MICROTRAC
PARTICLE CHARACTERIZATION

Advantages of upgrading from Previous CAMSIZERs to CAMSIZER 3D

State-of-the-art hardware with 3D particle tracking feature

Introduction

Introducing CAMSIZER 3D, the latest innovation in particle size and shape analysis from the renowned CAMSIZER series. Not only does it offer vastly improved traditional 2D measurements, but it also introduces an entirely new method for 3D particle analysis.

In its 2D mode, the dual-camera system captures millions of particles passing by in random orientations, providing comprehensive imaging. However, with the groundbreaking hardware upgrade, CAMSIZER 3D takes particle analysis to the next level. As shown in Fig. 1, in its 3D mode, a single particle is not just captured once but up to 30 times as it passes the camera system. Each image portrays a random "face" of the particle (perimeter/outline), and all images are then amalgamated into a dynamic "3D track" of the particle's journey (like a high-diver movie). This patented technology revolutionizes particle morphology analysis by offering multiple perspectives of each particle. Unlike conventional methods that capture only a single random face (outline), the 3D measurement provides a holistic view, including the precise angles required for accurate analysis. CAMSIZER 3D empowers users to select and analyze the most pertinent image from the particle's 3D track, tailored to their specific applications. Whether it's determining the true length, width, thickness, or identifying defects, CAMSIZER 3D ensures meticulous measurements by summing up data from a certain angle of each particle, resulting in unparalleled accuracy and insights.

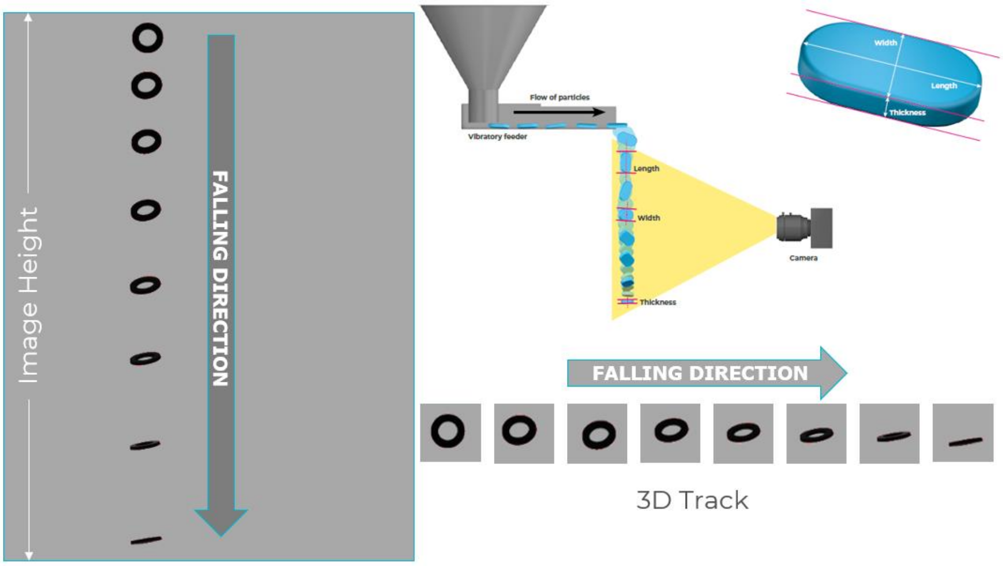


Fig. 1 – 3D measuring principle of one single particle. A particle falls through the measuring zone and is imaged up to 30 times. Each image shows a different and random face of the particle.

As an instrument equipped with both 2D and 3D methodologies, CAMSIZER 3D stands out as a unique particle size and shape analyzer. It offers the flexibility to serve as a legacy system while also providing the option to achieve more precise results through its advanced 3D technology. This dual capability makes it a versatile tool suitable for a wide range of applications, catering to both traditional needs and those demanding higher levels of precision and accuracy.

State-of-the-art hardware upgrade

CAMSIZER 3D boasts groundbreaking hardware upgrades, including notably larger analysis areas for both basic and zoom cameras compared to its predecessor, CAMSIZER P4. This enhancement not only facilitates the generation of sufficiently long 3D tracks but also, in 2D mode, alleviates customer concerns regarding the segregation effect. Thanks to these hardware upgrades, segregation correction algorithms are rendered unnecessary.

Additionally, the new zoom camera inside the CAMSIZER 3D (9 MP) allows for the evaluation of fine particles with great accuracy. In combination with the basic camera (5 MP), this enables a wide measurement range from 20 µm to 30 mm.

Why 3D particle tracking feature is much-needed

The 3D particle tracking technology of CAMSIZER 3D offers substantial advantages across various applications, including:

- Three-dimensional particles (such as extrudates, flaky particles, and fibers)
- Defective particles (twins, satellites, broken particles)

- Particle counting
- Replacing sieve analysis of mixtures with different particle shapes
- Replacing caliper analyses, etc.

Each aspect is supported by real case studies, demonstrating its efficacy.

3D particle sizes vs. 2D particle sizes

One of the key advantages of 3D measurement is the ability to separately measure the true length, width, and thickness of each particle, enabling the generation of their individual distributions. Many natural or artificial particles, such as extrudates, pellets, almonds, and coffee beans, possess three distinguishable axes to fully describe real particle dimensions.

As illustrated in Fig. 2, it is a 3D track of one single coffee bean while passing the 3D camera system. In this track, the smallest value of the minimum chord diameter ($x_{c\,min}$) is determined as the particle's **3D thickness**, the largest values of the $x_{c\,min}$ as the **3D width**, and the largest value of the maximum Feret diameter ($x_{Fe\,max}$) is considered the **3D length**. As shown in Fig. 3, by analyzing the tracks of all particles, three distinct particle size distributions are obtained: the distributions of **3D thickness (green)**, **3D width (red)**, and **3D length (blue)**.

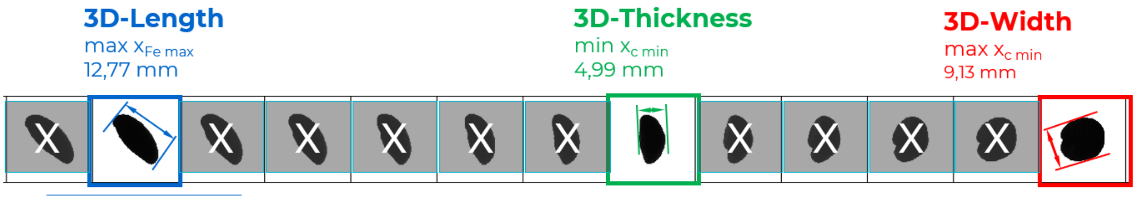


Fig. 2 – 3D track of ONE single coffee bean. The images at different angles were captured when it was passing the camera system.

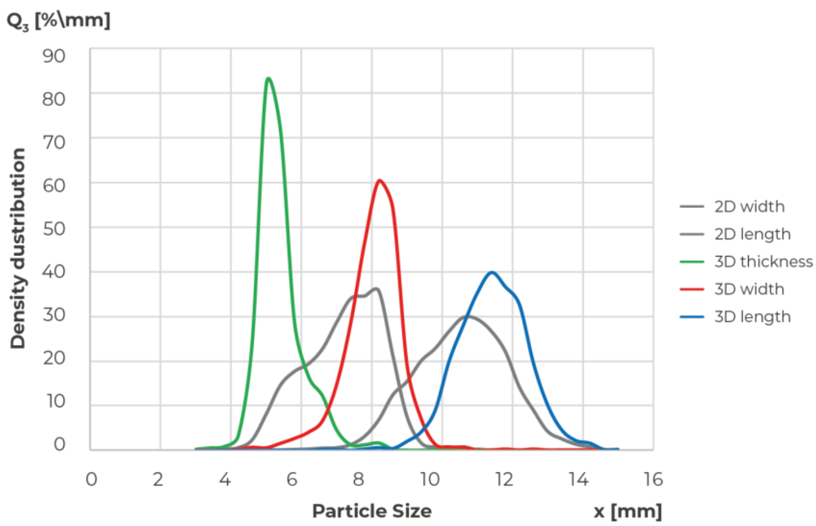
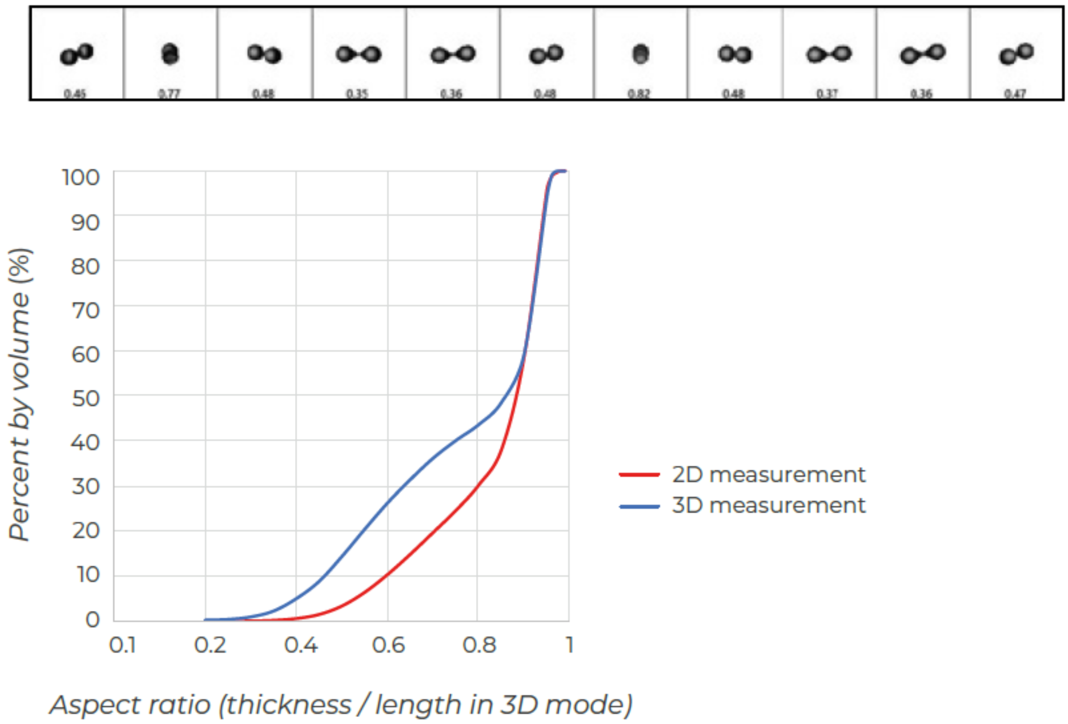


Fig. 3 – Particle size distributions of coffee beans. **3D thickness (green)**, **3D width (red)**, and **3D length (blue)**. For comparison, the 2D length ($x_{Fe\,max}$) and width ($x_{c\,min}$) are depicted in **gray**.

For comparison, traditional 2D measurements of the same coffee bean sample were conducted. In 2D mode, all randomly oriented particle images contribute to the final result. This yields distributions of 2D width ($x_{c\ min}$) and 2D length ($x_{Fe\ max}$). As depicted in Fig. 3, the 2D width (gray), resulting from random orientations, falls between the 3D thickness (green) and the 3D width (red). This discrepancy arises because 2D measurements cannot differentiate between the two main axes of the coffee bean. Additionally, the 2D length (gray) appears "too short" compared to the true 3D length (blue), further highlighting the limitations of 2D analysis in capturing accurate particle dimensions. This comparison underscores the superiority of true 3D measurements in providing comprehensive and precise particle sizes.

3D particle shapes vs. 2D particle shapes (defective particles)

Glass beads play a crucial role in retroreflective road markings, enhancing safety through heightened reflectivity. Quantifying the percentage of cullets, deformed or fused beads is essential for assessing product quality. As depicted in Fig. 4, the aspect ratio from 3D measurements tends to be lower than that of 2D measurements, indicating the detection of elongated particles (~17%). Such particles might have been inaccurately characterized as "round beads" in 2D analysis. At the top of Fig. 4, the 3D track of a fused particle illustrates how its aspect ratio can vary between 0.25 and 0.82 depending on orientation. In 2D mode, all these projections might be included in the calculation. However, in 3D mode, only the image corresponding to the lowest aspect ratio value is calculated. While 2D analysis can differentiate between samples of varying quality based on shape results aligned with different contents of fused glass beads, absolute determination of the proportion of particles meeting a specific shape threshold is achievable only with 3D methodology. This distinction arises because 2D mode measures only a particle's random orientation, obscuring its true morphology, whereas 3D analysis provides a comprehensive view.



True aspect ratio of particle thickness/length (3D)

Aspect ratio of randomly orientated particle (2D)

Fig. 4 – 3D analysis detects the true shape based on multiple projections and allows for more accurate size and shape analysis.

Accurate particle counting

In contemporary times, only a handful of dynamic imaging systems are capable of counting particles:

- Liquid particle counters utilizing electrolyte and orifice tubes that have a very limited size range and lack shape information;
- 1D line scan systems that provide insufficient 2D size and shape parameters;
- 2D systems that need meticulous calibration;
- 3D tracking systems stand out for their ability to accurately count particle numbers (one particle, one track) and measure particles in their true size dimensions, also offer genuine particle volume and deliver enhanced shape results.

Thanks to the 3D tracking capability, particle counting becomes feasible irrespective of the density or velocity of particles within the measurement chamber. This functionality enables the generation of various results, including absolute particle counts, average weight per particle, 100 particles, particle numbers per gram, etc.

Replacement of sieve analysis of mixtures

Classic imaging systems have the capability to translate measured particle size distribution results into outcomes akin to those obtained through sieve analysis. There are three sieve correlation methods available:

- Q3 fittings that shift the sizes and correct the amounts on the sieves or the passing values, highly unstable when dealing with mixtures and varying distribution widths;
- Meta fittings which learn from samples with different shapes;
- 2D elementary fitting that provides robust sieve correlation even when the width of distribution changes.

The first two fitting methods often falter when confronted with mixed particle sizes or fluctuating percentages of fines or oversized particles. All three fitting techniques above primarily involve adjusting the entire size distribution. Consequently, when particle shapes vary or different particle shapes are combined, the adjustments become invalid.

Conversely, the latest 3D fitting incorporated into CAMSIZER 3D corrects each particle individually. This groundbreaking approach enables accurate correlation with sieve results even when users mix angular particles with spherical ones.

Replacement of caliper analysis

Extruded catalysts serve as essential components within the chemical industry. Monitoring the width of extrudate catalysts is paramount, as it offers insight into the gradual wear and potential clogging of dies over time. Early detection of such changes, often indicated by alterations in diameter, is critical for maintaining operational efficiency. Additionally, assessing the quality of catalysts extends beyond mere width measurement; the distribution of length is equally crucial. Sieve analysis falls short in this regard. When granules align even slightly, sieve analysis predominantly determines width, neglecting length. Manual measurement using calipers, though commonplace, suffers from limited representativeness due to small sample sizes. To overcome these limitations, dynamic image analysis emerges as a promising alternative. As depicted in Figs. 5 and 6, 3D analysis utilizing particle tracking emerges as particularly advantageous for length measurements. This approach furnishes precise length determinations for each particle, thereby yielding a more accurate length distribution. In contrast, 2D measurements often result in an underestimation of length when particles are randomly oriented, highlighting the superiority of 3D methodologies. Although certain accessories enable the orientation of particles into their longest projection, the implementation of 3D tracking technology renders the wear and tear of such sensitive and complex accessories unnecessary.

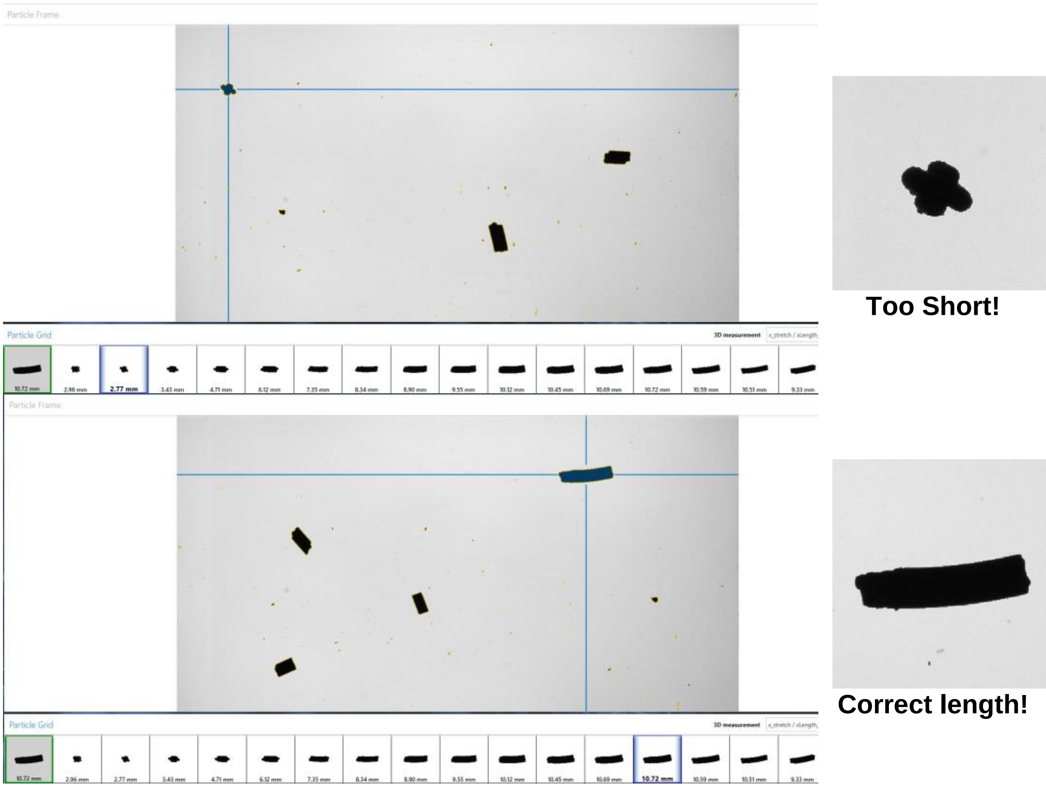


Fig. 5 – 3D analysis of extrudate particles with cross-shaped base surface. The top graph marks the start of particle falling, while the bottom graph tracks its ongoing descent. The 3D track displays this particle from different angles as it falls. In 3D length measurement, only the image capturing the particle's maximum (correct) length is utilized. The 3D measurement "always" sees the true length whereas the 2D measurement "often" sees it. This ensures accuracy despite variations in the particle's orientation during its descent.

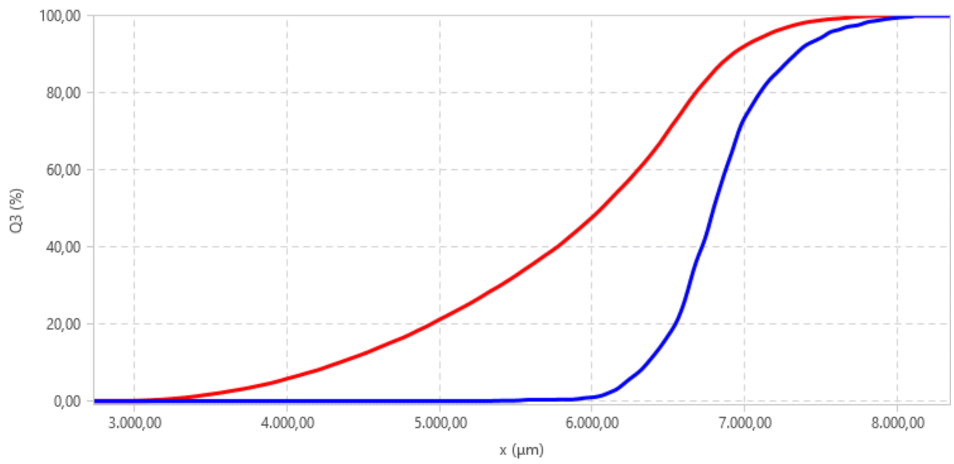


Fig. 6 – 3D length (blue) and 2D length (red) of extrudate particles.

In Fig. 7, the caliper result (**black**) and CAMSIZER 3D result (**red**) for the same 50 extrudates perfectly align, validating that 3D measurement can effectively substitute caliper analysis. Notably, the length distribution of the entire sample (**blue**) appears "shorter" compared to the distribution of the 50 particles (**red**), a phenomenon frequently observed. This discrepancy arises from human tendency to select longer particles, which are more noticeable and easier to handle. The 50 handpicked particles sampled (**red**) do not accurately represent the entire sample (**blue**).

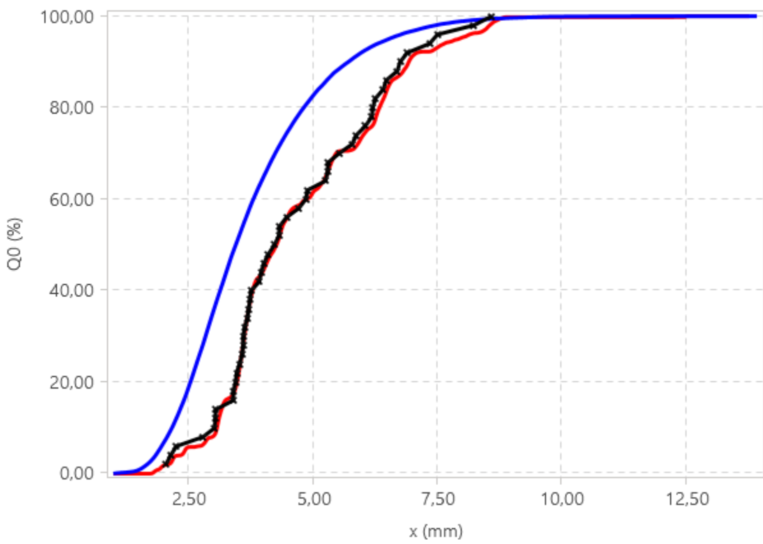


Fig. 7 – Caliper analysis of 50 particles (**black**), CAMSIZER 3D measurement of the same 50 particles (**red**), and CAMSIZER 3D measurement of the entire sample (**blue**).

Summary

The CAMSIZER 3D seamlessly integrates the advantages of both 2D and 3D measurements through dynamic image analysis methodology, as outlined in ISO 13322-2. As a result, it has emerged as a pivotal tool in both industrial and academic spheres. The implementation of 3D particle tracking technology offers significant benefits to a wide range of industries, including those dealing with extrudates, wood chips and pellets, catalysts, food, feed, seeds, polymers, sand and gravel, fibers, defective particles, and mixed particles with varied shapes.

If you’re unsure of the application or how this technology could help your research or industrial needs, please contact [lab.microtrac.us@verder.com].

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