:** Any material including aggregates used in and materials showing protrusions and sharp angles such as abrasives. **Range of values** 0 to 180. 180= many sharp edges. Value=0 for perfect circle.	 Particle shape, ***angularity***, and surface texture are critical properties in assessing aggregate usage for asphalt concrete. Fractured and flat and/or elongated particles are used in most specifications to assure quality.

Intensity Parameters

Intensity Parameter	Description
Transparency**	Transparency is the mean light intensity of the longest vertical line analyzed. The value is normalized to the range 0 to 1, with 0 being least transparent and 1 being the most transparent. See Particle Measurement section for more detail.
Curvature	The middle 50% of the line used to calculate Transparency (above) is fit to a parabolic function. The second order derivative of this function gives the Curvature value (concavity of the intensity gradient). On a scale of 0 to 1, any curvature values greater than 0.1 is very transparent, spherical particle.