PARTICLE SIZE AND SHAPE CHARACTERIZATION OF ABRASIVES

Many abrasives are either natural or synthetic minerals used to shape or finish a work piece through rubbing which leads to part of the piece being worn away. They are used in a wide range of domestic and industrial applications, giving rise to a wide range of chemical composition, physical size, and shape of the abrasive material. This study utilizes automated image analysis to quantify the size and shape of various abrasive materials.

Introduction

Abrasive minerals typically rely on a difference between the hardness of the abrasive and the material being worked upon, with the abrasive being the harder substance. Most are natural or synthetic minerals rated 7 or above on the Mohs scale of hardness. These minerals are either classified or crushed to a specified size ranging from around 10 µm to 2 mm. These particles called grit typically have rough edges (see Figure 1) in order to decrease the surface area in contact with the work piece and increase the localized contact pressure. Factors that influence the rate of abrasion include:

- The difference in hardness between the abrasive and work piece
- The size of the particles (grit size); larger particles cut faster and deeper
- The shape of the particles, including the number of rough corners
- The contact force applied to the process

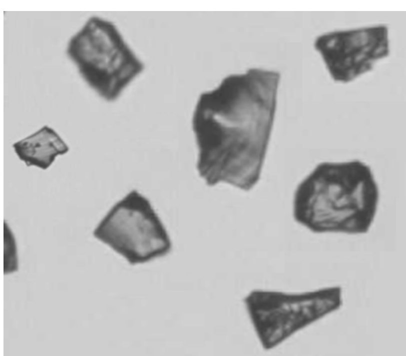


Figure1: Abrasive Particles

Common abrasive materials include sand, garnet, diamond (synthetic), silicon carbide, aluminum oxide, boron nitride, ceramic materials, zirconia alumina, and many others.
The grit size is a number used to describe the number of openings per linear inch in a sieve to classify the particle size. Low grit numbers are coarser and higher grit numbers are finer.

Experimental

Several abrasive powder samples were analyzed for particle size and shape using the PSA300 image analyzer. The samples are designated small, medium, and large. The small and medium samples are typical mineral abrasives and the large is synthetic diamonds. These samples were prepared using the Sample Disperser (Figure 3) and analyzed using the Horiba PSA300 (Figure 2). The small sample was measured using the 200x objective and the medium and large samples were measured using the 25x objective.

Figure 2: The PSA300

Figure 3: Sample Disperser

Settings used for the Sample Disperser are shown below:

Vacuum = 200 Torr
Time = 250 ms

Particle Size and Shape Parameters

The PSA300 quantifies particle size and shape using a variety of descriptive parameters. After preliminary studies on a few samples the following size and shape values were chosen for these abrasive samples:

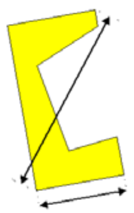
Value	Definition
Spherical Volume	Median particle size based on the volume distribution assuming particles are spheres*

$$V_{sph} = \frac{\pi}{6}\text{Circular diameter}^3$$

Circle Diameter = $\text{Mean chord} \times 1.27324$

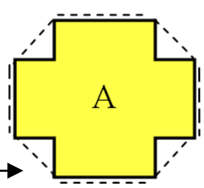
*Note: The PSA300 software can also construct the volume assuming other particle shapes including cylindrical, ellipsoidal, and tetragonal.

Roundness	4 x Area/(π x L x L) A sphere has a roundness value of 1.0. This value decreases (.9, .8, .7, etc.) as the particles become less spherical
Aspect Ratio	Longest Feret Length / Shortest Feret Length



Compactness	4 π Area/ Convex Perimeter²

A = Area



Convex Perimeter

In addition, a custom Angularity Roundness calculation was created to characterize abrasive particles. The number of sharp tips can be an indicator of abrasive effectiveness. This calculation counts the sharp tips on particles, and then weights the calculation including information about the particle roundness to emphasize sharp edges protruding from a round particle. The edges are defined and labeled as child objects. The Angularity Roundness is then calculated as:

Value	Definition
Angularity Roundness	roundness x child area

Results

Table 1 below shows the results for the three abrasive samples as described by the chosen size and shape descriptors. Note: Vol = spherical volume distribution, Round = Roundness, Comp = Compactness, AR = Aspect Ratio, Ang = Angularity Roundness. All shape descriptor values are reported on a count basis.

Sample	Vol	Round	Comp	AR	Ang
Small	(µm)				
d10	16	0.5	0.8	1.1	1.2
d50	38.8	0.7	0.9	1.3	2.3
d90	63.1	0.9	0.9	1.8	3.6
Medium					
d10	140	0.3	0.5	1.2	1
d50	211.8	0.5	0.7	1.6	1.9
d90	319.9	0.7	0.8	2.5	3.3
Large					
d10	332.9	0.6	0.7	1.1	2.1
d50	375.2	0.7	0.8	1.3	3.4
d90	421.4	0.8	0.9	1.5	5

Table 1: Size and shape results for abrasives

The following images provide an intuitive understanding of the function of the Angularity Roundness calculation and value to scientists studying abrasives.

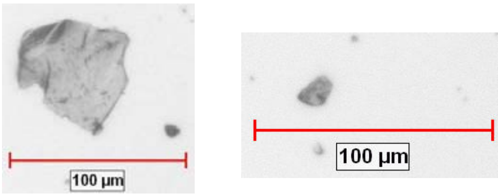


Figure 4: Small abrasive, high angularity (left), low angularity (right)

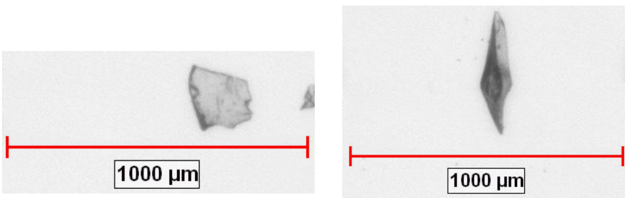


Figure 5: Medium abrasive, high angularity (left), low angularity (right)

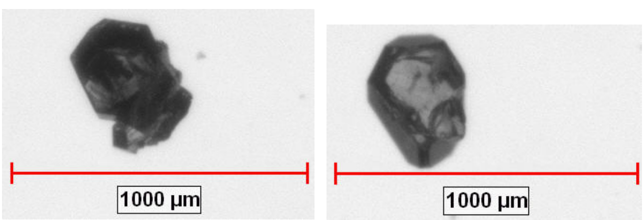


Figure 6: Large abrasive, high angularity (left), low angularity (right)

Conclusions

The PSA300 proved capable of defining the size and shape differences between the abrasive samples in this study. All of the selected shape parameters were able to provide information about abrasive morphology, but the Angularity Roundness value holds the most promise for correlating to abrasive effectiveness. This calculation is unique to the PSA300 and can only be defined when using the powerful features found in the Clemex software. Particle size and shape analysis characterization by automatic image analysis can be a valuable tool for the abrasives industry.

For further information on this document or our products, please contact:
HORIBA Instruments, Inc.
17671 Armstrong Ave.
Irvine, CA 92614 USA
1-800-446-7422
www.horibalab.com
labinfo@horiba.com