# Size and Shape of Metal Powders for Additive Manufacturing / Rapid Prototyping / Selective Laser Sintering / 3D Printing

Instrument: CAMSIZER X2

## Application

The term “Additive Manufacturing” describes a process in which digital 3D design data, typically generated by CAD, are used to build a component layer by layer by depositing material. Additive Manufacturing, also widely known as “3D printing”, is a red-hot topic for R&D departments and small-scale production companies alike. Many manufacturers offer 3D printers or systems for Additive Manufacturing based on a variety of technologies and materials, for example in automotive, aerospace, defense, food, jewelry, medicine, and many other industries. Some of these methods have matured from a development tool for rapid prototyping to a standard production method. The basis for most of the above-mentioned processes is a powder bed on which material is sequentially deposited. Depending on the desired specifications of the 3D components, different types of powders are employed in the printing process. The particle size distribution and shape of the powders is a critical parameter for the operating conditions of the printer and for the properties of the final product. The size distribution (average size, as well as the amount of dust and the number of oversized particles) but also the shape of the particles has a strong influence on the flow behaviour of the powders. Generally, round particles within a narrow size range are preferred as they flow more easily and can be deposited more homogeneously. On the other hand, if the size range is too narrow, the packing density of the powder decreases which can generate voids and inhomogeneities in the final component. Oversized particles may cause defects in the thin layer of the powder and in the structure of the finished component. Small particles, for example, melt faster than larger particles but contain more oxide due to their relatively large surface area. The oxide content changes the material properties which characterize pure metals, for example melting temperature, conductivity etc.

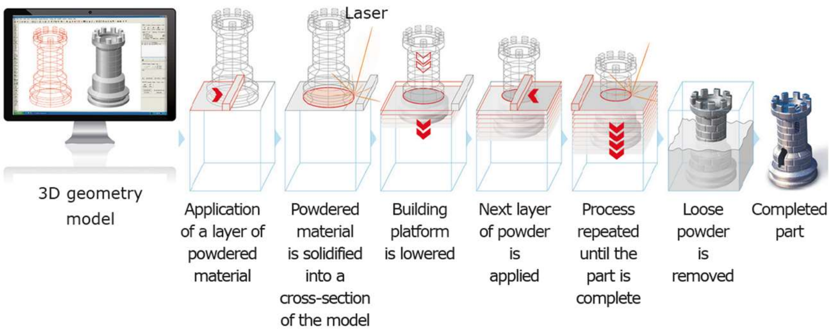


***Fig. 1:*** *Schematic of the additive manufacturing process (Source: www.eos.info).*

| Type | Technologies | Materials |
|---|---|---|
| **Extrusion** | Fused Deposition Modeling (FDM) or Fused Filament Fabrication (FFF) | Thermoplastics, eutectic metals, edible materials, rubbers, modeling clay, plasticine, metal clay (including precious metal clay) |
| | Robocasting or Direct Ink Writing (DIW) | Ceramic materials, metal alloy, cement, metal matrix composite, ceramic matrix composite |
| **Light polymerised** | Stereolithography (SLA) | Photopolymer |
| | Digital Light Processing (DLP) | Photopolymer |
| **Powder bed** | Powder bed and ink jet head 3D printing (3DP) | Almost any metal alloy, powdered polymers, plaster |
| | Electrom-beam melting (EBM) | Almost any metal alloy including titanium alloys |
| | Selective laser melting (SLM) | Titanium alloys, cobalt chrome alloys, stainless steel, aluminum |
| | Selective heat sintering (SHS) | Thermoplastic powder |
| | Selective laser sintering (SLS) | Thermoplastics, metal powders, ceramic powders |
| | Direct metal laser sintering (DMLS) | Almost any metal alloy |
| **Laminated** | Laminated object manufacturing (LOM) | Paper, metal foil, plastic film |
| **Wire** | Electron beam freeform fabrication (EBF) | Almost any metal alloy |

***Fig. 2:*** *Overview of the most commonly used 3D printing technologies (Source: Wikipedia)*

The cost for the raw powder materials is an important factor in the manufacturing process. Only a very small amount of the powder forms the component. The rest of the powder bed, which has not been sintered, is recycled. The used material however may contain an unwanted amount of oversized, fused particles. Also, the shape of the particles could be different from the original powder. It might be necessary to screen the recycled powder to remove the oversized particles and blend it with fresh powder. Therefore, it is essential to check the quality of the recycled powders.

The CAMSIZER X2 is the perfect tool to analyze the particle size and shape of these powders, thus characterizing the raw material in the most comprehensive way. Even smallest amounts (<0.01%) of out-of-spec particles are detected. This ensures consistent quality of the manufactured products.

  

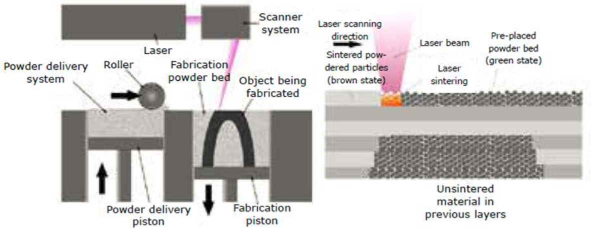


***Fig. 3:*** *Schematic of selective laser sintering (Source: Wikipedia)*

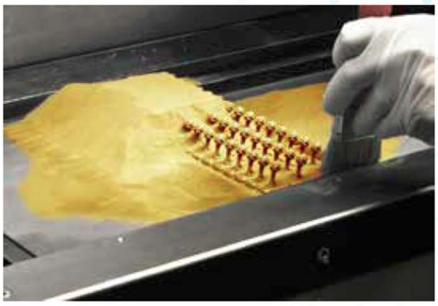

***Fig. 4:*** *Using gold powder to produce jewelry by additive manufacturing. (Source: want.nl)*

## Typical sample materials

The following metal powders can conveniently be analyzed with the CAMSIZER X2 (Fig. 6): aluminum, cobalt, chromium, inconel, manganese, molybdenum, nickel, steel, titanium, tungsten, silver, gold and respective alloys. The best approach is to use dry dispersion with the X-Jet module (Fig. 5) at a moderate dispersion pressure of 20 kPa.

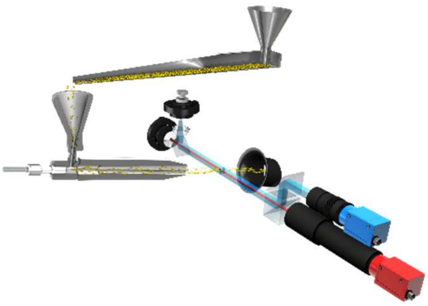

***Fig. 5:*** *The X-Jet dry dispersion module of the CAMSIZER X2 guarantees effective, yet gentle dispersion. Particles are measured in an air flow*

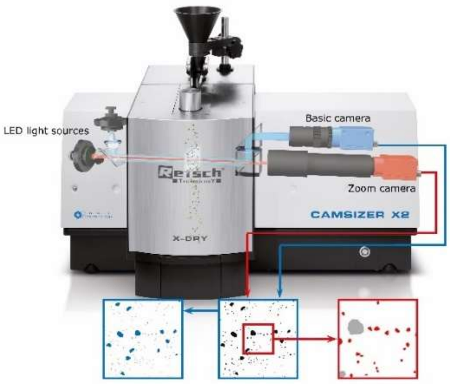


***Fig. 6:*** *CAMSIZER X2 dynamic image analyser with dual camera technology*

## Example 1: Comparison of laser diffraction and CAMSIZER X2

In the past, particle size analysis of metal powders was typically done by sieve analysis or laser diffraction. However, the method of Dynamic Image Analysis (DIA) allows a better understanding of the material properties, as length and width of the particles are detected independently. In contrast, laser diffraction analyzers calculate only one “size” parameter. The calculation algorithms of the laser instruments, irrespective of the brand or model, are based on a simple sphere model. The real shape of the particles is ignored and only the "equivalent diameter" is calculated. For irregularly shaped particles, laser diffraction analyzers often mix and misinterpret the data obtained from particle length and particle diameter, thus overestimating the percentage of large particles and pretending a wide size distribution.

Smallest amounts of oversized material, even below 0.01% Vol., are reliably detected by the CAMSIZER X2 as the measurement principle is based on the detection of individual particles in thousands of pictures per measurement. If a particle is captured, then the data of this particle is included in the measurement result, even if there is only one particle of a particular size and shape in the whole sample ("needle in a haystack").

Laser diffraction analyzers detect an averaged scattering signal from all particles simultaneously. Small quantities of oversize or undersize particles are only included in the results if the amount of these particles exceeds the detection limit of typically about 2% Vol. Below this limit the signal is treated as noise and ignored by the software. Consequently, a laser diffraction analyzer does not detect oversized particles safely and reliably. Both sieve analysis and CAMSIZER X2 offer much better sensitivity.

  

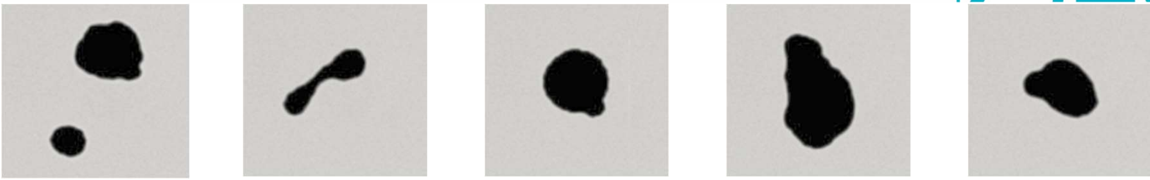

***Fig. 5:*** *Typical CAMSIZER X2 images of irregularly shaped metal particles of different sizes.*

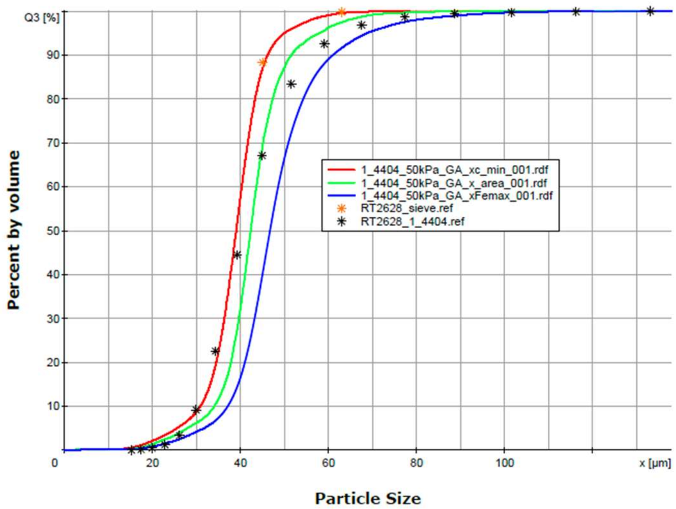


***Fig. 6:*** *The CAMSIZER X2 provides information on particle width (**red**), particle length (**blue**) and the equivalent circle diameter (**green**). The $x_{50}$ value of the latter is usually more or less similar to the measurement of the laser particle analyzer (**black ***). The laser diffraction analyzer and the CAMSIZER X2 width measurement show a similar distribution for small particles. The percentage of oversize particles detected by the CAMSIZER X2 is in very good agreement with the results of sieve analysis. (orange *) whereas the laser sizer calculates too many large particles compared sieve analysis.*

## Example 2: Titanium and steel powder

Titanium powder is used, for example, in the aerospace industry. Our example shows two sets of measurements of two powders with different size distribution. The CAMSIZER X2 measurements demonstrate excellent reproducibility and agreement with sieve analysis results.

Note that each measurement of the steel powders took less than 20 sec.

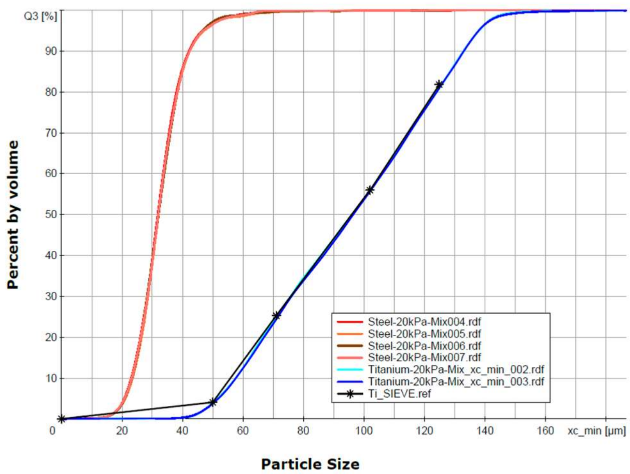


***Fig. 7:*** *Two metal powder samples (titanium and steel) measured with the CAMSIZER X2 using the X-Jet dry dispersion module with 20 kPa dispersion pressure. the four measurements of the steel powder (different shades of red) took less than 20 seconds each. The reproducibility is excellent as can be seen from the almost perfect overlap of the four curves. The same can be said for the two titanium powder measurements (light blue and dark blue), which also agree perfectly with sieve results (black *).*

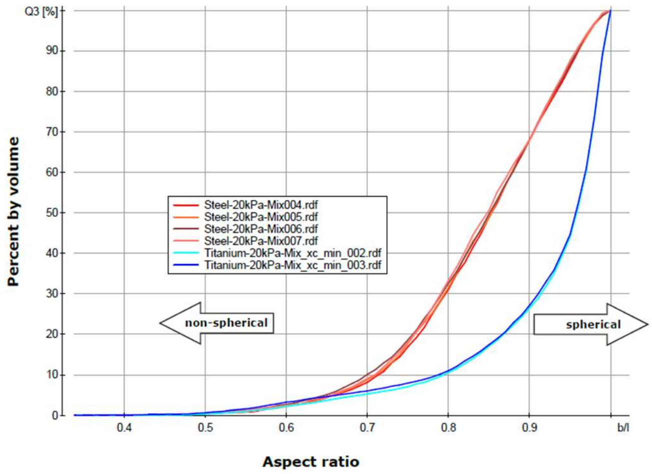


***Fig. 8**: Shape analysis of the titanium and steel metal powders. In this example, the steel particles are more compact than the titanium particles. Size and shape analysis are carried out simultaneously.*

## Example 3 – Fine Metal Powders

Even close to the detection limit of 1 µm, the Camsizer X2 offers better resolution and sensitivity than a laser particle sizer. These types of powders are typically used in Metal Injection Molding (MIM) processes.

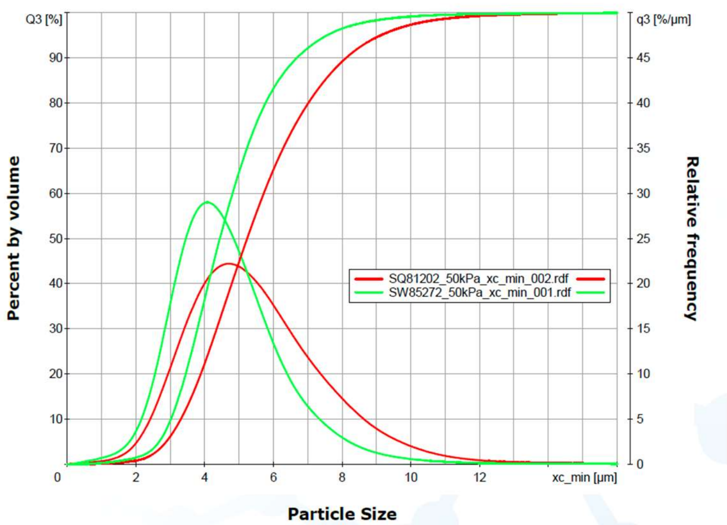


***Fig. 9**: Two measurements of fine metal powders with a d50 value of 4.5 µm and 5.2 µm measured in dry dispersion mode. The CAMSIZER X2 analyzes fine powders down to 1 µm with excellent resolution, repeatability and sensitivity.*

## Summary

The CAMSIZER X2 is ideal for determining the particle shape and particle size distribution of fine metal powders. Especially in modern powder metallurgical processes such as additive manufacturing, dynamic image analysis provides valuable information for the usability of both raw materials and recycled material. Particularly noteworthy are the short measuring times, the high sample throughput, the reliable detection of even the smallest amounts of oversize, and the finding of particles that deviate from the desired shape.

## CAMSIZER X2 -Benefits at a glance

- Flexible dispersion options (air-pressure, liquid, free-fall)
- Measuring range from 0.8 µm to 8 mm
- Very high sensitivity to oversize particles
- More than 300 images / second acquired and evaluated
- High smaple throughput: only 2-3 minutes per measurement
- Highly repeatable results with excellent instrument to instrument agreement
- Shape analysis of abrasives is possible: roundness, circularity, aspect ratio, etc.
- Low maintenance, robust design

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