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DETERMINATION OF ORE SIZE DISTRIBUTION WITH IMAGE ANALYSIS

In the mining industry determination of size distribution is traditionally done with big and very expensive ridars. In this paper a new method for analyzing crushed ore size distribution by means of image analysis from a conveyor belt is introduced. The method introduces a cheap and effective way to do size distribution analysis. Also a special analysis system based on the idea and built at Pyhäsalmi, Finland, is described. With this system the analysis can be performed on-line right after crushing.

As the computational power of modern computers increases it has enabled researchers to use more and more intensive calculations in on-line analysis or control applications. One important area is image analysis, which usually involves demanding calculations. In this paper a novel image analysis-based measurement system designed to calculate particle size distribution of crushed ore is presented. The system was built to measure the size distribution after the first crushing stage that is done in the mine right after blasting.

The crushed ore is separated into four different sizeclasses (0-35mm, 35-85mm, 85-100mm and over 100mm in diameter) in the surface and stored in four different silos. From these silos the ore is fed to the grinding mills in correct proportions in order to achieve the best possible result. Thus, it is obvious that the ore coming from the mine has to have correct amount of different sized particles, otherwise one or more silos in the surface will run out of ore. From the level measurements in the silos it is possible to determine the size distribution on the surface and thus see what size classes are running out. However, since the silos are on the surface and there are two additional buffer-silos in the mine the time delay from the crusher to measured change in the size distribution can be even days. This leads to situation where it is very difficult if not impossible to make corrective actions in time. To overcome the problem it was decided to implement size distribution analysis system in the mine, right after the crusher. This way there would be an estimate of the size distribution coming from the crusher that would have only few minute time delay. The basic idea of the analysis is to have a monochrome camera on top of the conveyor belt and a single light source coming from the side. This leads to situation where the rocks form shadows to the image. An example of this kind of image is shown in Fig 1. The length of the shadow is proportional to the size of the rock throwing it. This information is utilized in the calculations.

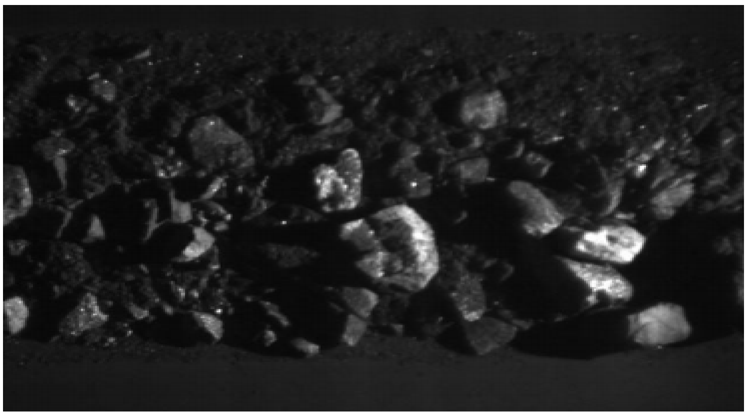

Figure 1. Crushed ore on a conveyor belt

The focus of this thesis is characterizing grainsize distribution of the waste-rock and quantifying gas transport in the test waste-rock piles.

Grain size of waste rock ranges from millimeters to meters. Sieve analysis typically only provides information of grain size <0.1 m at a single location. A computer program was developed using digital image-processing techniques to obtain a spatial grain-size distribution from photographs of tip faces of the test waste-rock piles acquired in the field. The program characterizes grain size >0.1 m and employs a region-growing algorithm for segmentation of waste-rock grains with pre- and post-processing techniques to improve the accuracy of segmentation. The program was applied to photographs of six different tip faces of the test waste-rock piles. For grain size <0.1 m, data from sieve analyses were attached to the grain-size curves generated from image grain-size analyses to obtain a full spectrum grain-size analyses ranging from boulders to fines. The results show that fine fractions are retained at the top of the tip faces and grain size increases non-linearly from top to bottom of a waste-rock pile. Calculations show that although the greatest mass is associated with the medium and coarse fractions, the greatest surface area is associated with the fine fractions. The results are consistent with field observation that the initial solute concentrations are greatest at the top of the pile and saturated hydraulic conductivity are lower at the top of the iv pile than in the pile interior. Statistical moments show that the test waste-rock piles have mean grain size of granules and are very poorly sorted, coarse skewed and leptokurtic. Permeability is calculated using empirical formulae and good agreement is obtained between calculated values and field measurements. The heterogeneity of grain size obtained from this study can provide a basis for future modeling efforts.

In order to perform theseparation by means of flotation the ore must be ground to small particles approximately 50-100μm in diameter (see [1] and [2]). The grinding method in Pyhäsalmi is so called autogenous method where the largest particles of the ore are used as grindstones.

Gas transport analysis focused on 1) substantiating the relationship between wind flow external to the waste-rock pile and gas pressures within the pile, 2) determining the gas flow regime in the pile, and 3) quantifying the temporal variation in wind speed and direction and determining the relevant time scales. Differential gas pressures were measured in 2008 at 49 locations within one of the three test waste-rock piles and 14 locations on the surface of the pile at one-minute intervals. Wind speed and direction were measured at 10-min intervals. Correlations between wind vectors and pressure measurements show that the wind influences pressure fluctuations in the test pile. The strength of the correlation is roughly inversely proportional to the distance between measurement ports and the atmospheric boundary. The linear relationship between internal pressure measurements and surface pressure measurements demonstrate that gas flow is Darcian within the test waste-rock pile. Spectral analysis of wind data and a one-dimensional analytical solution to the flow equations show that the persistence of wind in a certain direction has most pronounced effects on transient gas flow within the pile. The penetration depth of wind-induced gas pressure wave is a function of the periodicity of the wind and permeability of the waste-rock pile.

Recent developments in digital image processing provide an opportunity to gain a better understanding of large-scale grain-size distribution that is otherwise difficult to obtain through mechanical sieve analysis. An innovative method to obtain grain-size distribution information from photographs of waste-rock piles was developed and applied to a wellcharacterized study site in the Canadian arctic. The method is based on a region-growing algorithm with edge enhancement and image dilation as pre- and post-processing techniques and demonstrates sound reproducibility. The method was applied to photographs of six exposed faces of two test-scale waste-rock piles. The results are presented both as grain-size distribution curves and d50 contours. The results show that fine fractions are retained at the top of the tip faces and grain size increases non-linearly from top to bottom of the test-scale waste-rock pile. Calculations show that although the greatest mass is associated with the coarse fractions, the greatest surface area is associated with the fine fractions. Statistical moments demonstrate that these waste-rock piles have mean grain size of granules and are very poorly sorted, coarse skewed and leptokurtic. Field large-scale grain-size measurements are consistent with the image grain-size analysis results. Permeability is calculated using Hazen and Kozeny-Carmen empirical formulae, and reasonable agreement between field and laboratory measurements was obtained. The results also are consistent with the observation that the initial solute concentrations are greatest at the top of the pile and saturated hydraulic conductivity is lower at the top of the pile than in the pile interior.

There are some commercial applications that measure the ore size distribution (e.g. Split Engineering Ltd and Adept Electronic Solutions Pty Ltd) and many published papers around the subject (e.g. [3], [4]), but the idea to use shadow-length information in a statistical way – meaning that there is no segmentation or other difficult and error prone methods (3-D models etc.) – is unique. Also, especially segmentation-based methods would be difficult to implement in this particular case since the amount of fines is fairly large. The system is based on very robust image analysis methods and thus the camera is used just as a robust measurement device that will produce stable image quality to the following image analysis algorithms despite the possible changes in the external conditions.

The structure of the paper is the following: in the first section the physical setup of the system in terms of hardware and software components is described. The following two sections describe the calculations in detail and the last section draws conclusions and describes future research that will be performed regarding the analysis system.

The results obtained with the system are promising and there is growing interest towards the system among the personnel at the mine. In fact, there is quite much work being done to integrate the analysis and the end user software (referred earlier as TCP client program) as an integral part of the daily work of the plant personnel involved in ore production and grinding. However, there is still much work to be done. One important aspect of research is to automate the system as much as possible and include more information to the end user software.

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