

Abrasives: SYNC Diffraction Distributions, Image Analysis with Reference to Sharpness Determination of Abrasive Powders

Instrument: SYNC

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Application Note SL-AN-51 Rev. B

Introduction

Minerals are available in many forms. Some are mostly valued as gemstones while others are used for abrasives. An abrasive is a material that often is a mineral that reduces a surface by friction and rubbing. Some minerals that have good abrasive qualities include diamond, garnet, silicon dioxide, and aluminum oxide. Abrasives find use in all facets of life including chemical mechanical planarization manufacture of computer and DVR / CD discs, sandpaper, grinding wheels, cutting wheels, removing human skin blemishes and birthmarks, floor skidproofing, milling, toothpaste, kitchen and bathroom cleaners, hand cleaners, etc.

There are certain properties that make these materials applicable to being used as abrasives. Two of these properties are hardness and sharpness to reduce other surfaces. The third is toughness to withstand the abrading action when it ensues. The surface to be treated must have hardness less than the selected abrasive. High hardness is necessary to grind, polish or remove surface.

The materials used as abrasives are often acquired from mines and represent natural abrasives. These include garnet, diamond and aluminum oxide. Commonly the materials are synthetic in order to maintain supply and consistency of properties. Silicon carbide, diamond and alumina are a few examples of synthetic abrasives. Hardness is ascribed values by three primary scales: Mohs, Vickers and Knoop. Mohs is measured by determining which material will scratch another. Vickers and Knoop uses a shaped diamond to produce an indentation in a material. Vickers is primarily used for metals while the Knoop test was developed to measure brittle materials without damaging material or test material. Diamond represents the hardest material and the maximum values for each scale.

Table 1: Hardness values of selected abrasives

Material	Mohs	Vickers	Knoop
Industrial diamond	10	10000	8000
Corundum (nat. Alumina)	9	2200	1600 – 2100
Garnet	7-8	1100 – 1300	1300 -1350
Synthetic Diamond	10	10000	800 – 10000
Synthetic alumina	9	2200	2000 – 2600

This application note describes a short study on determining the characteristics of abrasives by using measurement of diffraction particle size distributions with simultaneous dynamic image analysis. Special significance is given to the use of various parameters available to define abrasive form / shape in context of sharpness of the particles by using a Krumbein Roundness calculation.

Size Measurement

Particle size is an integral part of the proper selection and use of an abrasive. Traditionally, the measurements have been made by sieves. However, sieve measurements are limited in capability to measure very small sizes and is subject to shape bias. Sizes for abrasives have a range from 6millimeters to as small as 6micrometers. Sizes smaller than 6 μ m are needed for special polishing. Typical measuring range of SYNC diffraction can span the range up to 0.020 to 4000 μ m using dry powder measurements. Measurements in fluids can be obtained over the range 0.020 to 2000 μ m. Diffraction measurements have become the most common means to obtain particle size distributions. It provides a quick, reliable measurement that is sensitive to changes and provides many values that can be used for characterizing materials.

Figures 1 and 2 show comparative graphs of many sizes of garnet abrasive measured using the Microtrac SYNC diffraction measurement. Plot were obtained using Microtrac FLEX software display capability. Percent passing data are displayed in order to demonstrate the sensitivity and resolving capability of the diffraction measurements. Distributions are volume (weight / mass) distributions since all particles have identical densities.

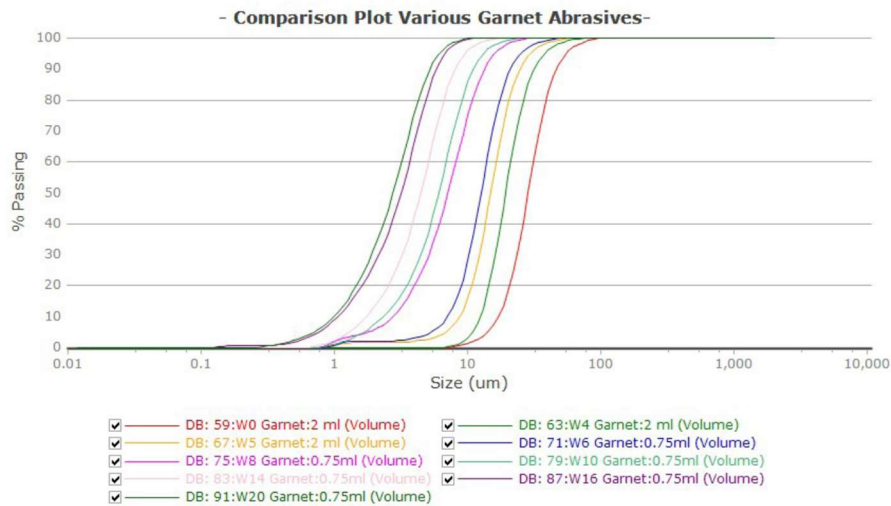


Fig. 1: Graph showing discrimination capability of the smaller size garnet

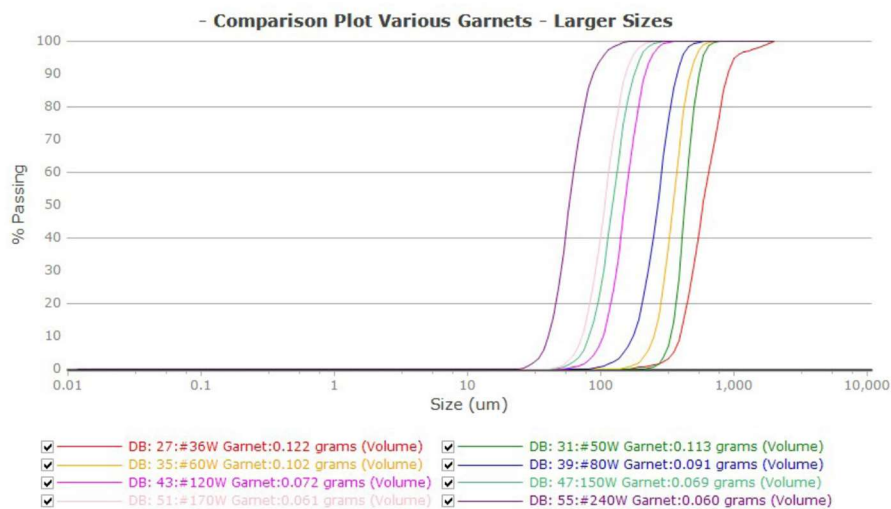


Fig. 2: Graph showing the discrimination capability of the larger size garnet

Sharpness and Shape Indicators of Abrasive by Dynamic Image Analysis (DIA)

As noted above, the shapes of the particles are important to the effectiveness of the abrading action of abrasives. Particle size is widely accepted as primary characteristic for abrasive activity. One particularly important shape consideration is sharpness. It is an indicator of the ability of a material to remove material from another surface. Asperity (roughness of the surface) affects wear rate of the under-treatment surface and effectiveness of the abrasive. It is well documented that a "particle size effect" whereby the wear rate decreases dramatically below a certain abrasive particle size. Sharpness is determined by procedures such as the SPQ (spike Parameter Quadratic) calculation and older methods.

One approach to understanding the shape and angularity of the abrasives which indicate abrasiveness capability is to compare microscopic or macroscopic images to those on a Krumbein chart as shown below (Fig. 3). Shapes are compared to those in the chart and a composite value is developed to indicate overall shape. The approach is limited due to the total number of items that can be included in the analysis suggesting statistical issues may enter into the final values. Figures 4 and 5 show Garnet 50W and Garnet 150W having very similar shape. Using such images, it would seem difficult to form useful decision as to the shape and any angularity of a given material.

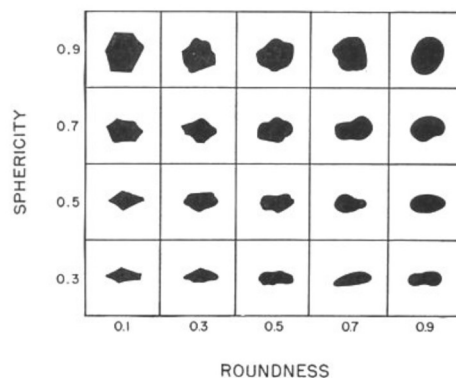


Fig. 3: Krumbein roundness chart

This visual chart can be used for estimating the roundness and sphericity of sand grains (from Krumbein, W.C., and Sloss, L.L., *Stratigraphy and Sedimentation*, 1956, Freeman and Company, San Francisco CA).

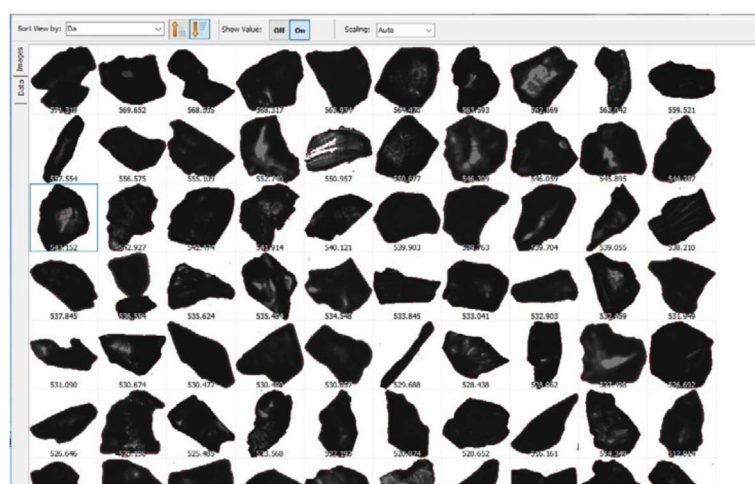


Fig. 4: Garnet 50 W – Images obtained using SYNC DIA measurement

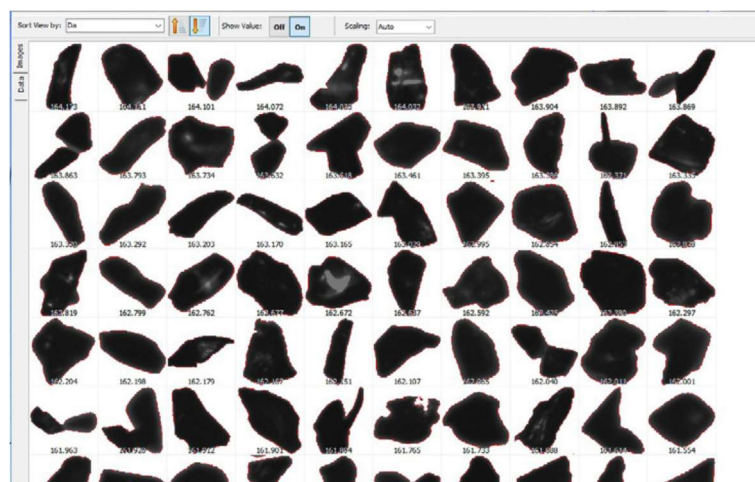


Fig. 5: Garnet 150W – Images obtained using SYNC DIA measurement

Image Analysis and Krumbein Calculations

Size difference for the two garnet materials is shown by the SYNC diffraction measurements above. These are data that are very important to the proper application of the abrasive. However, the characterization of application must include shape information as discussed above. The Krumbein chart above is a beginning, but with modern dynamic image analysis, more complete and statistically valid indication and qualification of the abrasive can be ascertained.

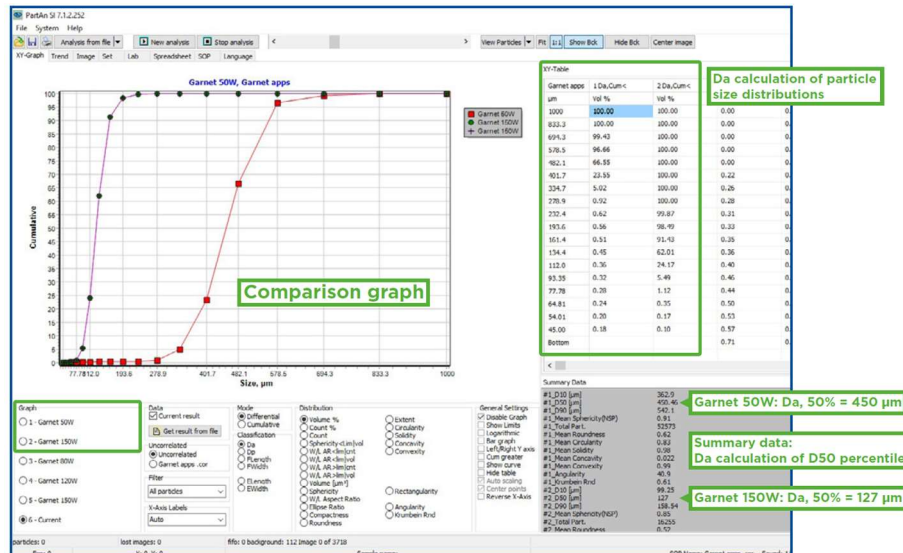


Fig. 6: SYNC image analysis computer display showing a comparison of the cumulative distribution for Garnet 50W and 150W

Figure 6 above shows comparison information for image analysis of garnet 50W and garnet 50W. The reported sizes calculated as Da are nearly identical to those calculated by SYNC laser diffraction shown in the previous diffraction figures. Figure 7 below, shows size comparison for 5 garnets used in this study and as used for the following graphic (Figure 8) for Krumbein distributions comparisons of the materials.

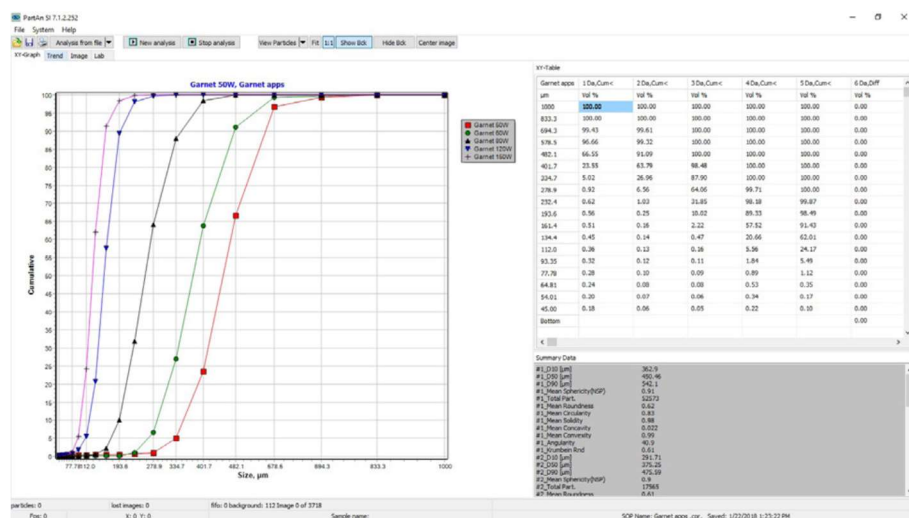


Fig. 7: SYNC image analysis computer display showing a comparison of the cumulative distributions for garnet abrasives in this study

The Krumbein calculation is used as a comparison to normally used form factors. For all materials, the Krumbein value describes the angularity for identification and characterization of the different grades of the materials. The size by both diffraction and image analysis is valuable for determining the use as a polishing, water jet or blasting. Within this type of grouping, differences can be ascribed to the materials and provide sensitivity and thus high accuracy for the characterization.

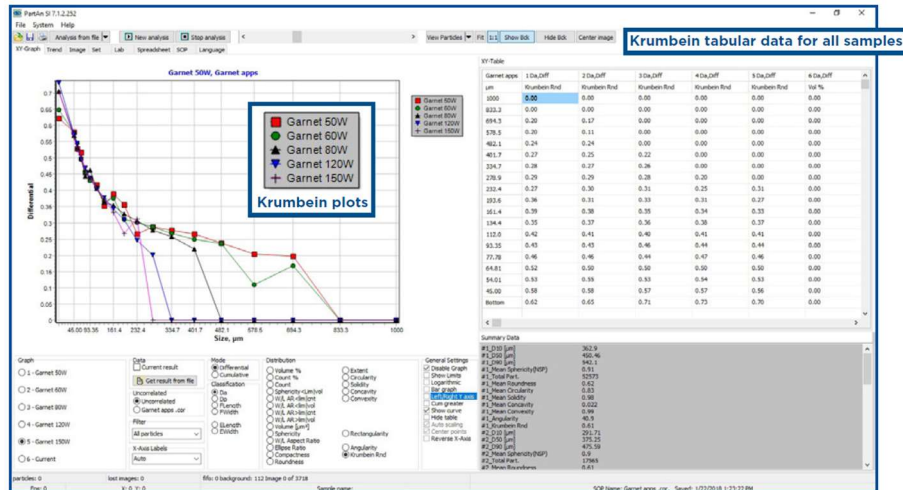


Fig. 8: SYNC Image analysis calculation and comparison of Krumbein distributions calculated for the garnets in Figure 7. This information contributes to the full characterization of the garnets and correct application of the material.

Knowledge of all particles in the distribution is important to selecting the proper distribution. In the present application, the weight (volume) distribution is important since materials are handled, weighed and evaluated on the volume basis. Even sieve measurements use weight as the means to assign size / volume information. Only in rare situations would the number distribution be used. The small particles are a consequence of particles attached to the large particles and finally being released by the sample preparation. The fines are typically produced during grinding and processing.

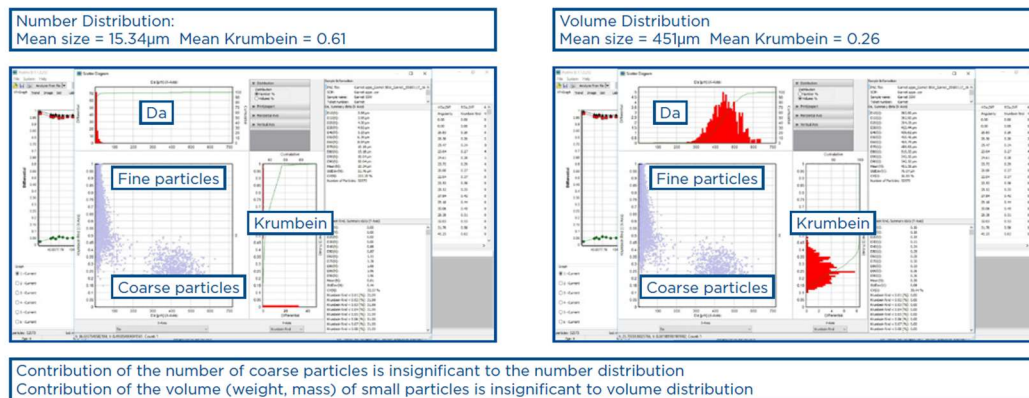


Fig. 9: Scatter Diagram shown in blue displays all particles individually. Data available as number or volume distributions. The choice influences summary data. Volume distributions are normally used for consideration of weight or mass as one would use in any industrial process. Many small particles are required to match the volume of one large particle. Thus, the distributions are very different.

Angularity (see image analysis plots below) may provide better indication of sharpness than Krumbein. This results because angularity takes into account all pointed edges for particles, while Krumbein is more limited. Krumbein is more limited due to limited ability to fit or squeeze the “circles: into all angular site”. Data for both Krumbein and angularity are presented for evaluation. While the trend is opposite, it must be realized that the purpose and calculation of each is different and thus have different capabilities to show certain particle shape features.

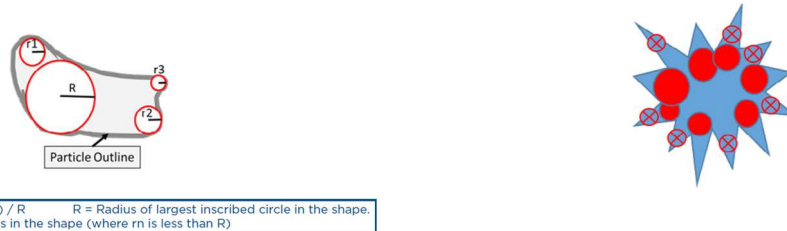


Fig. 10: Krumbein calculation cannot include all angles as shown by the “x” in the diagram. Angularity will include all angles in the calculation.

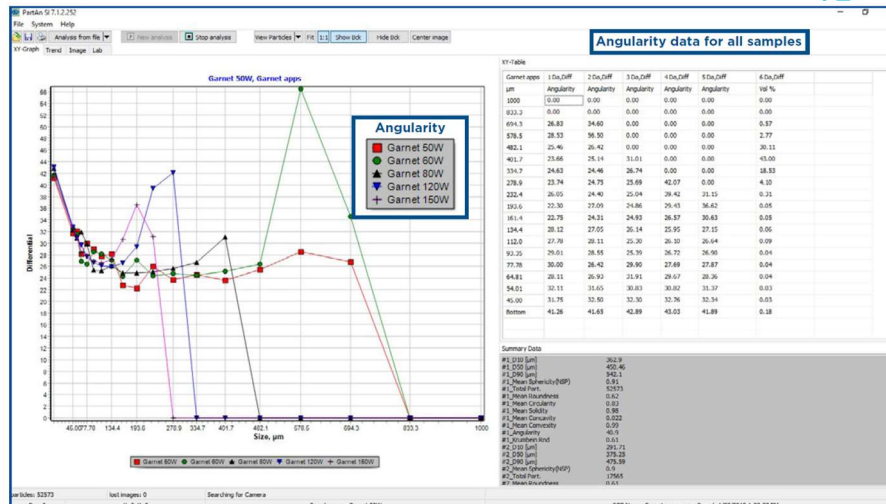


Fig 11: SYNC image analysis calculation and comparison of Angularity distributions calculated for garnets in Fig. 7. This information may provide better, more sensitive analysis than Krumbein.

Roundness is often used to establish the sharpness of abrasives. As shown in the table, this value often does not provide enough separation among the values to easily provide characterization data. Krumbein Roundness does provide that separation and thus much greater sensitivity and discrimination. This is observable with all three materials, but especially with diamond and alumina.

The information in Table 2 (below) provides support that the combination of diffraction particle size measurements and image analysis work together to promote a fuller characterization of the abrasives than size alone or size in combination with Krumbein chart estimates. There are several other shapes or forms shown for comparison. Often these other parameters can be used to segregate the materials according to angular features present in a material. However, except for angularity and Krumbein, evaluation of the above data by this approach may not fully discriminate the materials with a maximum sensitivity or be effective in demonstrating differences in shapes that address angles in materials. In some of the above situations, this can be demonstrated, but the difference in other cases is not pronounced and can lead to indecisive conclusions.

Table 2. SYNC Volume distribution data. Diffraction and Image analysis data for all samples measured in this study.

Color Code	Typically used for water jet. Tend to be finer. If alluvial, may be more round than those used for blast. Some lapping and polishing.				Typically used for blasting. Tend to be larger than water jet. Good for cutting tools. Often alluvial if a garnet.			Small size. Typically used for polishing and lapping operations. Small size and more angles (greater sharpness).	
Material	SYNC Diffraction D50 (µm)	SYNC Imaging Da D50 (µm)	Circularity	Solidity	Angularity	Convexity	Roundness	Krumbein	Angularity – lower values, more smooth Krumbein – lower values, less smooth They progress in opposite direction.
Garnet 150W	120	127	0.70	0.94	27.4	0.96	0.52	0.40	Garnet: As the particles become larger, the Krumbein value decreases and angularity increase as determined by image analysis.
Garnet 120W	151	155	0.69	0.94	26.9	0.96	0.52	0.37	
Garnet 80W	254	256	0.68	0.93	25.5	0.95	0.51	0.30	
Garnet 60W	357	375	0.68	0.94	25.1	0.95	0.51	0.27	
Garnet 50W	433	450	0.69	0.94	24.6	0.95	0.53	0.26	
Nom. 15um diamond	12	13	0.89	0.97	51.9	0.99	0.72	0.88	Diamond: Krumbein and angularity provide best evaluation and sensitivity to differences. Krumbein "tracks" differences and provides sensitivity (differences that are large to make differentiation easy). Other parameters do not provide distinguishing values available with Krumbein.
Nom. 20um diamond	16	18	0.89	0.98	45.1	0.99	0.72	0.83	
Nom. 30um diamond	27	29	0.88	0.98	37.4	0.98	0.73	0.72	
Coarse diamond	265	275	0.88	0.99	23.9	0.97	0.79	0.31	
Alumina Fused No.4	19	21	0.84	0.97	43.6	0.98	0.64	0.78	Alumina: Krumbein and angularity provides best evaluation and sensitivity to differences.
Alumina Fused No.5	34	39	0.82	0.97	34.9	0.98	0.63	0.64	
Alumina Fused No.6	68	73	0.81	0.97	31.9	0.98	0.61	0.51	

Comments: Circularity: 0 to 1. Value of 1 for perfect circle/sphere; Solidity: 0 to 1. Value of 1 very smooth; Convexity: 0 to 1. Value of 1 very smooth; Roundness: 0 to 1. Value of 1 circle or sphere; Krumbein Roundness : 0 to 1. Value of 1 perfect circle. Angularity: 0 to 180. 180 is very "spiky" similar to saw blade, 0 is very smooth

Summary

The effort to characterize sharpness is an on-going topic of consideration and research. Many methods are available for sharpness characterization, but usually these can be timeconsuming, lack sensitivity or require extensive groundwork to satisfactorily perform the analysis. The present short study, shows a potential method to obtaining the needed data on sharpness as it pertains to particles, specifically abrasives where this characteristic is a major contributor to effectiveness and durability. Use of diffraction measurements allows the opportunity to maintain present specifications and quality standards. The additional Krumbein calculation provides information available from image analysis. The value adds significantly to the characterization of materials used as abrasives and specifically sharpness.

SYNC measurement provides a unique measurement system that allows both diffraction and image analysis to be performed on the identical sample. This avoids any issues that can occur that are related to representative sampling as required when more than one instrument technology is needed by separate instruments.

Particles as large as 1/4 inch can be encountered when processing as mentioned previously. Particles of that size are not within the common measuring range of SYNC or any other laser diffraction instrument. However, Microtrac has available imaging instruments capable of measuring the very largest particles (patented 3 dimensional imaging) up to 5 inches for laboratory and in-line measurements.

For further information please contact us at:

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