Application Example: Analysis of Mineral Grinding Samples

Motivation

Wet grinding is used in mineral processing to control particle size distribution for a maximal mineral yield. The optimization of grinding parameters for varying mineral feeds is important due to their direct influence on energy consumption. The smallest particle fractions after grinding are below 10 μm, which makes the traditional sieving analysis time-consuming and inaccurate. Furthermore, the sieving analysis is not able to characterize the efficiency of the grinding process in terms of the resulting particle shape. A camera-based measurement system is thus preferred in the in-depth analysis of the particle characteristics, including size and shape distribution.

Measurements

A Pixact Particle Monitoring (PPM) system was installed on a sampling line to analyze the particles in the suspension. Because of a relatively small sample volume, the measurements were performed in a Pixcell DN8-OP3 flow-through cuvette equipped with a 3 mm optical path. The cuvette was connected to a bench-top flow loop, which circulates the sample through the measurement section. Due to high particle density the flow rate in the loop must be kept high enough to prevent the sedimentation of the largest particles. The suspension is also agitated with a mixer in the sample container. Figure 1 presents a schematic layout of the measurement system and the flow loop. The flow through cuvette with the camera and illumination units installed is presented in Figure 2. Because of the high particle concentration, dilution of the samples was required for optimal measurement data.

The camera provides real-time image data from the measurement section. An example of the image data is shown in Figure 3. The image stream is analyzed with the Pixact software. Each image is processed to detect individual particles and analyze their outlines (Fig. 4). Based on the detected outlines, both the size and morphological parameters of the particles can be computed. In this study, the particle aspect ratio – i.e. the ratio between the major and minor axis – is measured.

In this study, three samples are analyzed to compare the effects of grinding parameters for the selected feed material. These samples are labeled S1, S2 and S3. The amount of energy used for grinding was highest for S1 and lowest for S3. All samples were diluted with water with a ratio of 100:1 resulting in a sample volume of 1010 ml. The measurements were carried out by filling the sample container with the diluted particle suspension and starting the flow circulation and agitation. When all the air had diverged from the fluid, the measurement was started. A set of 5000 images was recorded and analyzed for each sample. This amount of images resulted in $O(10^8)$ particles for the computation of the particle statistics.
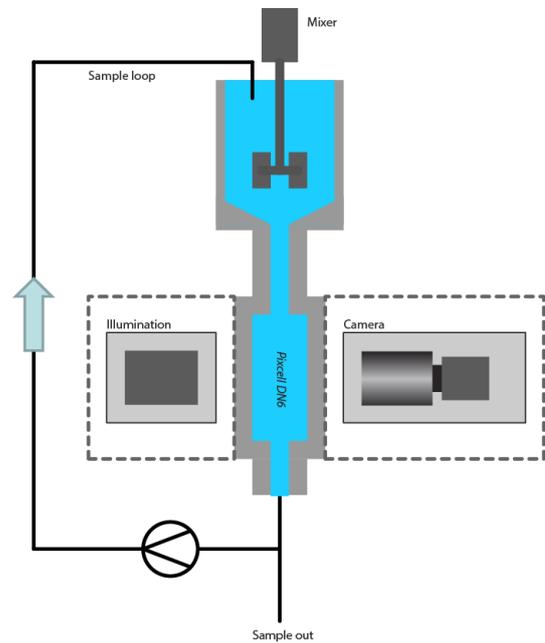

Figure 1. Schematic layout of the PPM installation

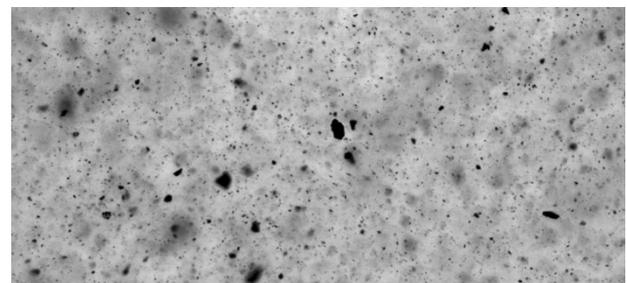*Figure 2. Pixcell DN8 flow-through cuvette*
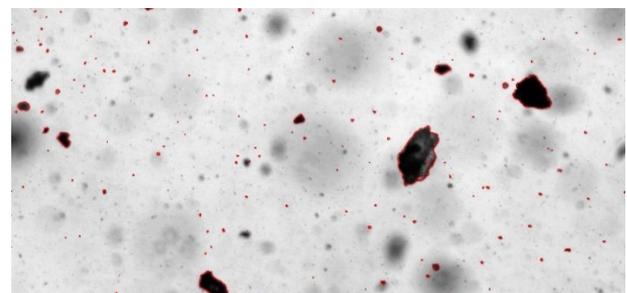

Figure 3. Example of the image data

Figure 4. Particle outline detection

Results

The measured particle size distribution for S1 is presented in Figure 5. The mode of the distribution is a little over 5 μm and the largest particles are about 50 μm in size. In Figure 6, the results for the three samples are compared by plotting the cumulative volume fraction of each sample. The difference between the samples can be clearly observed in the cumulative plots, which show that the smallest particles are found in S1. This is the sample with the highest energy input in grinding. The results show a monotonic decrease in particle size as a function of the energy input.
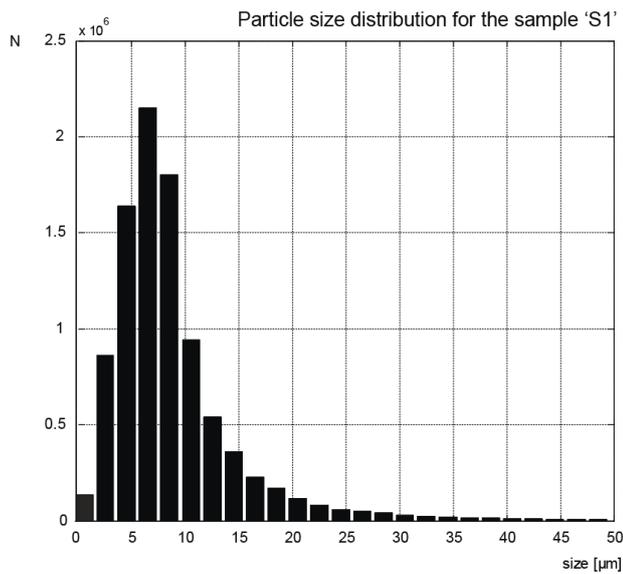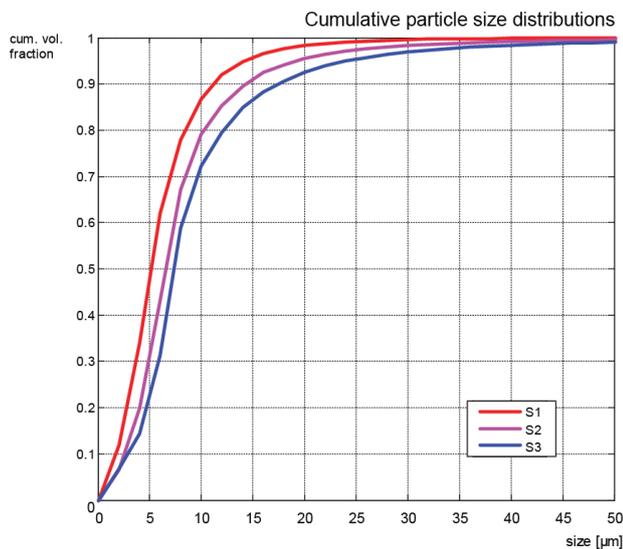
Figure 5. Particle size distribution data

Figure 6. Cumulative particle size distributions for three batches

Technical implementation

The PPM system is based on a Pixcell DN08 imaging unit (Fig. 2) that is installed in a closed sampling loop. The system is a bench-top installation for laboratory use and it is operated from a laptop.

A summary of the specifications of the measurement system is presented in the table below.

Imaging unit	Pixcell DN08-OP3
Material	Stainless steel AISI316L
Gaskets	NBR
Window material	Borosilicate
Imaging resolution	0.9 μm/pix
Image area	2.2 mm x 1.7 mm
Optimal measurement range	2–200 μm
Software	Pixact Particle Monitoring