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Algorithm for dynamic cone crusher control

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ABSTRACT

Cone crushers are used in the mineral, mining, and aggregate industry for fragmentation of rock materials. Control systems for cone crusher settings are widely used for compensating for wear and protecting the machines from high pressure. However, these systems focus on the crusher and not the crushed products.

By applying measurement devices on the process the crusher can be run optimally from the saleable products point of view (unlike most existing systems which only protect the machine) in each time. The measurement devices can be mass flow meters, e.g. conveyor belt scales. To analyze data from the process and convert them to a desired CSS value, an algorithm was developed.

The developed algorithm is tested and evolved at a real crushing plant for aggregates. The algorithm was loaded into a computer which could communicate with the crusher control system, read data from three mass flow meters, and also interact with the operators. The computer was reachable over the Internet by the researchers at Chalmers and the algorithm was tuned and improved on-line.

The result is an algorithm which was capable of providing CSS set-points to the automatic setting regulation system. The amount of saleable product from the crushing stage improved 3.5%, when not limited by the hydraulic pressure, compared to when a fixed closed side setting is used. The use of the algorithm automatically compensates for changes in the feed material and it also decreases the need for calibration of the underlying system.

1. Introduction

Cone crushers are widely used for size reduction of rock materials, such as aggregate products or ores, into finer fractions. Their main operating principle is the same today as when developed, a century ago. A mantle is rotated eccentrically in the crushing chamber having the rock material crushed between the mantle and the concave several times while falling down inside the crusher. As the mantle and the concave get worn, the distance between them must be adjusted in order to maintain the reduction ratio and to control the top size of the product. This is done in one of two ways, depending on the crusher type. In the first type the cone, on which the mantle is fixed, is adjustable vertically by a hydraulic system. The hydraulic system also serves as safety system by dropping the cone to its lowest position if tramp metal comes into the chamber. The concave is fixed in its position. In the other type of cone crusher the concave is attached to an upper part which has screw threads on the outside which allows the distance between the mantle and the concave to be adjusted vertically by turning the upper part. In this case, the mantle is fixed vertically. Both these two types of crushers can be equipped with an automatic control system which compensates for wear. Such a system helps the user to keep the setting constant.

However, the purpose of the crusher is to produce rock material with certain properties, not to keep a setting as constant as possible. Therefore from a user's perspective on an optimal control system, the parameters to adjust should be the different saleable product capacities, i.e. size distribution and shape. Proposed here is therefore an approach which focuses on the products of the crushing plant.

One way of obtaining the maximum plant output is to theoretically optimize the gross profit using simulation software and then run the plant accordingly. Such software has been developed by (Svedensten, 2007), who describes this type of optimization process. Reality, however, holds a wide range of variables; natural variations of the rock material properties in the feed, wear of the equipment, weather, unwanted stops, etc. So when implementing real time control of a crushing plant, a measurement of the status in the actual process is crucial. However, it is difficult to measure product properties in real time at a plant due to several factors, e.g. the high capacities, the dirty environment, and the wide range of product sizes. The historic lack of appropriate measurement devices is one of the reasons why there are so few advanced process control systems in the aggregates industry. However, there are a number of measurement systems, most of them optical, e.g. (BoBo and Taylor, 2005), and (Guyot et al., 2004).

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The principle outline of this paper is the usage of on-line product capacities as plant performance indicators and the adjustment of the crusher control parameters accordingly. A conveyor belt scale for instance can easily transmit information about the mass flow to a computer. Unfortunately, the cost of installing these is relatively expensive leading to a very scarce usage in the aggregates industry. A more cost effective way of measuring the capacity is to measure the power draw on a conveyor belt that is performing the lifting work. Such a measurement device can be obtained for a tenth of the cost of a traditional belt scale. This principle is described by (Hulthén and Evertsson, 2006). By measuring directly the quantity of each saleable products after a screen, as seen in Fig. 1, given that the quality aspects, e.g. shape, are acceptable, the control system (computer) can reliably estimate, and thus able to control, the plant output particle size distribution.

2. Earlier work

Although process control with respect to the product is common practice in many other process industries, it is rarely seen in an aggregates context.

Another type of crusher, impact crusher, is controlled by adjusting the feed capacity. (Reitemeyer, 2006) describes a method in which the feed rate to an impact crusher is controlled by a control system which takes the material flows into account. The throughput of feldspar produced was doubled when this control technique was introduced. The same principle of determining the capacity through the power draw of lifting conveyor belts was used in this work.

In the mining industry, milling operations have been more extensively investigated due to the higher economic values of the products. At the PT Freeport copper mine (Mills and Supomo, 2004) have constructed a real time optimization system which is adaptive. It is a model based control system where the models are calibrated continuously. The system is described as an "optimizer on a higher level". It runs on a conventional personal computer and delivers set-points to the existing control system. It also presents a number of non-measurable variables as estimates on the operator's screen. The throughput of the mill circuit increased by 5.7%.

(Moshgbar and Bearman, 1995) describes a product driven control strategy for cone crushers with wear sensors and adaptivity in its control parameters. They use a laser-based aggregate size measuring device.

There are several models which well describe performance of a crusher, e.g. (Evertsson, 2000). However, this kind of model not only requires input data about the feed and the crusher geometry but also is quite time consuming when it comes to calculation. Sensors capable of providing these data are rare. (Moshgbar and Bearman, 1995) utilize inbuilt sensors in the manganese liners for determining wear, thereby enabling compensation for liner wear.

3. Development of algorithm

Today, many cone crushers are equipped with control systems for cone crusher settings in order to keep the closed side setting (the distance between the mantle and the concave) constant. This setting is decided by the operator as a rule of thumb most of the time. However, both the quality and the size distribution of feed material change all the time. In addition, wear occur on both the crusher and the screens. So first of all, what is the aim for the crushing stage? The answer must most certainly be to produce the largest amount possible of one or more products. The quality of the material, e.g. the particle shape, must of course be high enough, but that is beyond the scope of this paper. Hence it is assumed that the quality is acceptable.

The main assumption which is made here is the existence of an optimal setting of the closed side setting at each time, see Fig. 2. Since several factors vary over time, a fair comparison between two different settings at different times cannot be conducted easily. When determining the best closed side setting, manual step changes are therefore usually performed. The performance of the crushing plant before and after the change can then be compared at similar conditions.

Hence an algorithm which makes series of step changes in order to find, and keep, an optimal setting is introduced. The choice of *CSS* for the next Δt s is first determined by

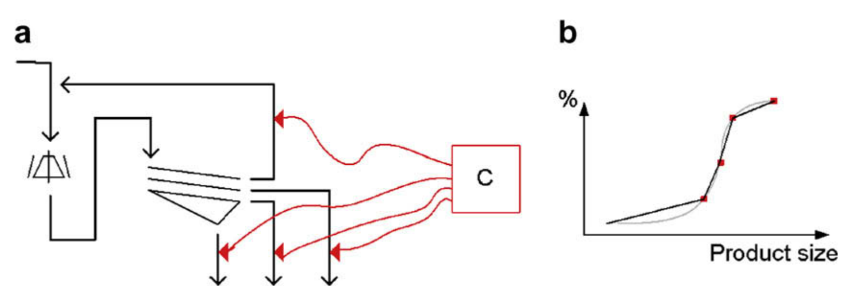

Fig. 1. (a) A mass flow meter, e.g. a conveyor belt scale, is attached to each stream from the screen, respectively. The computer then estimates the particle size distribution (PSD), seen in (b). The gray line is the real PSD and the black is the one estimated from the measurements, the boxes.

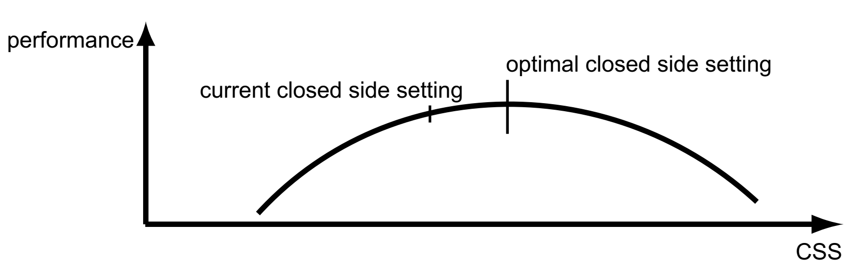

Fig. 2. At each time it is assumed that there is an optimal setting of the CSS.