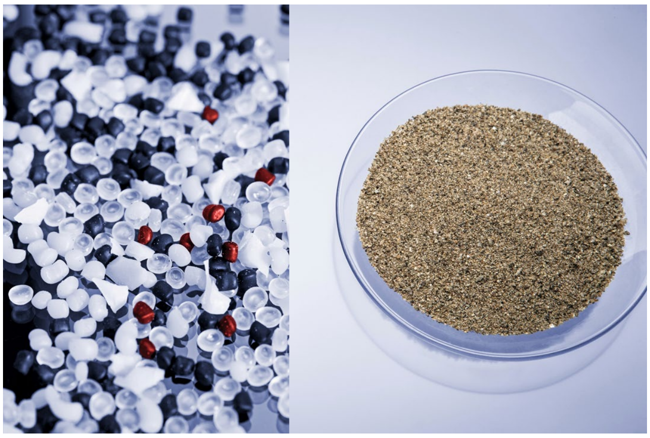
Full Blast: Monitoring of Size and Shape of Abrasive Materials

Relevant for: Abrasives, Corundum, Glass beads, Dynamic Image Analysis, Size and Shape Analysis

Abrasives are important components when changing appearance and texture in the finishing process of a workpiece. The size and shape of the abrasive's particles play a key role in the deburring, making them crucial parameters to control. With Litesizer DIA 500, high-quality shape and size distributions are obtained within a few seconds even for challenging samples.



1 Introduction

Abrasives are materials that are used to create friction in the finishing process of a workpiece. In 2020, the abrasives had a market value of more than USD 30 billion (1). There are numerous types of abrasive and deburring systems available for both industrial and domestic applications as briefly discussed below.

1.1 Barrel Tumbling Systems

Tumble finishing is a process used to deburr, polish, and smooth the surface of metallic, plastic, or ceramic components. It involves placing the parts in a rotating barrel along with a solid abrasive, and a liquid lubricant (usually water). As the barrel rotates, the media continuously rubs against the parts, removing any burrs or imperfections and leaving them with a smooth, polished surface. The process can take several hours or days depending on the desired level of finish.

1.2 Sandblasting Systems

Sandblasting is a process that involves the use of high-pressure air or water mixed with small, abrasive particles to remove surface coatings, contaminants, or texture a surface. The blasting medium, which might include metal shots, corundum, glass beads, or plastic, determines the aggressiveness of this procedure.

The appropriate deburring system is determined by the intended application and material. Abrasives can be made from a variety of metals, ceramics, and polymers, and their hardness, size, and shape all have an impact on the ultimate abrasive performance. A description of some abrasive types and their use is given in Table 1.

Abrasive type	Description
Stainless steel shot pins	Used in metal tumbling and are most suitable for brass, aluminum, and steel parts (2). The great advantage of this tumbling media is that they are magnetic, making their separation easy.
Corundum	Common blasting media with high hardness and strength. It is suitable for almost any type of surface, such as metal, glass, and wood.
Glass beads	Not as aggressive as the above blasting media, thus they are suitable for a soft finish.
Plastic abrasives	It is also a less aggressive blasting media and is commonly used in the removal and cleaning of anti-corrosion coatings, hydrocarbon deposits, waxes, adhesives, and sealants.

Table 1: Evaluated abrasive types and their description (3)

Larger particles have a stronger impact on the surface of the material, resulting in faster abrasion. In terms of shape, irregular particles with pointy edges will abrade more than spherical particles. Here, several abrasive materials used for metal tumbling and surface blasting were evaluated with Litesizer DIA 500 – the Anton Paar Dynamic Image Analyzer (Figure 1).

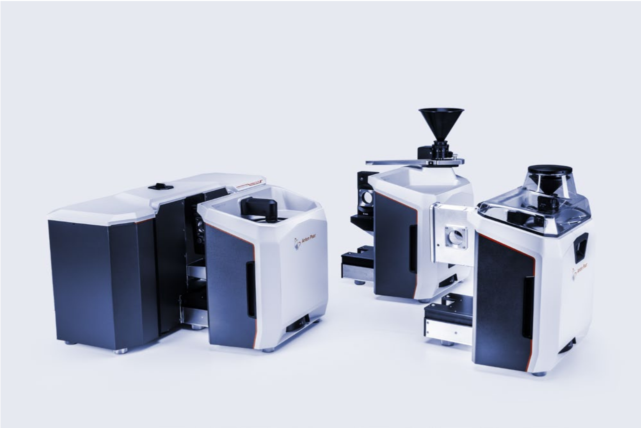


Figure 1: Litesizer DIA 500 Particle Analyzer and its three dispersion units: Liquid Flow, Free Fall, and Dry Jet (from left to right)

2 Experimental

The abrasive samples were analyzed with Litesizer DIA 500 equipped with the Free Fall dispersion unit (Figure 2), which is the ideally suited dispersion unit for dry free-flowing materials.

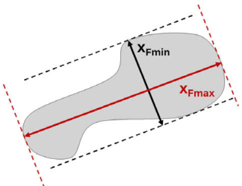
Figure 2: Free Fall dispersion unit

Four different abrasive types with a wide variety in size and shape were evaluated (Figure 3). Except for the stainless steel shot pins, which were tested using a measuring range of 10-8000 µm, the different classes of the abrasive materials were evaluated with two separate magnification modes, i.e., 0.8-300 µm and 10-8000 µm ranges. Both ranges are available with an automatic switch between objectives and an automatic merge of results is possible.

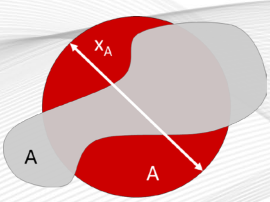
Figure 3: Representative samples of the analyzed abrasives: stainless steel shot pins, corundum, glass beads, and plastic

3 Results and Discussion

Different size models can be used to describe a particle, e.g., the Feret diameter, which is the distance between two planes parallel and tangent to the contour of the particle. The minimum and maximum distances between these planes are named minimum and maximum Feret diameter (x_{Fmin} and x_{Fmax}), respectively.



Another relevant size model is the projected area equivalent diameter (x_A), which represents the diameter of a sphere with the same projected area (A) as the particle's projection.



$$A=\pi r^2 = \frac{\pi x_A^2}{4}$$

$$x_A=\sqrt{\frac{4A}{\pi}}$$

3.1 Stainless steel shot pins

Two samples of the stainless steel shot pins were evaluated: fresh (pin_new) and worn (pin_used). The size distribution of both samples shows a single sharp peak, which is expected for such a homogeneous material (Figure 4).

The size models x_{Fmin} and x_{Fmax} were used to evaluate the difference between the new and used samples. As the shot pins are used in the tumbling process, they gradually wear away. Thus, a decrease in their thickness (x_{Fmin})and length (x_{Fmax}) is observed (Figure 5 and Table 2). The comparison of the relative decrease in size (Table 2) shows that the relative decrease of x_{Fmin} is higher than the relative decrease of x_{Fmax}. This observation is mirrored in one single shape parameter, the aspect ratio (Figure 5 and Table 2). Here, the value decreases when new and used shot pins are compared. As the pointy edges are one of the main characteristics of the high performance of this abrasive, the control of the particles' size is helpful in quality control.

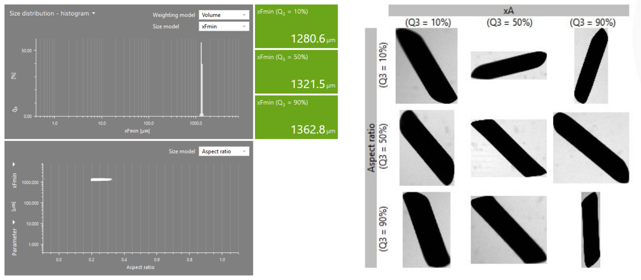


Figure 4: Measurement Results View of a stainless steel shot pin

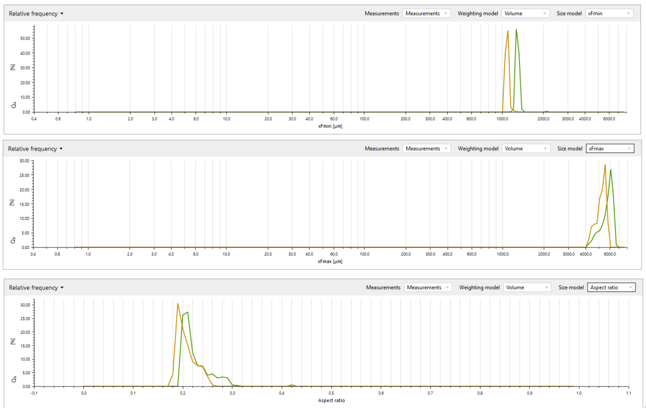


Figure 5: : Comparison of the particles' size, x_{Fmin} (top), x_{Fmax} (middle) and aspect ratio (bottom), between new (green) and used (yellow) stainless steel shot pins.

Even though experienced workers often visually estimate the lifetime of these pins, it is clear from the measured size distribution of over 400 particles that the worn material is thinner and less elongated when compared to the fresh one. Thus, an accurate and unbiased decision on the pins' replacement could be done within a few seconds with Litesizer DIA 500 allowing full control of the lifecycle of such an abrasive medium.

3.2 Corundum

Five different corundum samples, ranging from 30 µm to 2000 µm, were evaluated with both magnification modes (Standard and Zoom). All of them showed a monomodal volume-weighted size distribution (Figure 6). Interestingly, even though there is a significant deviation in particle size between the samples (Figure 7, top), they have a similar shape distribution, as shown by the circularity results (Figure 7, bottom).

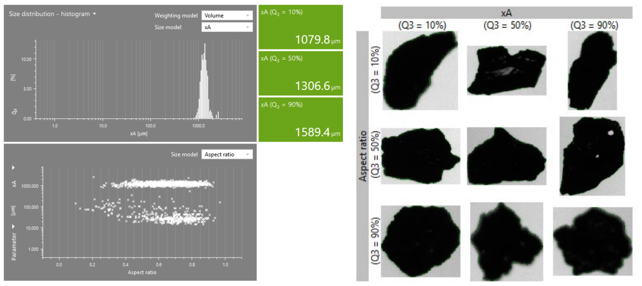


Figure 6: Measurement Results View of a corundum sample

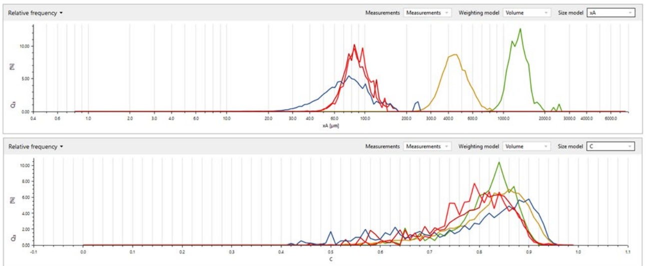
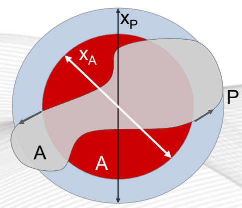


Figure 7: Size (x_A, top) and shape (circularity, bottom) distribution of corundum samples

Circularity is the degree to which the particle (or its projection area) is similar to a circle, considering the smoothness of the perimeter (P).



$$C = \sqrt{\frac{4\pi A}{P^2}}$$

$$C = \frac{x_A}{x_P}$$

Besides the circularity, it is possible to evaluate up to 17 size- and shape parameters in the measurement analysis. The range of the parameters can be adjusted by the user (Figure 8) and the results can be

Sample	Size (volume-weighted): x_{Fmin}				Size (volume-weighted): x_{Fmax}				Shape (volume-weighted): Aspect ratio			
	Q_{10}	Q_{50}	Q_{90}	Mean size	Q_{10}	Q_{50}	Q_{90}	Mean size	Q_{10}	Q_{50}	Q_{90}	Mean size
Pin_new	1280.6 µm	1321.5 µm	1362.8 µm	1321.6 µm	4935.0 µm	6009.3 µm	6415.1 µm	5841.4 µm	0.204	0.219	0.271	0.229
Pin_used	1085.0 µm	1112.0 µm	1143.9 µm	1143.9 µm	4611.5 µm	5397.7 µm	5297.0 µm	5297.0 µm	0.192	0.207	0.243	0.213
Relative decrease	15.3%	15.9%	16.1%	15.2%	6.6%	10.2%	17.4%	9.3%	5.9%	5.5%	10.3%	6.9%

Table 2: Particle size results for the stainless steel pins

recalculated also after the measurement is finished if necessary. Also, specific ranges can be set as default parameters for quality control and the creation of user-defined methods.

In the case of the corundum samples, the change to a number-weighted distribution allows clear visualization of the fine particles. The fine materials produced when the abrasives are broken down during the blasting process produce dust particles that may be hazardous to the ecosystem as well as the human body. Therefore, it is crucial to regulate the particle size of abrasives.

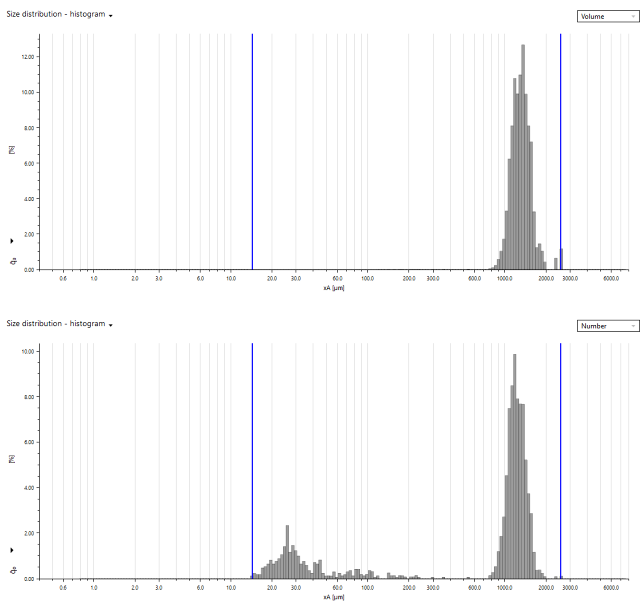


Figure 8: Volume- (top) and number-weighted (bottom) size distribution of a corundum sample

3.3 Glass beads

Three different glass beads samples, ranging from 40 µm to 2000 µm, were evaluated with both magnification modes (Standard and Zoom) and had a monomodal volume-weighted size distribution (Figure 9).

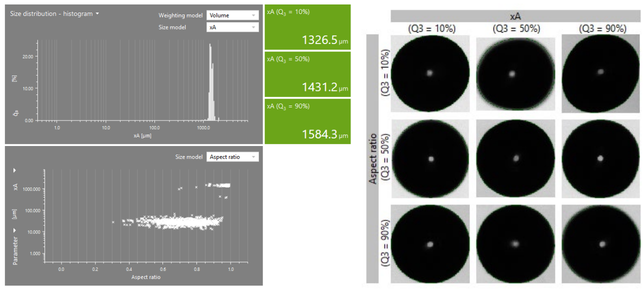


Figure 9: Measurement Results View of a glass bead sample

As observed for the corundum, the glass beads also varied significantly in size but showed a similar circularity distribution (Figure 10). Due to more regular (spherical) and homogeneous particles, the shape analysis, accessed by circularity, shows a sharp peak close to 1. As the samples are used in the deburring, they may break and gradually accumulate a fine fraction. These changes can be easily tracked by the size and shape distributions.

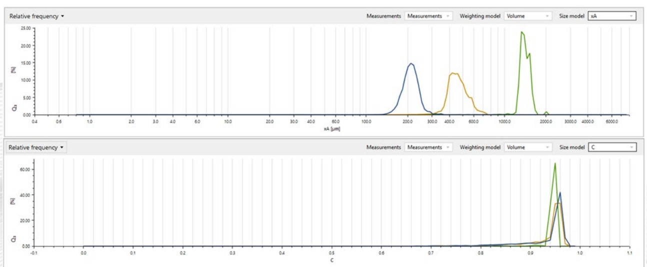


Figure 10: Size (x_A, top) and shape (circularity, bottom) distribution of glass beads samples

3.4 Plastic

Four plastic abrasives, ranging from 200 µm to 2000 µm, were analyzed with the Standard magnification. Once more, all of the samples showed a monomodal volume-weighted size distribution (Figure 11) with similar circularity (Figure 12).

Due to their irregular shape, the particles of the plastic abrasive had a broad circularity distribution. As discussed for the previous blasting media (corundum and glass beads), the analysis of the fine particles by the number-based distribution is crucial to monitor the potentially harmful dust that is formed during blasting.

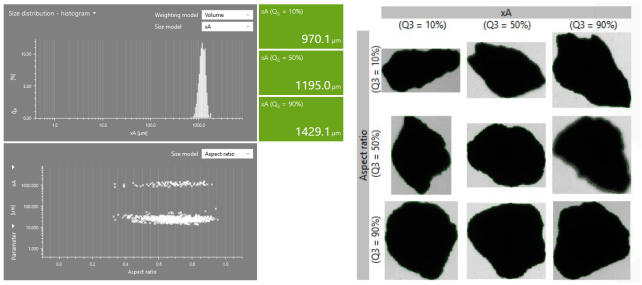


Figure 11: Measurement Results View of a plastic abrasive sample

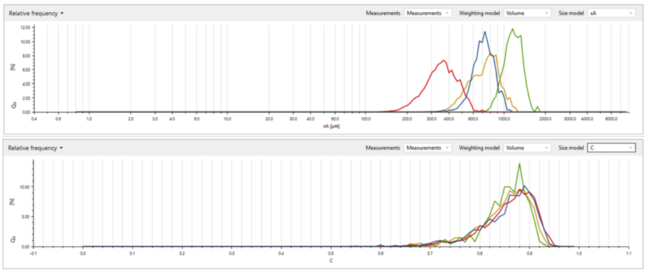


Figure 12: Size (x_A, top) and shape (circularity, bottom) distribution of plastic abrasive samples

4 Summary

The choice of a suitable deburring system heavily relies on the nature, size, and shape of the abrasive materials that are used. Thus, quick and high-quality size and shape distributions are crucial for ensuring deburring performance. Also, when the abrasive particles break during the blasting process, fine materials are created, and these dust particles may be harmful to both the environment and the human body. Therefore, it is essential to control the abrasives' particulate size. Here, different abrasive types used for metal tumbling and abrasive blasting were analyzed by Dynamic Image Analysis with Litesizer DIA 500. All the samples showed a monomodal volume-weighted size distribution and the fine fraction was easily visualized by number-weighted distribution. The shape of the particles was primarily assessed by circularity, which can be used to predict contamination and monitor the wear of abrasive materials.

5 References

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