



## Seamless Production Monitoring through On-Line Particle Analysis with a Special Emphasis on Fertilizers

### CAMSIZER Online

#### Background

Many different types of compounds containing nitrogen (N), phosphorous (P) and potassium (K) are found as major ingredients in synthetically manufactured fertilizers, used to supply nutrients for about half the world's food consumption.

A couple of examples of the many synthetic fertilizers are DAP (di-ammonium phosphate) and KCl (potassium chloride). Almost all fertilizer manufacturing processes produce solid "round" granules in the 1 to 6-mm range, many in the 2 to 4 range. However, the initial feedstock to the process is in liquid form, referred to as the "Melt". The diagram on page two (Figure 1.) shows a commonly used Drum Granulation process.

#### The Process

**Drum Granulation:** The Melt enters the front end of the drum granulator, which is rotating and contains lifters along the inside to gently throw the granules as they grow. The exit stream contains granules ranging in size from 0.1 to 10 mm. That stream is then screened at 4 mm, with the + 4-mm granules going to an oversize silo, and from there through a roll crusher and back into the granulator.

The - 4-mm stream is screened at 2 mm, with the - 2-mm stream going to an undersize silo and from there back to the granulator. The product is the 4 x 2-mm stream which makes up about 1/3 of the entire process stream at any one time.

**Pan Granulation** substitutes a pan (saucer-shaped) granulator for the drum granulator.

**Prilling** adds a liquid mixer into which the undersize silo stream goes for dissolution prior to return to the granulation process, in this case a prilling tower. The prilling tower is a tall vertical tower which is fed by a rotating funnel-shaped container with holes in it. The Melt and the dissolved undersize stream are fed to the funnel. A column of air rises through the

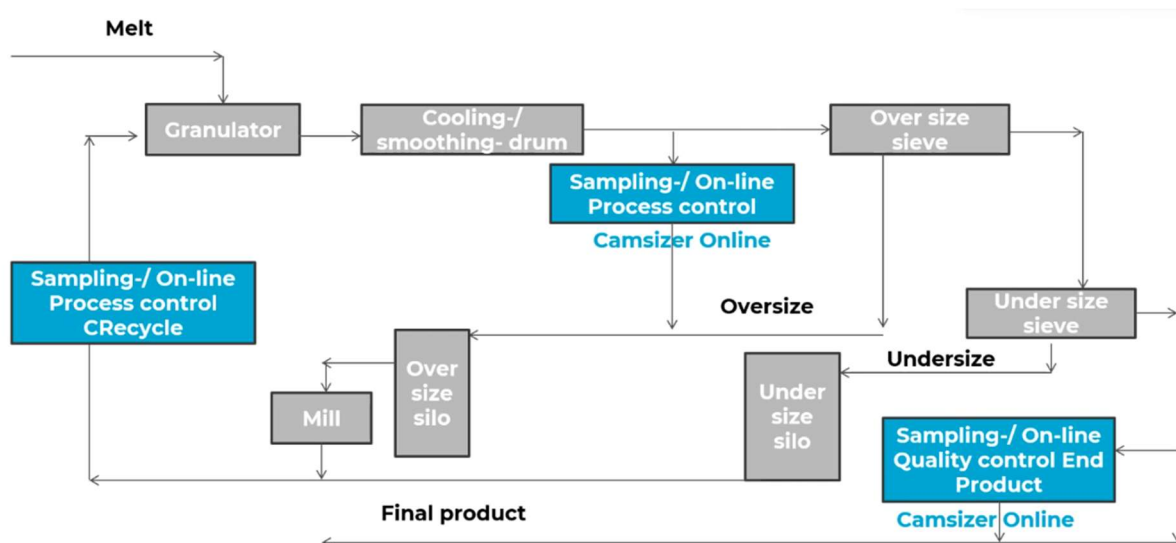
prilling tower while the droplets fall to the bottom arriving there as near dry granules, being fed then to the 4-mm screen.

The + 4-mm stream goes directly to the **roll crusher** and then to the undersize silo.

**Nozzle Spraying** involves recycling both the +4-mm and the -2-mm streams to a mixer for dissolution in oil. These dissolved streams are fed with the liquid Melt to sets of nozzles near the top of a tall tower which spray the combined feed streams upward after which the droplets begin to fall through a column of air coming up through the tower as in the prilling process.

**Fluid Bed processing** involves using a fluid bed unit operation in place of the drum granulator for producing the granules that are then screened.

**Pug Milling, Crystallization** and **Spheroidization** are lesser used processes, but they also basically replace the drum granulator and produce a narrowly sized stream of “round” granules.



**Figure 1:** Typical Flow Diagram of drum granulation fertilizer production. Optional sampling points to bring sample to an on-line CAMSIZER system for measuring particle size and shape are indicated. There are several variations of this basic setup for synthetic compound fertilizers.

## The Problem

A very important finishing step in all these processes is coating the granules with a thin wax layer which controls the leaching rate after the fertilizer is applied to crop fields. This is the reason that in addition to the need for a narrow size distribution, the granules should be as round and consistently smooth as possible. Irregularly shaped particles that are more like fused globules than round granules tend to break at the narrower points exposing surfaces with no coating and are more difficult to coat evenly over the entire surface.

## The Solution

Image Analysis is a particle characterization technique which is becoming more and more desired and used over traditional methods, because of all the additional information it provides. Traditionally, fertilizer quality and production control is performed by sieve analysis. However, this is a very time-consuming procedure as it requires manual sampling and transport to the laboratory, usually 10 minutes of sieving time, followed by weighing, cleaning of equipment and calculation of the result. Response time to production variations is therefore relatively long. Sieving only provides a maximum of eight data points, which is the number of sieves that fit on a normal sieve shaker and is not capable of measuring particle shape. Image Analysis, on the other hand, provides up to 30 different size and shape morphological parameters for each particle measured. For an application like optimizing control of fertilizer manufacturing, this technology can provide size, roundness, and surface

roughness information about the product, so that all of these properties can be measured and controlled with one analyzer.

**On-Line Analysis:** On-line Image Analyzers have been operating in fertilizer plants around the world since the first installation in 1988. Below is a predecessor of the Microtrac PartAn analyzer, a long time in operation without failure.



**Figure 2:** Left: On-line image analyzer in a fertilizer plant, working continuously since 1995 without service. Right: In-line image analyzer installed in December 2011

One major advantage of on-line image analysis over laboratory measurement is the quick and direct response. Sample is taken continuously and directly transferred into the instrument. Figure 3 shows one example for an automatic sampling system connected to an on-line particle analyzer.

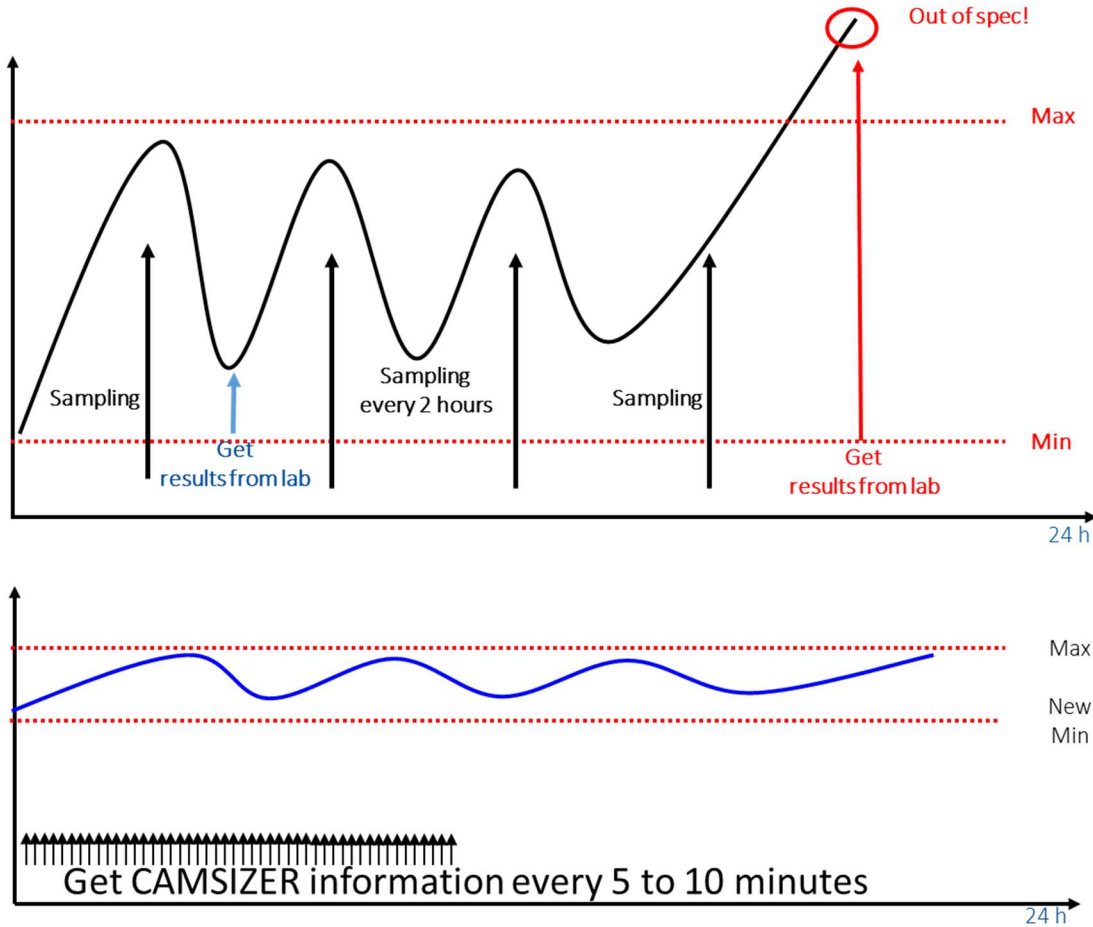


**Figure 3:** The sampler moves through the product stream from left to right and back. It takes approx. 0.5 - 0.8 kg sample at a time and transfers it to the image analyzer.

The graphs below show some of the advantages of on-line control of a process versus lab control. The top graph is illustrative of the typically long times between sampling and analysis using lab control. Here about 2 hours pass within one process fluctuation, based on a change in some control set point (average value) from data of the last analysis. In this example, the set point is shown at 80%. For a fertilizer process, one set point might be the % of product within 2.5 and 3.5 mm, the narrower the distribution the better. Or one set point could also be the % of product with a “roundness” factor greater than 0.88 (1.0 being a perfect sphere), or a Convexity value (surface roughness, 1.0 being perfectly smooth) greater than 0.92.

With on-line control, sampling and measurement are automatically nearly continuous. This means the process variables that might need to be changed to bring it back under control (moving back toward set point) are adjusted much more often than in lab control, and the set point can be raised to achieve more product within specification, 90 vs 80% in this example, and therefore optimizing the performance of the fertilizer in the field. In fact, the

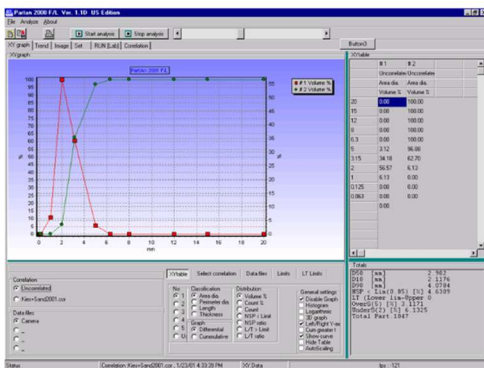
turn-around time for sending new on-line control signals automatically back to the process in fertilizer production is on the order of about only 5 minutes.



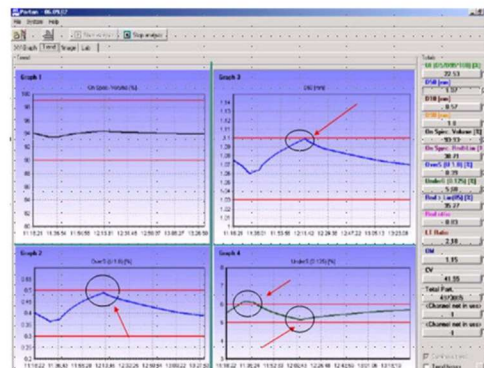
**Figure 4:** In sieve analysis, a particle size distribution is determined only every 2 hours. Therefore, reaction times are long and risk of “off spec” is higher. The on-line measurement gives the possibility to see process changes immediately. The operator can react in real-time. The benefit is a higher amount of on-spec production.

Figure 5 shows typical measurements results presented by the CAMSIZER on-line. The size is reported as a cumulative distribution or density distribution. Multiple parameters can be monitored simultaneously. Violation of product specification limits are detected immediately by trend analysis.

Size distribution



Trend results



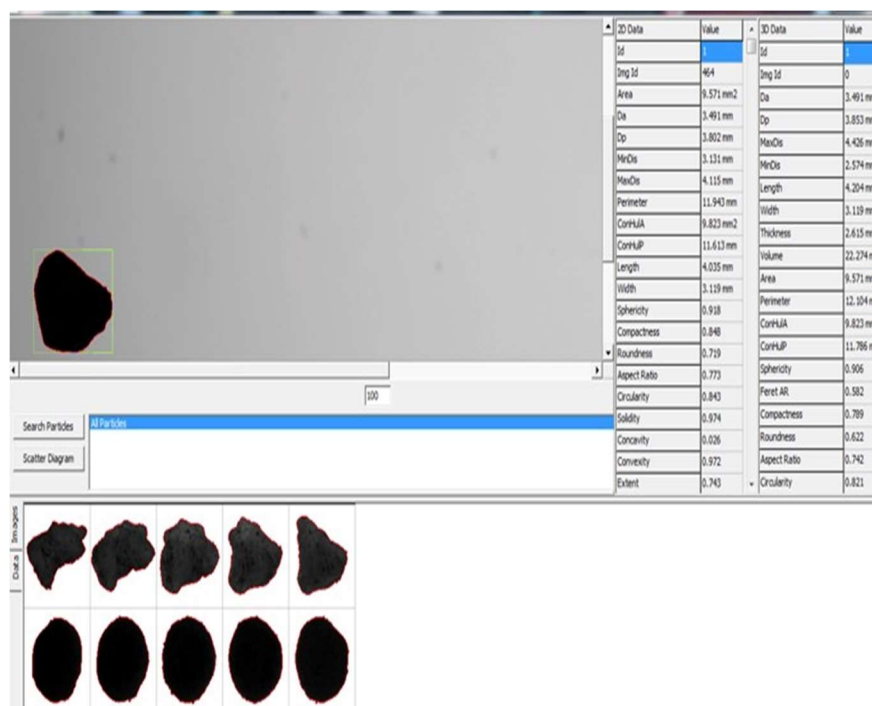
**Figure 5:** Size distribution of a fertilizer sample (left) and trend analysis for four different parameters (right). The product specification limits are indicated by red lines. As soon as a measurement value approaches a threshold value, production parameters can be modified to keep the material on-spec.

## Research and Development

CAMSIZER instruments are also available as a laboratory unit for R&D. As new and better fertilizers are developed from new compounds and/or processes, the ability to generate the same information about the product that would later be controlled on-line makes good sense. All the many morphological parameters measured during the development phase would be available in a history of how the product performed relative to these parameters. That information could then be directed to the control actions to take as on-line analysis would indicate in the process.

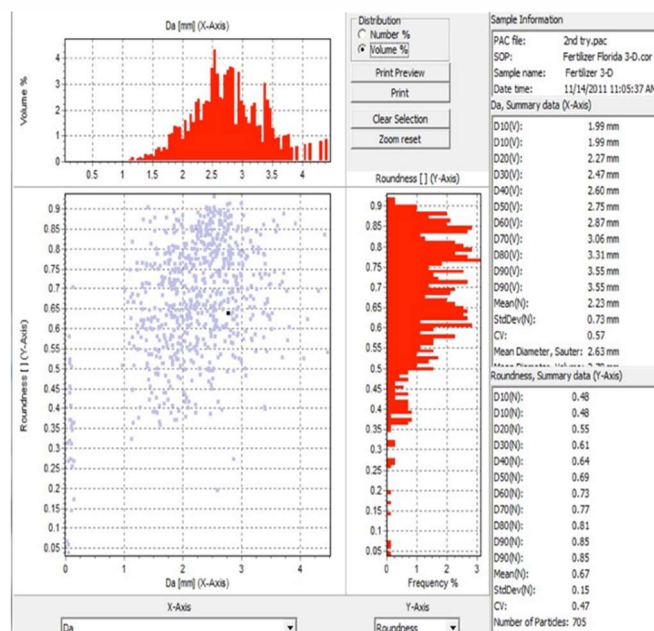
## The Technology

Image Analysis is one of the newer technologies being used for particle characterization. It's simple, logical, and easy, and it provides about 30 more morphological (sizes and shapes) parameters than traditional particle size analyzers do. A combination of a strobe light, optics, and digital camera records images of passing particles. The pixel size is known, and from the number and relative locations of the pixels, all the parameters are easily calculated. Various equivalent diameters, length, width, maximum and minimum distance are a few of the size parameters measured. Some of the shape parameters include aspect ratio, and various surface roughness and roundness parameters. Summary data and both number and volume distributions are some of the data forms available for each parameter. A file of images of all particles measured is provided, seen below, and both the 2-D and 3-D parameters are listed at the upper right for any particle selected (Fig. 6). The full 3-D results, based on a patented particle tracking technique, is presented by the CAMSIZER software.



**Figure 6:** As the sample particles are falling through the measuring zone, they are detected several times, showing different projections. This provides a thorough measurement of the 3D-morphology of each grain. The sequences of particle images above from left to right are two different fertilizer pellets, photographed five times. Round and angular particles are clearly distinguishable.

A Scatter Diagram, shown in Fig. 7, allows a view of where each particle resides relative to the two distribution parameters in the red histograms. In this case the two most important parameters to fertilizer are plotted, diameter (size) in the top graph and roundness (shape) to the right of the Scatter Diagram.



**Figure 7:** Scatter plot. Each blue point represents one particle detected by the CAMSIZER. Any size or shape parameter may be used on the x- and y-axis.

## Summary

Size and shape are important parameters for good fertilizer quality. Narrow size distributions and round and smooth particles are important for even leaching rate of the nutrients to crops. These two parameters, and many more, are easily measured by image analyzers.

On-line image analyzers are being used, since 1988, in fertilizer plants around the world, to provide rapid and tight automatic control of these parameters. Lab image analyzers can provide the historical size and shape data through the development process for new and better fertilizers. This information can be used to plan the production control schemes for the new products.

Pay-back time for the on-line installation is short, and can easily reduce unforeseen downtime.

The Microtrac CAMSIZER is the only image analyzer that gives full 3-D size and shape information

For further information please contact us at:

[www.microtrac.com](http://www.microtrac.com)